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Abstract

In the European Union (EU) context, regulatory instruments and incentive schemes targeting individual farms remain the main policy instruments implemented to control diffuse pollution from agriculture. Yet, collective approaches to policy implementation have been recently developing. This article aims at assessing the potential for hybrid policy instruments relying on collective action among farmers to limit diffuse nitrate pollution from agriculture. Transaction cost economics are used to assess the potential advantages of collective action as a complement to regulatory and incentive policy tools. The conditions under which such hybrid forms of governance may be successful are identified using the Social-Ecological System (SES) framework. A review of empirical studies documenting cases of collective action for policy implementation in the EU context serves as a basis for the identification of the factors likely to affect the potential of collective approaches for water quality management in agriculture. The analysis relies more particularly on two cases: the Environmental Cooperatives in the Netherlands and the "Ferti-Mieux" operations in France. The results suggest that collective action is a relevant tool to consider for improving the effectiveness and cost-effectiveness of policies targeting diffuse pollution from agriculture. In particular, relying on farmers' cooperation for policy implementation may be associated with advantages in terms of transaction costs. However, such advantages will be effective under a number of conditions related to the characteristics of the water resource, the actors involved, the governance of cooperation and the broader economic and institutional contexts.

Keywords: Diffuse pollution; Agriculture; Collective action; Hybrid policy instruments; Transaction costs; Social-Ecological System (SES) framework

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1. Introduction

The European Union (EU) Water Framework Directive, adopted in 2000, set the objective of achieving good water status for all bodies of surface waters and groundwater (EU, 2000). Despite a significant reduction in levels of nutrients in European freshwaters over the past two decades, diffuse pollution from agriculture still poses a major threat to the quality of surface and ground waters in Europe. More particularly, nitrate and phosphorus pollution from agriculture accounts for the largest proportion of diffuse run off (EEA, 2018).

The policy tools available to address diffuse pollution include regulatory instruments, economic instruments (taxes/subsidies) and voluntary compliance approaches (Shortle and Abler, 2001). Because of the diffuse nature of nitrate pollution, it is not feasible to define policy instruments based on emissions by farmers such as emissions charges or standards (Shortle et al., 2012). The policies implemented rather aim at modifying the agricultural practices known as influencing the extent of nutrient leaching and runoff (McCann and Easter, 1999; Shortle and Abler, 2001). Reductions in organic and mineral nitrogen fertilization, the introduction of nitrate catch crops into the cropping plan and the establishment of riparian buffers along watercourses are examples of the different measures that may be implemented.

In the EU context, regulatory instruments (the EU Nitrate Directive) and incentive schemes targeting individual farms (agri-environmental schemes) remain the main policy instruments implemented to control diffuse nitrate pollution from agriculture. Yet, collective approaches to policy implementation have been recently developing (Polman et al., 2010; OECD, 2013; Westerink et al., 2017). Since 2014, the EU rural development policy gives an opportunity to groups of farmers to commit jointly to collective agri-environmental schemes (EU, 2013). There also exist some examples of voluntary cooperation among farmers (and other stakeholders) for achieving water quality regulatory objectives, e.g., in drinking water catchments (Brouwer et al., 2002; Grolleau and McCann, 2012; Amblard, 2019).

Previous studies have assessed the relevance of cooperation for the provision of ecosystem services by farmers (Goldman et al., 2007; Stallman, 2011; Prager, 2015a; Westerink et al., 2017), including water quality management (Sarker et al., 2008; Stallman, 2011). The literature also stresses the need to compare individual and collective approaches as well as the range of policy instruments available for environmental public goods provision (Polman et al., 2010; Stallman, 2011; OECD, 2013). More particularly, there has been no systematic assessment of the costs and benefits of agri-environmental cooperation as a complement to regulatory or incentive policy tools for the prevention of diffuse pollution.

This article aims at assessing the potential of hybrid policy instruments relying on collective action among farmers for addressing diffuse nitrate pollution from agriculture. Collective action is defined as an "action taken by a group (either directly or on its behalf through an organization) in pursuit of members' perceived shared interests" (Marshall, 1998). The hybrid arrangements considered involve public authorities using an external body (cooperative or association) as an intermediary to coordinate the actions of individual actors (Van Huylenbroeck et al., 2009). In particular, this paper seeks to identify: (i) the benefits and costs of collective policy approaches to diffuse pollution control and (ii) the factors that influence the success of collective action.

A conceptual framework combining the Social-Ecological System (SES) framework with transaction cost economics (Amblard, 2019) is used to identify the conditions under which hybrid policy instruments are likely to be environmentally effective and cost-efficient tools for diffuse pollution control. Transaction cost economics are used to assess the potential advantages of collective action as a complement to other agri-environmental policy tools. For these advantages to be effective, the gains of collective action have to be superior to the associated costs, including transaction costs, for participating stakeholders. The conditions under which cooperation may be successful are identified using the SES framework (Ostrom, 2009; McGinnis and Ostrom, 2014). While the SES framework was originally designed for the study of common pool resource problems, its application to diffuse water pollution as an externality problem contributes to recent developments aimed at broadening the scope of application of the framework (Villamayor-Tomas et al., 2014; Bennet and Gosnell, 2015; Hinkel et al., 2015; Partelow, 2018).

A review of empirical studies focused on cases of collective action for agricultural water pollution prevention in the EU context serves as a basis for a first identification of the factors likely to affect the success/failure of such cooperation. This literature review is structured by the conceptual framework combining transaction cost economics with the SES framework. The analysis relies more particularly on two cases: the Environmental Cooperatives in the Netherlands and the "Ferti-Mieux" operations in France. While the Environmental Cooperatives in the Netherlands constitute an example of collective action initiated by farmers themselves, the "Ferti-Mieux" operations in France were initiated by public agencies. Furthermore, the comparison of two cases in different Member States allows for exploring the role played by factors related to the social, economic and political contexts at the national level. Previous comparative studies of collaborative arrangements in different Member States have focused on the role of collectives as bridging organizations (Prager, 2015b) or on the diversity of governance approaches to the spatial coordination of agri-environmental management (Westerink et al., 2017). To the best of the authors' knowledge, no comparative analysis has been conducted before with the objective of assessing the potential of collective action for water quality management in agriculture.

The paper is organized as follows. The second section of the paper introduces the conceptual framework used for the analysis. Section 3 describes the methodology applied. Potential advantages of collective action as a complementary tool to achieve water quality objectives and factors identified as crucial for the success of cooperation are presented in Section 4. In the final section of the paper, the results are discussed from a conceptual and policy perspective.

2. Conceptual framework

A comparative perspective in terms of transaction costs is adopted with regard to the alternative policy instruments targeting individual farmers versus collectives (Section 2.1). The factors affecting the benefits and transaction costs of cooperation among farmers are identified on the basis of the SES framework (Section 2.2).

2.1 A transaction cost analysis of policy options

Transaction costs are the resources used to define, establish, maintain, and transfer property rights (Allen, 2000). Transaction costs arise because information is incomplete and asymmetrically held by parties to exchange (North, 1990). Depending on the characteristics of the good or service considered, the level of transaction costs linked to market coordination will be more or less important. Diffuse pollution, as an output of agricultural production affecting the utility of the production activities of other economic agents, is an externality. Externalities are present "whenever some individual A's utility or production relationships, include real (that is nonmonetary) variables, whose values are chosen by others (persons, corporations, governments) without particular attention to the effects on A's welfare" (Baumol and Oates, 1988). Water pollution, similar to many externalities, presents some characteristics of a public good (Holtermann, 1972; Baumol and Oates, 1988). Pure public goods are goods that are non-exclusive and non-subtractive (Samuelson, 1954; Head, 1962). The restoration or maintenance of water quality by farmers constitutes a public good, as (i) everyone can benefit from the resulting improvement in water quality without diminishing others' benefits (non-subtractability) and (ii) it is difficult (impossible) to prevent anyone from enjoying the benefits of water pollution reduction (non-excludability). In this case, the transaction costs associated with decentralized market exchange are so high that the public good will be underprovided. For example, in the case of diffuse water pollution, the costs of identifying the sources of pollution and the other affected individuals will highly constrain market coordination (Falconer, 2002). Some form of organization is needed to overcome the suboptimal provision of the public goods (Ostrom and Walker, 2000). However, the alternative institutional arrangements (including the diverse types of government intervention) also present transaction costs and the question is then which arrangement allows for the provision of the public good at the lowest costs.

Coase (1960) suggested adopting a comparative perspective on the relative benefits and costs (including transaction costs) of the different social arrangements. Such an approach has recently been developed in the field of environmental policy. A growing body of research seeks to include transaction costs in the analysis and evaluation of environmental policies (McCann et al., 2005; Coggan et al., 2010; Garrick et al., 2013; McCann, 2013). In this context, transaction costs correspond to search and information costs, bargaining and decision or contracting costs and monitoring, enforcement and compliance costs (McCann et al., 2005). Several studies have empirically measured the extent of transaction costs linked to the implementation of environmental policies, showing their high significance (McCann and Easter, 1999; Falconer, 2000; Falconer et al., 2001; Mettepenningen et al., 2009).

In the paper, hybrid policy instruments relying on collective action are compared to regulatory and individual incentive instruments in terms of relative benefits and costs, including transaction costs. The potential of collective action for diffuse pollution control further depends on the potential private benefits and transaction costs borne by participants.

As farmers do not primarily bear the costs of water pollution or do not enjoy the benefits of water quality improvements, they have generally little incentive to engage in collective action to reduce the level of pollution (preventing the public bad) or contribute to the maintenance of water quality (providing the public good). Still, they can draw indirect economic advantages as well as non-monetary benefits from such cooperation. In some cases, farmers may reap some private economic benefits from changing their agricultural practices towards less polluting practices. A better management of fertilization may lead to some savings in fertilizer expenses without any decrease in yields (Brouwer, 2003; Buckley and Carney, 2013). Another economic motivation for farmers to participate in collective action may include the possibility to maintain or increase their profits through the certification of their products (e.g., ecolabels) or through the development of activities based on the improved quality of the environment (e.g., agritourism) (Ribaudo et al., 2010; Grolleau and McCann, 2012; OECD, 2013). Finally, besides economic benefits, nonmonetary incentives may play a role in farmers' willingness to participate in collective action. Farmers with preferences for environmental preservation will be more willing to participate in cooperation to reduce water pollution (Lubell et al., 2002; Dupraz et al., 2009). Transaction costs associated with collective action include the costs of defining actions to control diffuse water pollution (information and bargaining costs) and the monitoring and enforcement costs of actions. Collective action for the provision of environmental services with public goods characteristics such as the restoration/maintenance of water quality more particularly entails a potential free-riding problem due to the difficulty in excluding beneficiaries for failing to contribute to the maintenance of the public good (Ostrom, 2003). The extent of expected benefits and transaction costs and thus the effectiveness of collective action are influenced by a number of factors identified on the basis of the SES framework (Section 2.2).

2.2 Identifying the factors affecting collective action: the SES framework

The SES framework was developed as a tool for the analysis of complex Social-Ecological Systems (SESs) (Ostrom, 2007; 2009; Poteete et al., 2010). This ontological framework lists and structures the variables which have been found in previous research to influence the patterns of interactions and outcomes in diverse SES. The SES framework constitutes an extension of the Institutional Analysis and Development approach (Ostrom, 1998) with specific attention given to the characteristics of biophysical systems and their impact on natural resource management (Ostrom, 2011; McGinnis and Ostrom, 2014).

Focal action situations represent the diverse interactions occurring between actors within SESs (e.g., harvesting the resource, information sharing or self-organizing for resource management) leading to social and ecological outcomes (Figure 1). The characteristics of the natural resource considered (resource system and resource unit), the characteristics of actors involved and the characteristics of the governance system are the first-tier variables considered as potentially important to analyze interactions and outcomes achieved in a given SES. The broader social, economic and political contexts and related ecosystems are also included as interacting with the other subsystems.

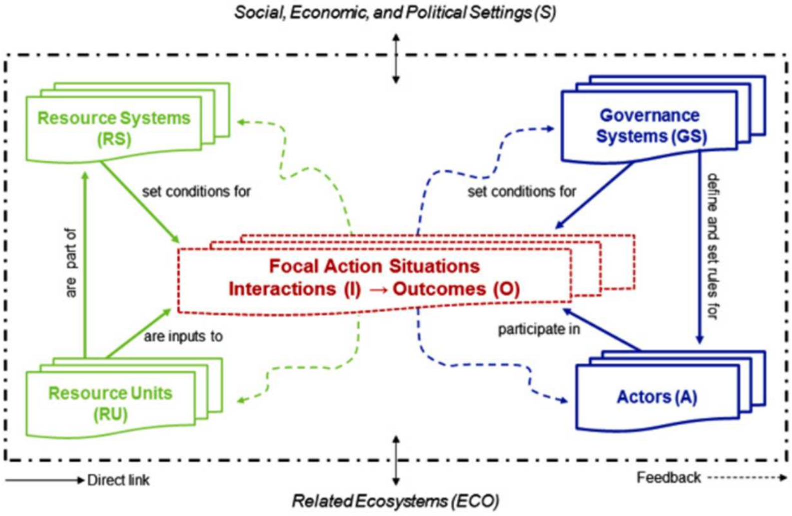

Figure 1: The SES framework (Source: McGinnis and Ostrom, 2014)

First-tier variables are further characterized by second-tier variables identified in previous studies to influence interactions and outcomes in SESs (McGinnis and Ostrom, 2014) (Appendix 1). Among the second-tier variables identified as potentially relevant, a subset of ten factors likely to affect the benefits and costs of collective action is seen to be critical for the success of self-organization by users of common-pool resources (Ostrom, 2009) (Table 1).

Table 1: The factors identified as crucial for self-organization by users for CPR management

First-tier variables	**Second-tier variables**
Resource system (RS)	RS3 – Size of resource system
	RS5 – Productivity of system
	RS7 – Predictability of system dynamics
Resource unit (RU)	RU1 – Resource unit mobility
Governance system (GS)	GS6 – Collective-choice rules
Actors (A)	A1 – Number of relevant actors
	A5 – Leadership-entrepreneurship
	A6 – Norms (trust-reciprocity)/social capital
	A7 – Knowledge of the SES
	A8 – Importance of the resource

Source: Adapted from Ostrom, 2009

The characteristics of the resource systems identified as affecting the likelihood of self-organization by users include the size and productivity of the system (RS3, RS5) and the predictability of system dynamics (RS7). A resource system of moderate size is seen as conducive to self-organization, as a larger size means higher management costs while a smaller size may imply a less valuable flow of products from the system (Chhatre and Agrawal, 2008; Ostrom, 2009). A moderate level of resource scarcity (productivity of the system) is also likely to induce collective action by users, unlike situations in which the resource is either already exhausted or abundant (Meinzen-Dick, 2007). A low predictability of system dynamics will increase the management costs of the resource, thereby reducing the likelihood of self-organization (Agrawal, 2001). Management costs also depend on the resource unit mobility (RU1), stationary units (e.g., water in a lake) being less costly to manage than mobile units (e.g., water in a stream) (Schlager et al., 1994; Agrawal, 2001). A larger number of users (A1) means higher transaction costs, however a small group size may constrain the pooling of resources needed to sustain collective action (Wade, 1987; Ostrom, 2010). The presence of well-respected local leaders (A5) and the existence of norms of reciprocity and/or social capital within the group (A6) are likely to decrease the transaction costs associated with collective action (Pretty and Ward, 2001; Meinzen-Dick, 2007; Poteete et al., 2010). The sharing of a common knowledge of the SES (A7) is seen as decreasing the perceived costs of organizing by users (Ostrom, 2009). The importance of the resource to users in terms of economic or noneconomic value (A8) will affect the expected benefits of collective action relative to its costs (Acheson, 2006). Finally, identified as crucial for the success of self-organization is the autonomy users have to define and enforce the rules governing resource management, i.e., their autonomy at the collective-choice level (GS6) (Ostrom, 2009; Poteete et al., 2010).

The SES framework is used to identify the factors influencing collective action for the control of diffuse pollution from agriculture. More particularly, the subset of ten factors highlighted by Ostrom (2009) (Table 1) constitutes an initial set of assumptions with regard to the variables affecting the benefits and costs, including transaction costs, of cooperation.

3. Methodology

Section 3.1 introduces the case study approach adopted for the analysis. The next subsection briefly describes the cases of Environmental Cooperatives and “Ferti-Mieux” operations. Table 2 presents the main characteristics of the two cases.

3.1. A case study approach based on a literature review

The analysis of hybrid policy instruments relying on collective action for nitrate pollution control relies on a review of empirical studies focused on cases of collective action for agricultural water pollution prevention in the EU context. Two cases are more particularly analyzed: the Environmental Cooperatives (ECs) in the Netherlands and the "Ferti-Mieux" operations in France. The two cases were selected because of their historical depth; both initiatives have developed since the beginning of the 1990s. Furthermore, while the ECs in the Netherlands constitute an example of collective action initiated by farmers themselves, the “Ferti-Mieux” operations in France were initiated by public agencies. Finally, the comparison of two cases in different Member States allows for exploring the role played by factors related to the social, economic and political contexts at the national level.

The secondary sources used include scientific and technical journal articles, research and policy reports, PhD and master theses as well as policy briefs. While the case of Environmental Cooperatives has been the subject of multiple analyses published in the academic literature, the Ferti-Mieux operations are mostly documented in technical outlets and policy reports.

The evidence from the diverse secondary sources was reviewed through the lens of the conceptual framework combining transaction cost economics with the SES framework. More particularly, the second-tier variables highlighted by Ostrom (2009) (Table 1) served as a frame for identifying the factors affecting the benefits and costs, including transaction costs, borne by the participants to agri-environmental collective action. Other second-tier variables were selected in the list updated by McGinnis and Ostrom (2014) (Appendix 1) when identified as having an impact on cooperation in the documents reviewed. Third- and fourth-tier variables characterizing the second-tier variables (Basurto et al., 2013; Frey and Cox, 2015; Thiel et al., 2015) were also developed if the literature review suggested that they play a role in the success/failure of collective action. The references supporting the influence of each identified factor on cooperation are presented in Appendix 2.

3.2. Two cases of collective action in the EU context

3.2.1. The Environmental Cooperatives in the Netherlands

The ECs have developed as a new governance structure since the beginning of the 1990s (Glasbergen, 2000; Renting and van der Ploeg, 2001). They are regional groups of farmers, including in some cases other rural stakeholders (e.g., environmental organizations and local authorities) (Wiskerke et al., 2003). Most ECs are formal associations, some are foundations, and a few have legal cooperative status (Polman et al., 2010).

By 2016, 160 associations involving 10% of the Dutch farming population (65% of which were dairy farmers) managed 25% of the rural area of the Netherlands. Their activities covered land areas ranging from 1,000 up to 130,000 hectares (Ministry of Economic Affairs, 2011; Terwan et al., 2016). The ECs' environmental activities are not restricted to water quality management and one EC can be active in several environmental "domains," including also biodiversity conservation or wildlife management (Franks and Mc Gloin, 2007a). In addition to nature management and the reduction of environmental pollution, some ECs have also developed activities in the fields of rural tourism and regional quality production (Renting and van der Ploeg, 2001; Franks and McGloin, 2007a).

The ECs are generally managed by a board elected annually. Subcommittees are responsible for managing individual projects and developing new activities. Regular meetings take place, as well as an annual general meeting at which changes to the group's plan and constitution can be made (Franks and McGloin, 2007a). Individual members decide for themselves whether to participate in any EC activity. While they can suggest programs for the ECs to be involved in, only those initiatives supported by a large share of members will be supported by the ECs (Franks, 2010).

The development of ECs led to innovations in the implementation of agri-environmental policy in the Netherlands. In some cases, ECs have been allowed to develop themselves the measures and instruments used to achieve the regulatory objectives defined by state agencies (Glasbergen, 2000; Renting and van der Ploeg, 2001; Wiskerke et al., 2003; Stobbelaar et al., 2009; Termeer et al., 2013). With regard to the implementation of agri-environmental schemes, priority has been given to collective rather than individual applications since 2000 (Franks and Mc Gloin, 2007a; 2007b). While some ECs had received and distributed payments to farmers, contracting with ECs as collectives turned out to be incompatible with the EU regulations at the time. From 2003, ECs were compensated by national funds for their role in coordinating their members' applications to agri-environmental schemes while payments were directed to farmers (Franks and McGloin, 2007b; OECD, 2013).

In anticipation of the recognition of farmer groups as eligible beneficiaries of agri-environmental payments in the 2014-2020 EU rural development program, the Ministry of Agriculture chose four ECs as pilot projects to assess the feasibility and added value of the collective implementation of agri-environmental measures (Ministry of Economic Affairs, 2011; OECD, 2013; Westerink et al., 2015). In 2016, the Dutch government chose to implement agri-environmental schemes through collective applications only. New farmer collectives were established as formal contract partners of the regional governments in charge of the implementation of agri-environmental policy. While some of the collectives were initiated by the original ECs, others were created by farmer unions (Terwan et al., 2016; Jongeneel and Polman, 2018). There are currently 40 new collectives, involving more than 6,300 farmers and covering a land area of 68,000 hectares (Jongeneel and Polman, 2018).

There is no formal appraisal of the environmental impact of ECs, however, they are perceived as being ecologically effective for their positive influence on the participation of farmers in agri-environmental schemes and on the evolution of agricultural practices (Franks and Mc Gloin, 2007a; 2007b; Smits et al., 2008; Slangen et al., 2008; Van Dijk et al., 2015). Data collected between 1995 and 2000 on trends in the nitrogen surpluses of member farms of the two first ECs (VEL and VANLA[1]) and a regional reference group of farms show that member farms realized lower nitrogen surpluses and reduced these losses at a higher rate than the regional average over the five years (Renting and van der Ploeg, 2001). In 2000, 33% of VEL and VANLA dairy farmers reached nitrogen surpluses below the national policy

[1] These respectively are the acronyms for Vereniging Eastermar's Lânsdouwe and Vereniging Agrarish Natuur en Landschapsbeheer Achtkarspelen.

objectives of 2003 while only 10% of dairy farms at the national level achieved this result (Sonneveld and Bouma, 2003).

3.2.2. The "Ferti-Mieux" operations in France

The "Ferti-Mieux" operations were launched in 1991 by the French Ministry of Agriculture. Managed by the National Association for Agricultural Development (ANDA)[2], the goal was to promote and label local collective actions of farmers for a better management of nitrogen use at a water catchment level (Papy and Torre, 2002). Within this frame, farmers voluntary committed to changing their practices to limit water pollution with no financial compensation, along collectively defined prescriptions. Participating farmers benefited from free technical support for modifying their practices, on the basis of a diagnosis of the local context (water resource system, farming systems, sources and risks of nitrate pollution). Participants also benefited from the label "Ferti-Mieux" as official recognition that their farming practices limited the risk of water pollution.

At the national level, a national steering committee gathering representatives from the Ministries of Agriculture and Environment, the Water Agencies and farmers' organizations was in charge of defining the overall orientations of the "Ferti-Mieux" program. A national scientific and technical committee involving researchers and technical representatives of agricultural organizations was responsible for the evaluation of local operations as a basis for the decision to award the "Ferti-Mieux" label. At the local level, a steering committee and a technical committee involving farmers' organizations, local public agencies and in some cases water suppliers and agro-industrial cooperatives were in charge of the management of operations. A coordinator (usually working for a local Agricultural Chamber[3]) was responsible for defining, together with the participating farmers, nitrogen management plans (Sebillotte, 2003).

A pre-label was granted to local operations based on two criteria: (i) the area covered by the involvement of farmers in the water catchment and (ii) the adaptation of the nitrogen management plan to the local context. The official "Ferti-Mieux" label was granted and renewed if the agreed changes in farmers' practices were effective (Ramonet, 2003).

Between 1991 and 2001, 65 operations were granted the "Ferti-Mieux" label, involving approximately 35000 farmers and representing 4.6% of the agricultural area. The effects of the "Ferti-Mieux" operations on water pollution were mixed with no evidence of a decrease in nitrate rates in groundwater bodies; however, this could be attributable to the time lags in groundwater quality response to changes in agricultural practices. In areas where surface waters were targeted, more than a half of the operations led to a decrease or stabilization of nitrate rates, demonstrating the environmental relevance of the operations (Papy and Torre, 2002).

Following the dissolution of ANDA in 2002, the "Ferti-Mieux" operations were officially stopped at the national level. However, Agricultural Chambers and the Water Agency of the Rhin-Meuse water basin decided to undertake similar operations under the name "Agri-Mieux." Indeed, the ongoing "Ferti-Mieux" operations in the area were evaluated as successful in terms of farmers' involvement and water quality improvement. The new "Agri-Mieux" operations have the additional objective of reducing diffuse pesticide pollution (Bernard, 2004). In Lorraine, eleven "Agri-Mieux" operations gather 22% of farmers, covering 25% of the agricultural area in the region, while in Alsace, 4500 farmers participate in eight operations in the plain area (Rettel and Revest, 2013; Burtin, 2014).

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[2] This association, which was disbanded in 2002, had a mixed membership of representatives from agricultural interest groups and the State. Its role was to provide advice to the Ministry of Agriculture and to fund agricultural development programs.

[3] Agricultural Chambers in France are public organizations led by representatives of agricultural and other rural stakeholders. Agricultural Chambers are active at the regional and the department level.

Table 2: Two cases of agri-environmental collective action in the EU context: the Environmental Cooperatives in the Netherlands and the "Fertimieux" operations in France.

	Environmental Cooperatives (The Netherlands)	**“Fertimieux” operations (France)**
Initiative	Farmers	Public agencies (Ministry of Agriculture)
Composition	Farmers or Farmers and non-farmers	Farmers and non-farmers
Structure	Formal organization	Ad hoc network
Funding	Member fees Public agencies (direct support, contracts)	Public agencies (Agricultural Chambers, Water Agencies, ANDA, local governments)
Environmental “domain”	Multiple (water quality, biodiversity, wildlife)	Water quality
Activities	▪ Information sharing and advice provision ▪ Coordination of changes in agricultural practices ▪ Fundraising ▪ Interest representation/lobbying ▪ Research activities	▪ Information sharing and advice provision ▪ Coordination of changes in agricultural practices

Sources: Franks and McGloin, 2007a; Verron, 2007.

4. Results

The advantages of collective approaches to regulation and incentive schemes for diffuse pollution control are specified in Section 4.1. Factors affecting the potential of cooperation are presented in Section 4.2.

4.1 The advantages of hybrid policy instruments relying on collective action for diffuse pollution control

Reaching the objectives of water quality improvement requires action that extends beyond farm boundaries at the scale of the drinking water catchment or watershed. Coordination at the appropriate scale of management can be achieved by regulations through zoning. For example, the EU Nitrate Directive is implemented in areas designated as "vulnerable zones" for nitrate pollution. Agri-environmental incentive schemes are also frequently offered in specific areas chosen to match the environmentally relevant scales (Prager, 2015a; Westerink et al., 2017). However, the incentives provided, on an individual farm basis, are not linked to the implementation of measures at a larger scale (Goldman et al., 2007; Mettepenningen et al., 2013). Collective contracts with groups of farmers allow environmental actions to be taken across land management boundaries (Falconer, 2000; Franks and McGloin, 2007a; Mettepenningen et al., 2013).

The agricultural impact in terms of nitrate diffuse pollution shows high levels of spatial variation depending on hydroclimatic conditions, soil types and agricultural practices. The adaptation of measures to local conditions is thus of importance for an effective reduction of water pollution (Lacroix et al., 2010). However, designing precise measures may be very costly for public agencies in terms of information collection and processing. Relying on collective action permits taking advantage of the knowledge held by farmers about their own farming system and local environment (Stuiver et al., 2003; Wiskerke et al., 2003; Franks, 2010). In turn, collective action among farmers favors their access to research and extension services (Slangen, 1994; Franks and McGloin, 2007b).

The level of information asymmetry between public agencies and farms is an important issue in monitoring diffuse nitrate pollution (Shortle and Horan, 2001). Relying on a collective for controlling and enforcing farmers' practices will lower public costs (Slangen, 1994; Renting and van der Ploeg, 2001). Compared to public agencies, farmers' collectives may be advantaged by easier access to information and the possibility of using enforcement mechanisms such as trust or reputation (Falconer, 2002; Franks, 2011; Westerink et al., 2015). Still, public agencies will remain ultimately accountable for the group's performance and thus will incur some monitoring and enforcement costs (OECD, 1998; Falconer, 2002).

Farmers may be more willing to comply with measures they contribute to design than with measures externally imposed to them. There is growing empirical evidence on the effects of external interventions (positive monetary rewards or regulations with sanctions) on the intrinsic motivation of individuals (Frey and Jegen, 2001; Moller et al., 2006; Akers and Yasué, 2019). More particularly, external interventions may crowd out motivation if individuals affected perceive them to be controlling. As a result, individuals react by reducing their intrinsic motivation in the activity controlled (Frey and Jegen, 2001). Self-organization for the definition of actions to address diffuse pollution may thus improve the extent to which policy objectives are reached, by enabling farmers to endorse the policy goals (Stobbelaar et al., 2009; OECD, 2013).

Several studies have shown that significant transaction costs have been associated with the implementation of agri-environmental schemes in the EU context, both for implementation agencies and for the participating farmers (Falconer, 2000; Falconer et al., 2001; Mettepenningen et al., 2009; Mettepenningen et al., 2011). Transaction costs borne by farmers include the search and information costs involved in their decision to participate in an agri-environmental program as well as the contracting costs linked to the administrative tasks required with participation. Public agencies also incur contracting costs with the management of farmers' applications and monitoring and enforcement costs of farmers' compliance with the prescriptions. The transaction costs borne by farmers have been shown to constrain their participation in the schemes and thus the achievement of environmental objectives. In this regard, smaller farms may be relatively more affected due to the presence of high fixed transaction costs (e.g., required farm audits for participation) (Falconer, 2000).

Transactional economies of scale may be achieved by making collective management agreements (Falconer, 2000). Information and knowledge sharing about agri-environmental schemes and implications of participation within a group may reduce the costs of decision-making for individual farmers (OECD, 1998; Franks, 2010; Mettepenningen et al., 2013). Collective applications for participation in agri-environmental schemes may also reduce contracting costs, both for the farmers and for the public agencies in charge (Mettepenningen et al., 2011). Several studies report effective transaction cost savings achieved in the implementation of agri-environmental schemes in the Netherlands with the development of collective contracts between the administration and the Environmental Cooperatives (Franks and McGloin, 2007a; 2007b; Smits et al., 2008; Slangen et al., 2008; Franks, 2011; Prager, 2015b). Van Dijk et al. (2015) found, on the basis of a quantitative empirical study, that the facilitating role played by ECs in collective agri-environmental schemes was positively related to farmers' intentions to participate in the schemes.

Collective approaches to regulatory and incentive instruments may thus present some advantages for reaching water quality objectives in a cost-efficient way. The achievement of cooperation among farmers will however depend on a number of conditions identified on the basis of the SES framework.

4.2 The factors affecting the potential of collective action

The potential of collective action depends on the expected benefits and transaction costs associated with farmers' participation in cooperation. The first subsection presents the factors likely to affect the extent of benefits that farmers can draw from collective action oriented towards the management of water quality. In the second subsection, the variables that may influence the transaction costs of cooperation are reviewed. The variables identified through the literature review are presented in Table 3. References for each variable are given in Appendix 2.

4.2.1. The factors affecting the private benefits of farmers

As discussed above, farmers have little direct economic incentive to engage in collective action for diffuse pollution control. In some instances, they can benefit from cost savings by changing their farming practices. However, the extent of these cost savings will vary according to the **type of farming system (A2.1)**. In a context of intensive crop farming, reducing mineral fertilization may induce high costs while cattle breeding farms have the potential to substitute organic for mineral fertilization to a certain extent (AE RMC, 2007b; Lacroix et al., 2010). Prevailing inefficiencies in production methods as well as personal characteristics of farmers (attitudes and skills) also affect the potential for increased economic benefits (Brouwer, 2003; Groot et al., 2006).

The development of ecolabels or ecotourism as additional economic motivations will depend on the existence of a demand for "green" products and activities (Ribaudo et al., 2010; Grolleau and McCann, 2012; OECD, 2013). Several ECs have pursued initiatives related to regional marketing and agritourism to provide additional benefits to their members (Renting and van der Ploeg, 2001; Termeer et al., 2013). Conversely, if **market incentives (S5)** are such that participation in collective action leads to drastic income reductions, farmers will be less willing to engage into cooperation. Busca (2004) found farmers' participation in Ferti-Mieux operations to be lower in areas in which the economic weight of supply chains for high quality cereals was high. Restrictions on fertilization have a direct impact on farmers' capacities to access such supply chains in terms of product quality (e.g., the high protein content of the produce) or quantity. Not surprisingly, the "Ferti-Mieux" operations involving agro-industrial cooperatives or other trading partners were identified as attracting stronger support from farmers (Busca, 2002; Verron, 2007).

Two further motivations can be identified in relation to the expected economic benefits associated with collective action. The **threat of regulations or penalties (S4.1.1)** may encourage voluntary collective action by reducing expected net farm profits (Ayer, 1997). This can be illustrated by the emergence of the first environmental cooperatives in the Netherlands. The two cooperatives VEL and VANLA were created in the Frisian Woodlands area as a reaction among farmers to a series of national regulations aiming at limiting the environmental impacts of agriculture (including the reduction of nitrogen losses by dairy farms) (Glasbergen, 2000; Stobbelaar et al., 2009). Farmers considered these policies to threaten the viability of their local farming systems and to be ineffective with regard to the environmental objectives targeted (Renting and van der Ploeg, 2001; Wiskerke et al., 2003). The two cooperatives negotiated with the Dutch government for exceptions concerning the application of state regulations and committed in exchange to undertake alternative actions to reduce nitrogen losses (Wiskerke et al., 2003; Franks, 2010). The threat of regulation by public water utilities was also identified as a factor favoring the participation of farmers in Ferti-Mieux operations in drinking water catchments (Bernard, 2004; AE RMC, 2007b).

Another motivation for cooperation can be to gain political weight. Farmer-led collectives may be seen by farmers as a political tool to influence policy decisions in favor of their economic interests. The Environmental Cooperatives have become major actors in agri-environmental policy definition in the Netherlands (Franks and McGloin, 2007a). Their emergence and success among farmers may be explained by the initial dominance of ecological expertise in the definition of environmental policies in the Dutch context, which led to a weak representation of farmers' interests (Daniel and Perraud, 2009; Franks and McGloin, 2007a; 2007b; Franks, 2008; 2010). The role of **political representation (S4.1.2)** as a strong driver for environmental collective action was less important in France, where an institutionalized co-management of agri-environmental policies between the State and farmers' organizations has for a long time permitted farmers to effectively represent their perspectives (Brives, 1998; Daniel and Perraud, 2009). This may help explain the lack of support provided by agricultural professional organizations to the national Ferti-Mieux program, which was identified as an obstacle to its continuation after the dissolution of ANDA (Sebillotte, 2003).

Finally, a **stronger sensitivity to water protection (A8.1)** was identified as a factor influencing farmers' participation in Ferti-Mieux operations (Sebillotte, 2003). In contrast, Stobbelaar et al. (2009) and van Dijk et al. (2015) identified diverse attitudes towards environmental conservation among EC members. This could be explained by the difference in the general objectives of the two cases of collective action. While the Ferti-Mieux program promoted changes in farming practices without any financial compensation, the ECs have aimed at improving both the ecological and economic performance of agriculture.

Table 3: The factors identified as affecting the benefits and costs of collective action

First-tier variables	**Second-, third- and fourth-tier variables**
Social, economic and political settings (S)	S4 – Other governance systems
	S4.1 – Larger scale governance systems
	S4.1.1 – Regulatory threat
	S4.1.2 – Political representation of agricultural interests
	S4.1.3 – Support from public agencies
	S5 – Markets
Resource system (S)	RS3 – Size of resource system *
	RS3.1 – Size of water catchment
	RS7 – Predictability of system dynamics *
Governance system (GS)	GS6 – Collective-choice rules *
	GS6.1 – Autonomy at the collective choice level
	GS8 – Monitoring and sanctioning rules
Actors (A)	A1 – Number of relevant actors *
	A2 – Socioeconomic attributes
	A2.1 – Type of farming system
	A2.2 – Heterogeneity of actors
	A5 – Leadership-entrepreneurship *
	A6 – Norms (trust-reciprocity)/social capital *
	A7 – Knowledge of the SES *
	A8 – Importance of the resource *
	A8.1 – Environmental preferences of farmers

* Second-tier variables identified by Ostrom (2009) as crucial for self-organization by users for CPR management

4.2.2. The factors affecting the transaction costs of collective action

Among the factors affecting the transaction costs of collective action, the characteristics of actors involved were found to play a major role.

In the case of "Ferti-Mieux," the success of operations was clearly related to the **number of participants (A1)** involved. Operations initially involving a large number of farmers either failed or split up into smaller subgroups (Kockmann et al., 2003; Verron, 2007). The environmental cooperatives in the Netherlands show great variation in the number of their members, ranging from 15 to 1700 members (Franks and McGloin, 2007a). Westerink et al. (2017) found that the larger size of a cooperative positively influenced its organizational capacity and institutional capital while putting at risk the social links between the association and its members. With regard to group composition,

heterogeneity (A2.2) in production systems and individual abatement costs of farmers may increase the bargaining costs of defining the actions to implement for the prevention of water pollution (Grolleau and McCann, 2012). Heterogeneity in preferences for environmental preservation of group members is also likely to constrain the agreement process (Lubell et al., 2002). The participation of farmers and non-farmers may also increase decision-making costs. In the case of the ECs, the different goals and perspectives of farmers and other stakeholders (e.g., environmental associations or water suppliers) could lead to conflicts (Franks and McGloin, 2007a). While heterogeneity in preferences and interests among group members appears to be a barrier to collective action, heterogeneity in terms of resources and skills may be a positive factor (OECD, 2013). In some ECs, the participation of non-farmers was also recognized as bringing complementary resources, knowledge and skills (Franks, 2008; Uetake, 2014).

The **presence of a local leader/social entrepreneur (A5)** able to stimulate and animate collective action also appears to be an important factor (Davies et al., 2004). The most successful "Ferti-Mieux" operations were characterized by the involvement of a coordinator familiar with the local context and considered to be knowledgeable and trustworthy by farmers (Kockmann et al., 2003; AE RMC, 2007a; 2007b; Verron, 2007). The role of respected leaders was identified as crucial in the emergence and success of ECs as well (Franks, 2008; 2011). Political and inter-organizational leadership also proved important for negotiating rules and policies favorable to the development of ECs with public authorities at the local and national levels (Franks, 2010; Termeer et al., 2013).

The existence of **trust and shared norms of reciprocity (A6)** was found to play a crucial role in the success of ECs and Ferti-Mieux operations (Polman and Slangen, 2002; Eshuis and van Woerkum, 2003; Kockmann et al., 2003). Local networks in small communities favor the development of trust (Eshuis and van Woerkum, 2003). However, Lundqvist (2001) documents the case of a failed attempt to induce collective action in a water catchment in Sweden where collective memories of trust and reputation within the farming community seemed to rule out any possibility of cooperation. Further, Davies et al. (2004) stress that the match between the optimal management scale and informal social networks is context specific. The authors found in the Scottish context that, most often, strong social relationships do not fall in contiguous spatial patterns, but may be scattered throughout a local area.

Finally, the costs associated with the definition and assessment of actions depend on the **knowledge of the hydrogeological system (A7)**. In both EC and Ferti-Mieux cases, the definition of measures targeting nitrate diffuse pollution benefited from partnerships with research and technical institutes (Kockmann et al., 2003; Bernard, 2004; Stuiver et al., 2003; Eshuis and Stuiver, 2005; Van Der Ploeg et al., 2006; AE RMC, 2007a; 2007b). The monitoring of water quality may also serve as a tool for enhancing farmers' involvement in collective action to the extent that the response time of the water system allows for short-term and visible results of changes in farming practices (Bernard, 2004; AE RMC, 2007b; Verron, 2007).

Further, two variables characterizing the resource system were identified as influencing the level of transaction costs. In relation to the size and heterogeneity of the group of participants, the **size of the water catchment or watershed (RS3.1)** will affect the likelihood of successful collective action. A larger water basin means a larger number of farmers and potentially more heterogeneity in their farming systems (Brouwer, 2003). Ferti-Mieux operations located in large water basins usually split up into groups working at a sub-basin scale (Kockmann et al., 2003). The **predictability of water system dynamics (RS7)** is likely to affect the costs of defining the actions to implement and the costs of assessing their impact on water quality (Nimmo Smith et al., 2007; Grolleau and McCann, 2012). The short time lag between changes in agricultural practices and the evolution of nitrate concentrations in hydrosystems targeted by Ferti-Mieux operations in the Lorraine region facilitated an evaluation of the effectiveness of actions (Bernard, 2004; AE RMC, 2007b).

Transaction costs of collective action will also strongly depend on the rules defined for the decision-making process and the enforcement of decisions within the group.

The two cases of ECs and Ferti-Mieux operations highlight the positive effect of an **autonomous design of the rules by participants (GS6.1)**. In the Netherlands, all Environmental Cooperatives have developed their own rules (Franks and McGloin, 2007a; Franks, 2008; 2011; Termeer et al., 2013). In France, farmers created independent structures (e.g., associations), through which they could define and enforce their own rules while remaining within the general "Ferti-Mieux" frame. This greater autonomy among farmers was identified as having a positive effect on the durability of operations (Kockmann et al., 2003; AE RMC 2007b).

Most cooperatives have developed **monitoring and sanctioning systems (GS8)**, involving members or external professionals. Sanctions used by ECs include warnings, exclusion from activities and/or financial penalties (Polman and Slangen, 2002; Eshuis and van Woerkum, 2003). The board of cooperatives may also exclude individual members who do not respect the agreed rules (Wiskerke et al., 2003). Evidence suggests that the use of a graduated system of sanctions, observed in some ECs, is effective in preventing free-riding from members (Polman and Slangen, 2002; Eshuis and van Woerkum, 2003; Termeer et al., 2013; Westerink et al., 2017). In the Ferti-Mieux case, the evaluation of farmers' practices was realized by the local technical committee and then validated at the national level. Evaluation was based on direct visits and checks of a representative sample of individual farms (Verron, 2007). The risk of non-renewability of the Ferti-Mieux label was real: 12% of the operations lost their label between 1991 and 2001 (Ramonet, 2003).

Finally, government policies can help lower the transaction costs associated with collective action (Lubell et al., 2002; OECD, 2013; Villamayor-Tomas et al., 2019). The Dutch Ministry of Agriculture supported the development of Environmental Cooperatives through grants to cover start-up costs (Glasbergen, 2000; Franks, 2008; 2010), by approving exemptions from general regulations and adjusting the national agri-environmental program to include an option of joint applications from EC members (Wiskerke et al., 2003; Franks and Mc Gloin, 2007a; 2007b; Franks, 2010; Westerink et al., 2015). **External support from public agencies (S4.1.3)** also included the provision of expert knowledge and administrative support as well as research funding (Glasbergen, 2000; Franks, 2010; Termeer et al., 2013). Termeer et al. (2013) note that the fragmentation of public organizations in the Netherlands could have acted as a constraint for collectives seeking access to various resources. In the French context, public funding compensated the extra-costs of coordination and follow up of the “Ferti-Mieux” operations (Verron, 2007). Public support also took the form of providing rules for framing collective action among farmers and the labeling of operations (Kockmann et al., 2003). It seems that such support was crucial to the emergence and durability of local collective actions. After the official stop of the policy at the national level, most operations collapsed, except in the Rhin-Meuse water basin area where the Water Agency decided to maintain a similar program at the water basin level (Bernard, 2004).

5. Discussion and conclusions

The analysis shows that collective action is a relevant tool to consider for improving the effectiveness and cost-effectiveness of regulatory and incentive policies targeting diffuse pollution from agriculture. Self-organization by farmers for reaching regulatory objectives will be associated with lower design and enforcement costs for public agencies. A greater participation of farmers in the definition of measures that they must implement is also likely to increase their compliance and thus foster the realization of water quality objectives. Collective action for joint applications to agri-environmental schemes allows for transaction cost savings both for farmers and for public agencies compared to individual schemes. Cooperation will also improve environmental outcomes, as water quality improvements require action at a larger scale than at the individual farm level.

However, as stressed by scholars in the field of institutional economics (Ostrom and Cox, 2010; Ménard, 2011), no single policy approach or instrument is likely to solve complex environmental problems in all settings. The results suggest that the success of collective action involving farmers depends on a number of conditions related to the characteristics of the resource, the actors involved, the governance of cooperation and the broader economic and political contexts (Table 3).

The size of the water system targeted, in conjunction with the number of potential participants and their degree of heterogeneity, was found to affect the likelihood of successful collective action, with a collective management of larger basins or catchments involving greater transaction costs. The less predictable are the hydrogeological system dynamics, the higher are the management costs.

The level of management costs also depends on the knowledge available to participants regarding the impact of farming practices on water quality. Among the characteristics of actors involved, the type of farming system and the preferences of farmers were found to potentially influence the private benefits drawn from collective action. Farmers incurring fewer costs in changing their practices and/or having strong preferences for environmental preservation will be more likely to participate in collective action. The results suggest that a larger number of farmers together with a greater diversity in preferences and farming systems increase the costs of collective action. However, the participation of non-farmers in collective action was identified as a positive factor for pooling the resources needed for cooperation. The presence of a leader or the existence of trust and social capital within the group of participants were shown to decrease transaction costs.

Characteristics of the governance system are identified as a crucial factor for the success of collective action within the SES framework. Especially, the presence of a control and sanction system was found to be important in limiting free-riding from participants in the two cases (Environmental Cooperatives and "Ferti-Mieux" operations). The analysis also highlights the positive effect of an autonomous design of rules by the participants.

Most factors highlighted by Ostrom (2009) as crucial for self-organization by users of a common-pool resource were also identified in the case of collective action for water pollution control (Table 3). Two variables were not found relevant for the analysis of collective action for diffuse pollution control: the productivity of the resource system and the resource unit mobility, in relation to the non-subtractive character of water quality (Hinkel et al., 2015). Further, the nature of market incentives, the political context and the existence of government support were identified as strongly determining the emergence and sustainability of agri-environmental cooperation. The importance of these conditions can be related to the public good nature of diffuse pollution control by farmers. In the presence of few direct economic incentives, the success of collective action will substantially depend on external economic and political incentives.

From a policy perspective, the findings of this paper may serve as a basis for assessing whether conditions are gathered for collective action to be an effective and cost-effective tool for diffuse pollution control. When applied to a specific setting, such a diagnostic may inform policy choices regarding the adoption of a collective approach and/or the design of measures addressing the constraints identified as bearing on collective action.

Combining transaction cost economics with the SES framework proved useful to assess the potential of hybrid policy instruments relying on collective action for water quality management in agriculture. The results presented here were drawn from existing case studies mostly using different conceptual approaches to address this issue. Further investigation is needed, including direct empirical data collection to test the assumptions made on the factors identified as affecting cooperation for water pollution control.

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Appendix 1: Second-tier variables of a social-ecological system (McGinnis and Ostrom, 2014)

First-tier variables	Second-tier variables
Social, economic and political settings (S)	S1 – Economic development
	S2 – Demographic trends
	S3 – Political stability
	S4 – Other governance systems
	S5 – Markets
	S6 – Media organizations
	S7 – Technology
Resource systems (S)	RS1 – Sector (e.g., water, forests, pasture, fish)
	RS2 – Clarity of system boundaries
	RS3 – Size of resource system
	RS4 – Human-constructed facilities
	RS5 – Productivity of system
	RS6 – Equilibrium properties
	RS7 – Predictability of system dynamics
	RS8 – Storage characteristics
	RS9 – Location
Governance systems (GS)	GS1 – Government organizations
	GS2 – Nongovernment organizations
	GS3 – Network structure
	GS4 – Property-rights systems
	GS5 – Operational-choice rules
	GS6 – Collective-choice rules
	GS7 – Constitutional-choice rules
	GS8 – Monitoring and sanctioning rules
Resource units (RU)	RU1 – Resource unit mobility
	RU2 – Growth or replacement rate
	RU3 – Interaction among resource units
	RU4 – Economic value
	RU5 – Number of units
	RU6 – Distinctive characteristics
	RU7 – Spatial and temporal distribution
Actors (A)	A1 – Number of relevant actors
	A2 – Socioeconomic attributes
	A3 – History or past experiences
	A4 – Location
	A5 – Leadership-entrepreneurship
	A6 – Norms (trust-reciprocity)/social capital
	A7 – Knowledge of SES
	A8 – Importance of the resource (dependence)
	A9 – Technologies available
Action situation: Interactions (I) - Outcomes (O)	I1 – Harvesting
	I2 – Information sharing
	I3 – Deliberation processes
	I4 – Conflicts
	I5 – Investment activities
	I6 – Lobbying activities
	I7 – Self-organizing activities
	I8 – Networking activities
	I9 – Monitoring activities
	I10 – Evaluative activities
	O1 – Social performance measures (e.g., efficiency, equity, accountability, sustainability)
	O2 – Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability)
	O3 – Externalities to other SESs
Related ecosystems (ECO)	ECO1 – Climate patterns
	ECO2 – Pollution patterns
	ECO3 – Flows into and out of focal SES

Appendix 2. The factors identified as affecting the costs and benefits of hybrid policy instruments

Table 2.1: The characteristics of the social, economic and political settings

First-tier variable	Second-tier variables	References: Environmental cooperatives	References: Ferti-Mieux operations
Social, economic and political settings (S)	S4 – Other governance systems		
	S4.1 – Larger scale governance systems		
	S4.1.1 – Regulatory threat	Glasbergen, 2000; Renting and van der Ploeg, 2001; Wiskerke et al., 2003; Stobbelaar et al., 2009; Franks, 2010	Bernard, 2004; AE RMC, 2007b
	S4.1.2 – Political representation of agricultural interests	Franks and McGloin, 2007a; 2007b; Daniel and Perraud, 2009; Franks, 2008; 2010	Sebillotte, 2003
	S4.1.3 – Support from public agencies	Glasbergen, 2000; Wiskerke et al., 2003; Franks and McGloin, 2007a; 2007b; Franks, 2008; Franks, 2010; Termeer et al., 2013; Westerink et al., 2015	Kockmann et al., 2003; Bernard, 2004; Verron, 2007
	S5 – Markets	Renting and van der Ploeg, 2001; Termeer et al., 2013	Busca, 2002; 2004; Verron, 2007

Table 2.2: The characteristics of the resource

First-tier variable	Second-tier variables	References: Environmental cooperatives	References: Ferti-Mieux operations
Resource system (RS)	RS3 – Size of resource system		
	RS3.1 – Size of the water catchment		Kockmann et al., 2003
	RS7 – Predictability of system dynamics		Bernard, 2004; AE RMC, 2007b

Table 2.3: The characteristics of actors

First-tier variable	**Second-tier variables**	**References**	
		Environmental cooperatives	**Ferti-Mieux operations**
Actors (A)	A1 – Number of relevant actors	Westerink et al., 2017	Kockmann et al., 2003; Verron, 2007
	A2 – Socioeconomic attributes		
	A2.1 – Type of farming systems	Groot et al., 2006	AE RMC, 2007b
	A2.2 – Heterogeneity of participants	Franks and McGloin, 2007a; Franks, 2008; Uetake, 2014	
	A5 – Leadership-entrepreneurship	Franks, 2008; 2010; 2011; Termeer et al., 2013	Kockmann et al., 2003; AE RMC, 2007a; 2007b; Verron, 2007
	A6 – Norms (trust-reciprocity)/social capital	Polman and Slangen, 2002; Eshuis and van Woerkum, 2003	Kockmann et al., 2003
	A7 – Knowledge of SES	Stuiver et al., 2003; Eshuis and Stuiver, 2005; Van Der Ploeg et al., 2006	Kockmann et al., 2003; Bernard, 2004; AE RMC, 2007a; 2007b ; Verron, 2007
	A8 – Importance of the resource		
	A8.1 – Environmental preferences of farmers	Stobbelaar et al., 2009; van Dijk et al., 2015	Sebillotte, 2003

Table 2.4: The characteristics of the governance system

First-tier variable	**Second-tier variables**	**Environmental cooperatives**	**Ferti-Mieux operations**
Governance system (GS)	GS6 – Collective-choice rules		
	GS6.1 – Autonomy at the collective-choice level	Franks and McGloin, 2007a; Franks, 2008; 2011; Termeer et al., 2013	Kockmann et al., 2003; AE RMC, 2007b
	GS8 – Monitoring and sanctioning rules	Polman and Slangen, 2002; Eshuis and Van Woerkum, 2003; Wiskerke et al., 2003; Termeer et al., 2013; Westerink et al., 2017	Ramonet, 2003; Verron, 2007