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Collective action for water quality management in agriculture: the case of drinking water source protection in France

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Abstract: Nonpoint source pollution from agriculture represents a major threat to the quality of water in the European Union (EU) context. As part of the implementation process of the EU Water Framework Directive in France, the cooperation between water suppliers and agricultural stakeholders has been recently promoted for limiting diffuse agricultural pollution at the water catchment level. Based on a conceptual framework combining transaction cost economics and the social-ecological system (SES) framework, this paper identifies the conditions under which such collective action is effective for the restoration/maintenance of water quality. The research relies on a cross-case comparison of cooperation in six drinking water catchments. A qualitative analysis of primary data collected at the national, water basin and local levels serves as a basis for the multi-case investigation. Variables related to the hydrogeological system, the stakeholders involved, the contracts governing cooperation and the economic and policy contexts are shown to interact in their influence on collective action. The results highlight the importance of the match between contract incentives and the characteristics of the local context and the potential complementarities between informational, regulatory and economic policy tools for enhancing the effectiveness of collective action for water pollution control.

Keywords: collective action; nonpoint source pollution; water drinking catchments; transaction costs; social-ecological system (SES) framework

Highlights:

- A cross-case comparative analysis of cooperation for water pollution control in France.
- A conceptual framework combining transaction cost theory and the SES framework.
- Features of the hydrogeological system, the involved actors and governance influence cooperation.
- Market and policy incentives play a major role in collective action.
- Identified variables interact in their influence on cooperation.

Acknowledgements:

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Declaration of interest: None

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1. Introduction

Despite an important reduction in the levels of nutrients in European freshwaters over the past two decades, nonpoint source pollution from agriculture still represents a major threat to the quality of surface and ground waters in Europe (EEA, 2015). In France, nitrate pollution, mostly from agriculture, remains high in surface waters. The contamination of ground waters by nitrates and pesticides has worsened in the past few years (CGDD, 2014).

While pollutants from point sources enter at discrete identifiable locations, pollutants from nonpoint sources follow indirect and diffuse pathways to the environment (Shortle and Horan, 2001). Diffuse pollution from agriculture has multiple environmental, social and economic impacts. High nitrogen and phosphorus levels in water lead to eutrophication, reducing biodiversity and affecting recreational and economic activities that depend on aquatic ecosystems (Shortle et al., 2001). Due to the human health risks posed by pollutants in drinking water, the European Union (EU) Drinking Water Directive established standards for nitrate and pesticide rates in water intended for human consumption (EU, 1998). In France, water utilities adopted costly curative (water treatments) or palliative strategies (resource blending or substitution) to comply with regulatory standards. In 2007, treatments were applied to 10% of the drinking water resources to reduce nitrate rates and to more than 20% of the drinking water resources to eliminate pesticide residues. Between 1998 and 2008, diffuse pollution was one of the main causes for catchment abandonment. In total, the extra costs incurred by water supply services to address nitrate and pesticide pollution were estimated to be between 580 and 1010 million euros (Bommelaer and Devaux, 2011).

Adopted in 2000, the EU Water Framework Directive established the objective of achieving a good water status for all water bodies. This directive more particularly encourages EU member states to ensure the protection of water bodies used for the production of drinking water “in order to reduce the level of purification treatment required” (EU, 2000).

As an alternative to curative/palliative approaches to drinking water quality management, decentralized cooperation between water suppliers and agricultural stakeholders for limiting nonpoint source pollution has recently been developing in the French and European contexts (Brouwer, 2003; De Groot and Hermans, 2009; Grolleau and McCann, 2012). Such cooperation involves water suppliers and agricultural stakeholders (farm organizations, farmers) who jointly define and implement action plans at the water catchment scale (Brouwer, 2003). The action plans include measures (e.g., reductions in nitrogen and pesticide use or the establishment of riparian buffers along watercourses) aimed at modifying agricultural practices known to influence the extent of contaminant leaching and runoff. The definition and implementation of action plans are based on self-organization among key actors: drinking water suppliers, farmers and other potential stakeholders (e.g., farm organizations and state agencies) (Brouwer, 2003).

In France, most cases of collective action for drinking water catchment protection have developed in the context of the “Grenelle” policy launched in 2009. More than 500 priority drinking water catchments were identified as being particularly threatened by nonpoint source pollution (Loi n° 2009-967, 2009). The policy prescribes the definition and implementation of action programs based on the cooperation between water suppliers and agricultural stakeholders. The implementation of actions targeting nonpoint source pollution at the water catchment level relies on the voluntary participation of farmers. The initial objective of the “Grenelle” policy was to protect all priority catchments by 2012; however, the action plans were effective in only 23% of the catchments at the end of 2014 (Ménard et al., 2014). In 2019, the share of catchments where an action program was implemented increased to 76% (MEDDE, 2019). While a few successful cases of drinking water catchment protection have been documented, to date, the “Grenelle” policy has not led to a significant improvement in water quality (Barataud et al., 2014a; Bénézit et al., 2014; AE Adour-Garonne, 2017).

75 The delayed implementation of the “Grenelle” policy as well as the diverse outcomes achieved by
76 collective action initiatives in France highlight the need to better understand the conditions under which
77 the cooperation between drinking water suppliers and agricultural stakeholders is effective for protecting
78 the water resource from diffuse pollution. The objective of the paper is thus to identify the factors
79 influencing the success or failure of collective action involving water suppliers and agricultural
80 stakeholders for the definition and implementation of programs targeting diffuse pollution in France.

81 Similar to many environmental goods, water quality presents the characteristics of a public good
82 (Baumol and Oates, 1988). Pure public goods are goods that are non-exclusive and non-subtractive
83 (Ostrom, 2003). The restoration or maintenance of water quality constitutes a public good, as (i)
84 everyone can benefit from the improvement in water quality without diminishing others’ benefits (non-
85 subtractability) and (ii) it is difficult (impossible) to prevent anyone from enjoying the benefits of water
86 pollution reduction (non-excludability). The collective action dilemma at stake is thus similar to a public
87 good provision problem (Esteban and Albiac, 2012; Villamayor-Tomas et al., 2014; Ban et al., 2015).

88 The analysis relies on a conceptual framework combining transaction cost economics and the social-
89 ecological system (SES) framework. Within the framework of transaction cost economics, it is assumed
90 that the development of cooperation depends on the benefits and costs, including transaction costs that
91 accrue to the participating stakeholders. A growing body of research seeks to include transaction costs
92 in the analysis of environmental policies and natural resource management (Birner and Wittmer, 2004;
93 McCann et al., 2005; Coggan et al., 2010; Ménard, 2011; McCann, 2013; Thiel et al., 2012; 2016).
94 Several studies have empirically measured the transaction costs linked to the implementation of
95 environmental policies and showed their high significance (McCann and Easter, 1999; Falconer et al.,
96 2001; Mettepenningen et al., 2009; McCann and Claassen, 2016). However, there is still a limited
97 understanding of the factors influencing the type and the level of transaction costs associated with
98 different modes of governance or environmental policy instruments (Coggan et al., 2010; Garrick et al.,
99 2013). The SES framework was developed to analyze the patterns of interactions and outcomes in
100 diverse social-ecological systems (Ostrom, 2009; McGinnis and Ostrom, 2014). This framework has
101 been applied for descriptive, diagnostic, or, in association with various theories, explanatory purposes
102 (Thiel et al., 2015; Partelow, 2018). We follow the third approach by using the SES framework to
103 identify the factors affecting the benefits/costs and transaction costs of collective action for drinking
104 water catchment protection. More particularly, the variables highlighted by Ostrom (2009) are used as
105 initial assumptions regarding the factors that influence the cooperation between drinking water suppliers
106 and agricultural stakeholders.

107 With the objective of identifying the factors that foster or constrain collective action, the adopted
108 research strategy is an explanatory, multiple-case study design, structured by the conceptual framework
109 combining transaction cost economics and the SES framework (Yin, 1994). Case study research is
110 particularly helpful for disentangling complex causal processes involving interactions between multiple
111 variables (Poteete et al., 2010). Based on a qualitative analysis of primary data collected at the national,
112 water basin and local levels, six cases of successful and unsuccessful collective action for drinking water
113 catchment protection in France were investigated.

114 This paper is organized as follows. Section 2 develops the conceptual framework used for the analysis.
115 The methodology of the research is detailed in section 3, including background information on the six
116 selected cases of cooperation. The factors identified as affecting the benefits and transaction costs of
117 collective action are presented in section 4. The final section discusses the results and the insights they
118 provide for understanding the cooperative processes involving water suppliers and agricultural
119 stakeholders, their policy implications and future research areas.

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125 **2. Conceptual framework**

126 Transaction cost economics are used as the theoretical framework for identifying the benefits and costs,
127 including transaction costs, of cooperation for drinking water catchment protection (section 2.1.). The
128 factors likely to affect the benefits and costs of collective action involving water suppliers and
129 agricultural stakeholders are further identified on the basis of the SES framework (section 2.2.).

130 2.1. Transaction cost economics

131 Transaction cost theory relies on the assumption of bounded rationality proposed by Simon (1978). Due
132 to uncertainty about the relevant elements that must be considered and cognitive limitations with regard
133 to information processing, actors make decisions without considering all options and their consequences
134 (Simon, 1979). Boundedly rational actors are unable to establish contracts forecasting all future
135 contingencies. Such contract incompleteness allows for the participants' strategic behavior, which
136 manifests as adverse selection, moral hazard or shirking (Williamson, 2000). Transaction costs are "the
137 comparative costs of planning, adapting, and monitoring task completion under alternative governance
138 structures" (Williamson, 1985). In the natural resource management and environmental policy field, *ex-*
139 *ante* transaction costs are defined as information collection costs, decision-making costs and/or
140 bargaining costs for reaching agreements, while *ex-post* transaction costs correspond to the monitoring
141 and enforcement costs of agreements (Birner and Wittmer, 2004; McCann et al., 2005).

142 Participation in collective action for protecting water quality at the source involves potential benefits
143 and costs as well as transaction costs.

144 The objective of water suppliers engaging in collective action for water catchment protection is to
145 maintain or restore water quality to meet the regulatory standards for drinking water supplies (Brouwer,
146 2003; Lehmann et al., 2009). The water suppliers' incentives to cooperate depend on the opportunity
147 costs of alternative options, such as purification treatments, to enhance drinking water quality (Abildtrup
148 et al., 2012; Grolleau and McCann, 2012). The costs borne by water suppliers also encompass the
149 economic resources devoted to water catchment protection, such as monetary payments delivered to
150 farmers as compensation for changing their practices to improve water quality (De Groot and Herman,
151 2009). In turn, farmers participating in collective action incur costs for changing their practices
152 (Lehmann et al., 2009; Abildtrup et al., 2012). These costs are opportunity costs, i.e., the loss of profit
153 or revenue potentially induced by the adoption of measures that target nonpoint source pollution. They
154 also include labor costs and investment costs; for example, changes in farming systems may require the
155 acquisition of new equipment (De Groot and Hermans, 2009). Farmers may benefit from savings by
156 changing their practices, for example, by reducing the expense of chemical inputs, without experiencing
157 any decrease in yields (Buckley and Carney, 2013). Finally, economic incentives for farmers to
158 participate in collective action also include potential benefits such as investment subsidies or monetary
159 compensation (Lubell, 2004; Grolleau and McCann, 2012).

160 The transaction costs associated with collective action for drinking water protection correspond to the
161 costs incurred for defining and implementing actions targeting nonpoint source pollution. The costs for
162 defining the actions include the costs of collecting and processing information concerning the pollution
163 sources, vulnerable areas and farming systems in the catchment and the consultation/negotiation costs
164 of actions with farmers (Falconer et al., 2001; Mettepenningen et al., 2011). Farmers also bear decision-
165 making costs regarding their participation in collective action, including the costs for accessing
166 information on the measures to be implemented and their consequences for their farming system
167 (Falconer, 2000; 2002; Lehmann et al., 2009; Mettepenningen et al., 2009). The implementation costs
168 incurred by water suppliers are the control and enforcement costs of actions. These costs depend on the
169 level of difficulty for observing changes in farming practices (Falconer, 2002). The *ex-post* transaction
170 costs also include the time spent by farmers to fulfill the monitoring requirements and the costs related
171 to sanctions in the case of noncompliance (Lehmann et al., 2009; McCann, 2009; Mettepenningen et al.,
172 2009).

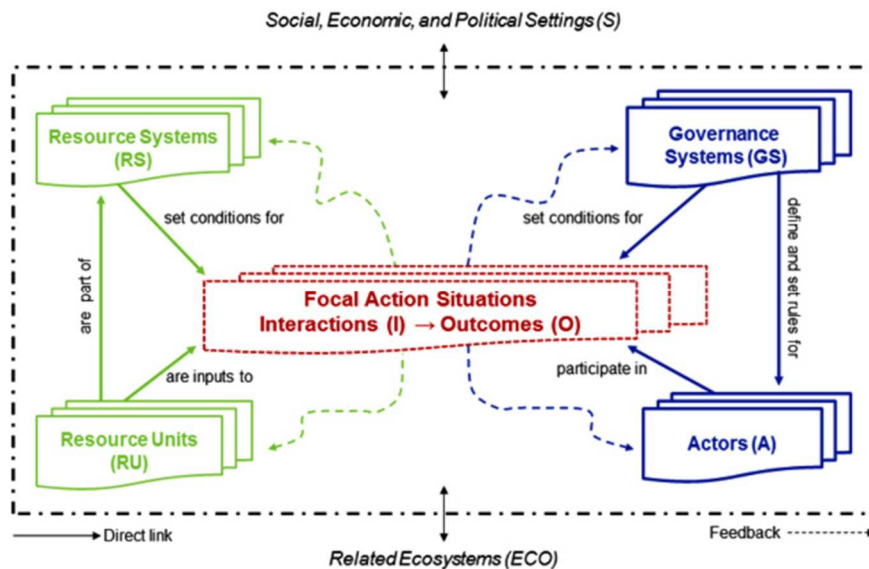
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175 2.2. SES framework

176 The SES framework was developed for analyzing, from an institutional analysis perspective, the
 177 governance of common-pool resources (Ostrom, 2007a; 2009). This framework draws on the IAD
 178 (Institutional Analysis and Development) approach (Ostrom, 1998; Ostrom, 2011). It has been applied
 179 to diverse sectors, including the management of fisheries (e.g., Basurto et al., 2013; Ernst et al., 2013;
 180 Torres Guevara et al., 2016; Partelow et al., 2018a), irrigation systems (e.g., Meinzen-Dick, 2007;
 181 Ostrom and Cox, 2010), pond aquaculture systems (Partelow et al., 2018b) or grassland (e.g., Risvoll et
 182 al., 2014; Robinson et al., 2017). While the framework was originally designed for the study of common
 183 pool resource problems, recent developments have been aimed at broadening its scope of application.
 184 These developments include the analysis of the various public goods and services generated by SESs
 185 (McGinnis and Ostrom, 2014; Ban et al., 2015; Bennett and Gosnell, 2015) as well as investigations of
 186 sectors outside the natural resource management field (e.g., Blanco, 2011; Marshall, 2015). Several
 187 studies have used the IAD or SES framework for analyzing the emergence of partnerships for water
 188 quality management (Lubell et al., 2002; Sarker et al., 2008; Nagendra and Ostrom, 2014, Villamayor-
 189 Tomas et al., 2014) or for assessing the performance of community-based drinking water provision
 190 (Madrigal et al., 2011; Naiga et al., 2015). However, no study so far has applied the SES framework to
 191 the protection of drinking water catchments.

192 The SES framework gathers and structures the variables that have been found in previous research to
 193 influence the patterns of interactions and outcomes (focal action situations) in diverse SES (McGinnis
 194 and Ostrom, 2014). Four first-tier variables are considered as potentially important to analyze the
 195 outcomes achieved in a given SES: the characteristics of the natural resource considered (the resource
 196 system and the resource unit), the characteristics of the actors involved and the characteristics of the
 197 governance system. In addition, the broader social, economic and political contexts as well as the related
 198 ecosystems are included as first-tier variables interacting with the other variables (Figure 1).



199
 200 Figure 1: SES framework (Source: McGinnis and Ostrom, 2014)

201 Potential explanatory factors for the outcomes achieved are included in the SES framework as second-
 202 tier variables, which are defined as the characteristics of the first-tier variables (McGinnis and Ostrom,
 203 2014). When applying the framework, the second-tier variables can be further characterized by third-
 204 tier variables and so on, if relevant for the analysis (Basurto et al., 2013; Partelow and Boda, 2015).
 205 Appendix A presents the list of second-tier variables that was updated by McGinnis and Ostrom (2014).

206 Among the second-tier variables identified as potentially relevant, a subset of ten factors likely to affect
 207 the benefits and costs of collective action has been found in previous research to be critical for users of
 208 a common-pool resource to successfully self-organize rules to manage the resource (Ostrom, 2009;
 209 Poteete et al., 2010).

210 While managing large resource systems involves higher transaction costs, a small size may imply a less
211 valuable flow of products from the system. Thus, a moderate size of the resource system is seen as most
212 conducive to self-organization (Chhatre and Agrawal, 2008; Ostrom, 2009). Unlike situations where the
213 resource is either already exhausted or abundant, a moderate level of resource scarcity (productivity of
214 the system) is also likely to induce collective action by users (Meinzen-Dick, 2007). A low predictability
215 of the system dynamics will increase the management costs of the resource, thereby reducing the
216 likelihood of self-organization (Ostrom, 1990; Agrawal, 2001). Management costs also depend on the
217 resource unit mobility; stationary units (e.g., water in a lake) are less costly to manage than mobile units
218 (e.g., water in a stream) (Schlager et al., 1994).

219 A larger number of users means higher transaction costs (Casari and Tagliapietra, 2018); however, a
220 small group size may be a constraint on the pooling of resources needed to sustain collective action
221 (Wade, 1987; Ostrom, 2010). The sharing of a common knowledge of the social-ecological system is
222 seen as decreasing the perceived costs of organizing by users (Ostrom, 2009). The importance of the
223 resource to users, in terms of economic or noneconomic value, will affect the expected balance of
224 benefits and costs associated with collective action (Acheson, 2006). The presence of well-respected
225 local leaders and the existence of norms of reciprocity and/or social capital within the group are actors'
226 characteristics that are likely to decrease the transaction costs associated with collective action (Pretty
227 and Ward, 2001; Meinzen-Dick, 2007). Leaders can reduce the costs of information diffusion and
228 agreement formation (Villamayor-Tomas et al., 2014). Norms of cooperative behavior lower the
229 negotiation and enforcement costs of agreements (North, 1990; Poteete et al., 2010).

230 Governance systems in the SES framework are conceptualized as being composed of multilevel sets of
231 rules. Operational rules affect the decisions of actors with regard to the direct management of the
232 resource. Collective-choice rules frame the collective-choice situations where operational rules are
233 defined, and constitutional rules affect the constitutional situations where collective-choice rules are
234 crafted (Ostrom, 2007b). A variable identified as crucial for the success of self-organization is the
235 autonomy of users at the collective-choice level to define and enforce the operational rules governing
236 resource management (Ostrom, 2009; Poteete et al., 2010).

237 The long-term sustainability of collective action will also depend on the match between operational rules
238 and local conditions (the attributes of the resource and the characteristics of the actors). Furthermore,
239 the effectiveness of governance systems also depends on the monitoring and enforcement of rules and
240 on the interactions with the larger scale governance systems (Ostrom, 2009).

241 In this paper, we analyze collective action for the definition and implementation of programs targeting
242 farming practices to control nonpoint source pollution at the water catchment level (I). The resource
243 system (RS) considered is the hydrogeological system, from which water, as a resource unit (RU), is
244 abstracted for drinking water production. Collective action involves two main sets of actors (A):
245 drinking water suppliers and agricultural stakeholders (farm organizations and farmers). The contracts
246 framing the implementation of actions are understood as operational rules defined by stakeholders at the
247 collective-choice level (GS). The objective of the cooperation between water suppliers and agricultural
248 stakeholders is to limit or reduce water pollution; thus, the outcome (O) of interest in the study is the
249 restoration or maintenance of water quality.

250 The set of factors highlighted by Ostrom (2009) as affecting the costs and benefits of self-organization
251 (Table 1) is used as initial assumptions for identifying factors affecting collective action in the case of
252 drinking water catchment protection in France.

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259 Table 1: Subset of factors identified as affecting the likelihood that common-pool resource users will
 260 engage in collective action to self-organize (adapted from Ostrom, 2009)

First-tier variable	Second-tier variables	Impact on the benefits/costs and transaction costs of collective action	Impact on collective action	
Resource systems (RS)	RS3 – Size of resource system	A large resource system increases transaction costs	-	
		A small resource system decreases benefits	-	
		A moderate size of the resource system increases benefits and decreases transaction costs	+	
	RS5 – Productivity of system	Resource exhaustion decreases benefits	-	
		Resource abundance decreases benefits	-	
		Moderate levels of resource scarcity increase benefits	+	
	RS7 – Predictability of system dynamics	A high predictability of system dynamics decreases transaction costs	+	
		GS6 – Collective-choice rules	User autonomy at the collective-choice level decreases transaction costs	+
		Resource units (RU)	RU1 – Resource unit mobility	Mobile resource units increase transaction costs
Actors (A)	A1 – Number of relevant actors	A large number of users increases available resources and transaction costs	-/+	
	A5 – Leadership-entrepreneurship	The presence of entrepreneurs/local leaders decreases transaction costs	+	
	A6 – Norms (trust-reciprocity)/social capital	Shared norms of reciprocity/trust between users decrease transaction costs	+	
	A7 – Knowledge of SES	Shared knowledge of relevant SES attributes decreases transaction costs	+	
	A8 – Importance of the resource	A more important resource to users increases benefits	+	

261

262 3. Methodology

263 The identification of factors affecting collective action relies on the comparative analysis of six cases of
 264 cooperation. The multistep methodological approach followed in the research is presented in section
 265 3.1. A short description of the six cases is provided in section 3.2.

266 3.1. Multistep methodological approach

267 The data collection and treatment followed a multistep approach summarized in Figure 2.

268 3.1.1. Identification of variables likely to affect collective action

269 In the **first step**, the initial set of assumptions drawn from the conceptual framework (Ostrom, 2009)
 270 was developed and adapted for (i) the specific case of cooperation between drinking water suppliers and
 271 agricultural stakeholders for nonpoint source pollution control and for (ii) the French context.

272 The revision of the assumptions regarding the variables likely to affect collective action was based on
 273 the following: (1) a review of the scientific literature focused on cooperative agreements for drinking
 274 water quality management in the French and European context; (2) a review of research and policy
 275 reports addressing collective action for drinking water catchment protection in France; and (3) 12 semi-
 276 structured interviews with water and agriculture policy stakeholders at the national and river basin levels
 277 (Table 2).

278 Table 2: Interviews conducted at the national and river-basin levels in 2013.

Organization	Number of interviews
Water Agencies	5
Ministries	2
Agricultural organizations	3
Private water operators	2

279

280 The selection of stakeholders to be interviewed was informed by a preliminary review of research and
 281 policy reports. The interviewees were chosen to include the main public and private stakeholders
 282 involved in the protection of drinking water catchments at the national and river-basin levels (Table 2).
 283 The semi-structured interviews were based on a common questionnaire to ensure a systematic collection
 284 of comparable data. The questionnaire was organized around two main sections. One section addressed
 285 the characteristics of cooperative agreements (stakeholders, types of contractual arrangements and their
 286 prevalence at the national or water basin level). Based on the initial set of assumptions, the second
 287 section was designed to assess the perception of the interviewees regarding each factor assumed to
 288 foster/constrain collective action for drinking water protection. In addition, interviewees were invited to
 289 indicate other variables that in their opinion have an impact on the cooperation between water suppliers
 290 and agricultural stakeholders.

291 The interviews were conducted either face-to-face (9) or by phone (3) between May and November
 292 2013. The time spent for an interview ranged between one and three hours. Appendix B presents the
 293 interviews in greater detail. All interviews were recorded and transcribed by using the structure provided
 294 by the questionnaire. The transcripts were sent to the interviewees to verify the accuracy of the data
 295 collected and opinions expressed.

296 Through the triangulation of data sources (Yin, 1994), the evidence collected served as a basis for
 297 assessing the relevance of the initial set of SES second-tier variables and their hypothesized impact on
 298 collective action in the specific case of drinking water catchment protection in France. New third- and
 299 fourth-tier variables were also added, as they were found to be potentially relevant for explaining the
 300 outcomes of cooperation between drinking water suppliers and agricultural stakeholders. Those
 301 variables characterize either the initial second-tier variables or new second-tier variables identified in
 302 the list updated by McGinnis and Ostrom (2014) (Appendix A). The criterion used for adding a new
 303 variable was the identified impact of this variable on the benefits, costs or transaction costs of collective
 304 action. The inclusion of additional variables was thus theoretically motivated (Thiel et al., 2015; Cox et
 305 al., 2016) by using transaction cost economics. As suggested by Frey and Cox (2015) and Thiel et al.
 306 (2015), the development of the third-tier and the fourth-tier variables followed the logic underlying the
 307 SES framework as a multitier nested framework.

308 The first step led to a revised set of assumptions regarding the factors likely to affect the benefits, costs
 309 and transaction costs associated with collective action for drinking water catchment protection in France.
 310 Appendix C presents the revised set of assumptions.

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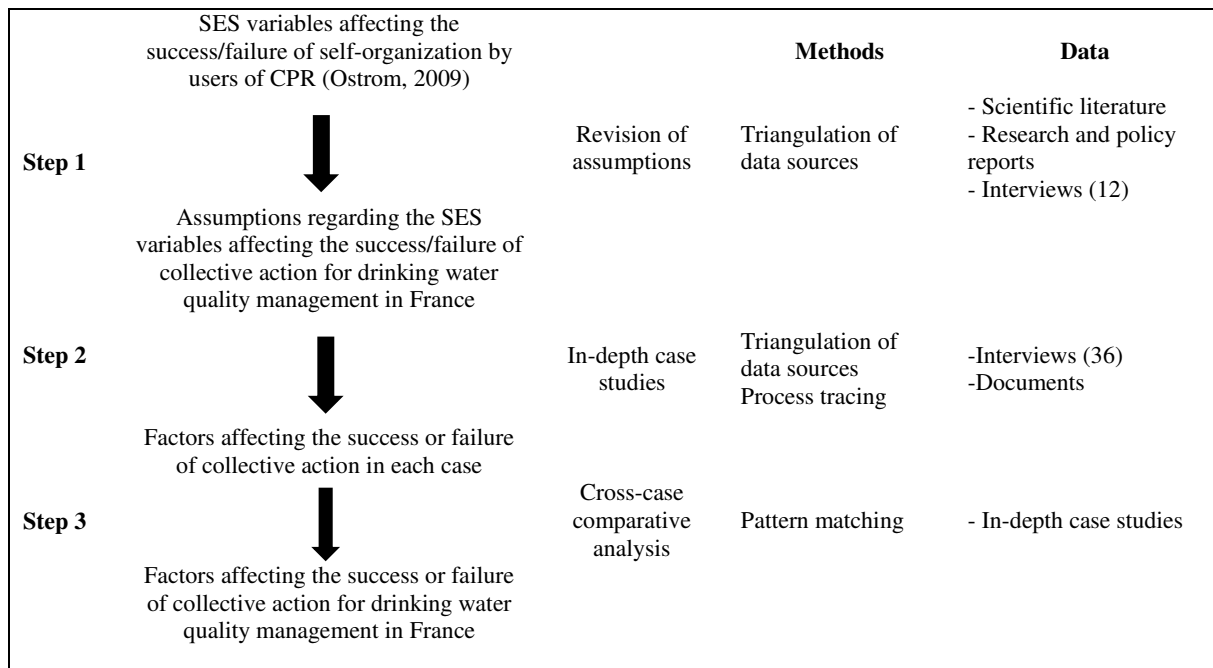


Figure 2: Multistep research design

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3.1.2. In-depth case studies

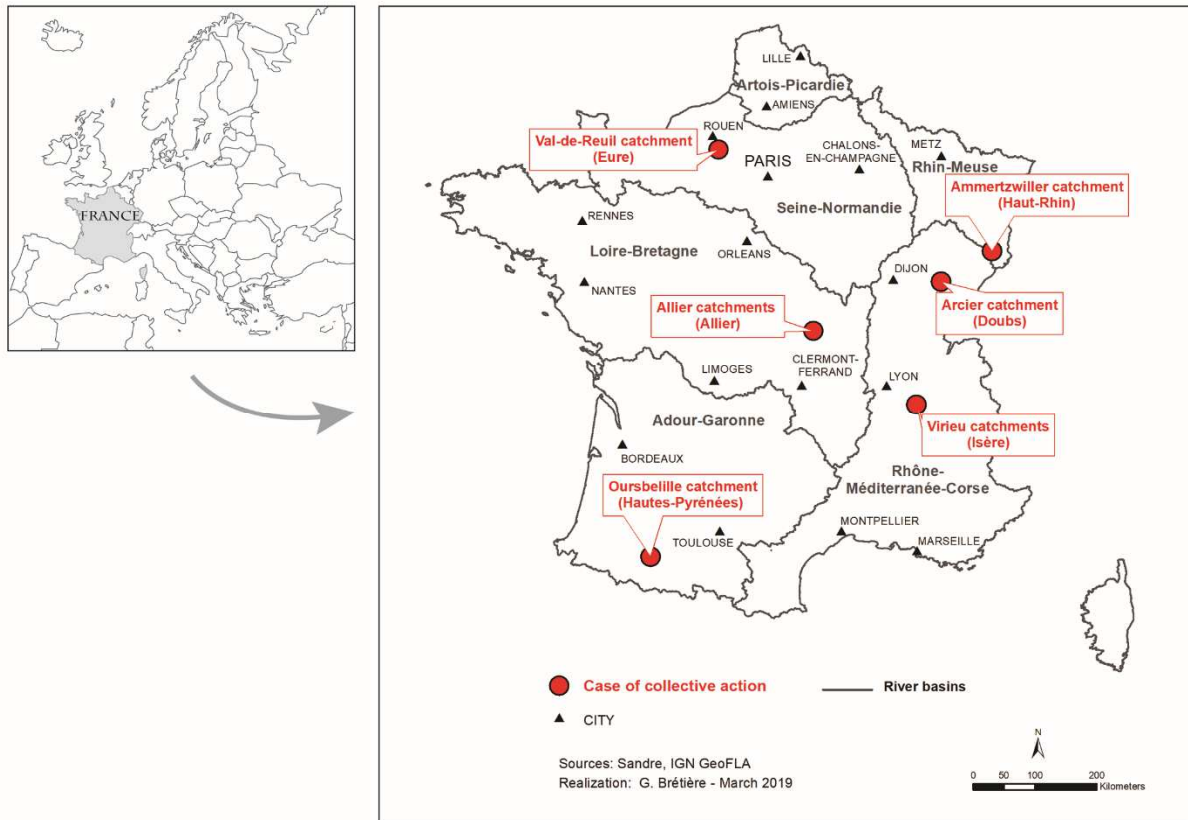
322
323 In a **second step**, in-depth case studies of collective action for the protection of six selected drinking
324 water catchments were conducted.

325 Case study research is based on analytical rather than statistical generalization (Yin, 1994). Thus, the
326 case selection followed a purposive sampling logic, which was framed by the conceptual framework of
327 the analysis (Agrawal, 2003). The information collected in the first step was used for the selection of
328 cooperation cases to be studied in depth (Map 1).

329 The cases were selected to represent the diversity of the types of contractual arrangements identified at
330 the national and river-basin levels in order to gain insights into the specific influence of variations in the
331 governance of collective action as a basis for policy recommendations. The review of the contractual
332 arrangements realized in the first stage of the study shows that actions targeting water pollution control
333 in the French context have been mostly implemented through Agri-Environmental Schemes (AES) co-
334 funded by the EU as part of the rural development policy. Other, less prevalent, types of contracts have
335 been established between water suppliers and farmers. These agreements include environmental land
336 leases and purchase contracts for agricultural products (organic products used for collective public
337 restaurants or low-input energy crops used for public district heating). In France, the choice of EU agri-
338 environmental measures implemented locally is framed by a set of unitary commitments established at
339 the national level by the Ministry of Agriculture. In contrast, local stakeholders have the autonomy to
340 define the measures and compensation in environmental land leases and purchase contracts. Following
341 Ostrom (2009), autonomy at the collective-choice level is assumed to be crucial for the success of
342 collective action. Specific attention was also given to choosing both successful and unsuccessful cases
343 of collective action with regard to the impact of cooperation on water quality. The indicators used to
344 assess the success of collective action include the evolution of pollutant rates in water used for drinking
345 water production. Due to the complexity and uncertainty surrounding the hydrogeological system
346 dynamics, the observed short-term water quality trends may represent an imperfect measure of collective
347 action success (Brouwer, 2003; Bennett and Gosnell, 2015). Thus, we also consider two intermediate
348 collective action outcomes: (i) the farmers' participation in cooperation, which is defined as the adoption
349 of measures included in the action plans, and (ii) the extent of the agricultural area covered by changes
350 in farming practices in the drinking water catchment.

351

352 Map 1: Map of the selected cases of collective action for drinking water catchment protection



353

354 Data used for the in-depth case studies include data collected through 36 semi-structured interviews with
355 local stakeholders involved in cooperation as well as data obtained from secondary sources.

356 The interviewees were chosen to include the main public and private stakeholders involved in the
357 protection of drinking water catchments at the local level: water suppliers, farm organizations and local
358 and regional state administrations. Participating and non-participating farmers were also interviewed in
359 each case (Table 3). A preliminary review of the available documents and initial contacts with drinking
360 water suppliers and/or farm organizations were used for the identification and selection of informants.
361 While the information available at this stage of the study allowed for the adoption of a purposive
362 selection strategy with regard to the choice of “institutional” stakeholders, the selection of interviewed
363 farmers was more dependent on the guidance provided by the stakeholders. Nevertheless, the potential
364 diversity in the farmers’ perspectives could be assessed based on interviews with farm organizations,
365 which fulfill a role of representing farmers in collective action processes.

366 Identical questionnaires were used for the interviews conducted across the six cases. The first section
367 was dedicated to the collection of descriptive data concerning the water resource and drinking water
368 catchment, the characteristics of the stakeholders involved, the governance and the broader policy
369 context of cooperation. The questions in this first section were adapted to the specific area of expertise
370 of the informants. The second section was based on the revised set of assumptions developed in the first
371 step and was designed to collect in a systematic and comparable way the stakeholders’ perceptions about
372 the variables fostering or constraining collective action. The interviewees were asked whether each
373 variable had an impact on collective action and whether the impact was positive or negative. They were
374 also invited to elaborate on the reasoning behind their statement. The development of this section
375 involved rephrasing the variables to clarify their content for the stakeholders having no scientific
376 background (Delgado-Serrano and Ramos, 2015).

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379

380 Table 3: Interviews conducted at the local level in 2014

	Allier	Virieu	Oursbellile	Arcier	Ammertzwiller	Val-de-Reuil
Water suppliers						
Public water utilities	1	1	1	1	1	1
Private water operators			1			
Agricultural organizations						
Agricultural Chambers	1	1	1	1	1	
Regional organic farmers group						1
Organic supply chain association						1
Society for land and rural development		1				
Agricultural cooperative				1		
Farmers	1	2	2	2	2	2
Other stakeholders						
Watershed management boards		1		1		
Local/regional state administration	3					
Local offices of water agencies	1		1		1	1

381

382 The interviews were conducted during short-term stays at each case site between January and September
 383 2014 (Appendix D). The time spent for an interview ranged between one and two hours. All interviews
 384 were recorded and transcribed by using the structure provided by the questionnaires. The transcripts
 385 were sent to interviewees to verify the accuracy of the collected data and opinions.

386 The information collected through face-to-face interviews was complemented with relevant
 387 documentation, such as environmental and agricultural diagnoses of water catchments, action plans,
 388 contracts, meetings minutes and evaluation reports. Documents were either accessed via the
 389 stakeholders' web sites or provided by the interviewees themselves.

390 The data were used to describe the collaborative processes and to identify the factors that favor or
 391 constrain collective action in each case. The descriptions of cooperation include the presentation of the
 392 water resource and agricultural land use context in the studied water catchments and the characterization
 393 of the cooperation process and its outcomes. The factors were assessed on the basis of indicators
 394 measured through a qualitative assessment of quantitative or qualitative data. Appendix E presents the
 395 indicators chosen, the type of data used and the criteria implemented for the assessment of variables.
 396 The characterization of the influence of factors on collective action was based on the triangulation of
 397 primary and secondary data sources (Yin, 1994). The perception of the interviewees regarding the
 398 impact of factors influencing collective action was critically assessed against the perception of other
 399 stakeholders as well as against the evidence from secondary sources. Process tracing was used as a
 400 complementary tool to characterize the causal relationships between the variables and the outcomes of
 401 collective action (Steinberg, 2007; Poteete et al., 2010). Appendix F presents a synthesis of the in-depth
 402 case studies, including the assessment of the factors and their impact on collective action in each case.

403 3.1.3. Cross-case comparative analysis

404 In a **third step**, the results of the individual case studies were compared in relation to the revised
 405 assumptions set in the first phase. Pattern matching (Yin, 1994) was used as a method for testing the
 406 revised assumptions against the case study evidence (Appendix G). The impact of each variable on
 407 collective action was compared across all cases to assess whether the pattern observed was similar to
 408 the corresponding revised assumption. Furthermore, systematic comparisons between cases presenting
 409 similarities on one or several variables were performed to consider the potential interactions between
 410 variables in their influence on collective action.

411 3.2. Background on the case studies

412 This section provides background information on the six selected cases of collective action. Table 4
 413 displays the main characteristics of the water resource and the agricultural context in each case. The
 414 collective action processes and outcomes are presented in Table 5.

415 In the **Allier** case, ten drinking water catchments were classified as “Grenelle priority catchments” in
416 2009 because of increasing nitrate and pesticide rates. Approximately 120 mixed crop and livestock
417 farms have all or part of their agricultural area in the large protection zone (8300 ha) (SMEA, 2013).
418 Drinking water catchment protection relies on the cooperation between the Syndicat Mixte des Eaux de
419 l’Allier (SMEA), representing the six intermunicipal water suppliers managing the catchments, and the
420 departmental Agricultural Chamber. Collective action led to the establishment of an action plan in 2014.
421 In addition to a free technical support program, EU Agri-Environmental Schemes (AES) were
422 implemented. In 2015, a total of 71 farmers were involved in the support program, while only three
423 farmers adopted agri-environmental measures, which covered 60 ha in the protection zone (SMEA,
424 2015). Water quality did not improve and deteriorated in some catchments.

425 The **Virieu** catchments are managed by the Syndicat Mixte d’Eau et d’Assainissement de la Haute-
426 Bourbre (SMEAHB). They were identified as “priority” in the framework of the Grenelle policy in 2009
427 because of the noncompliance of the pesticide rates with the regulatory standard (AE Rhône
428 Méditerranée Corse, 2013a). A Zone Soumise à Contrainte Environnementale (ZSCE) procedure, which
429 gave the “département” state agency the option to prescribe regulatory measures if voluntary
430 cooperation was not effective in restoring water quality after three years, was also adopted (Décret
431 n°2007-882, 2007). Grassland represents two-thirds of the agricultural area in the catchments, where ten
432 cattle breeding farms are located (Chambre d’Agriculture de l’Isère, 2012). In 2010, the water supplier
433 became the owner of 17 ha of agricultural land within the catchments through land acquisition and
434 exchange. The establishment of environmental land contracts (land leases and loan agreements) with
435 five farmers led to the conversion of 27 ha of cropland into grassland, increasing the share of grassland
436 from 60% to 87% of the agricultural area. The pesticide rates have shown a tendency to stabilize and
437 decrease (AE Rhône Méditerranée Corse, 2013a).

438 The Syndicat Intercommunal d’Alimentation en Eau Potable (SIAEP) Tarbes-Nord relies on the
439 **Oursbelille** catchment for its total drinking water production, for which supply is delegated to a private
440 company. In 2009, the catchment was identified as a Grenelle “priority” catchment, as the nitrate rate
441 regularly exceeded the regulatory standard between 2003 and 2008 (SIAEP Tarbes-Nord, 2013).
442 Nineteen farmers own parcels in the catchment, with irrigated corn farming representing 88% of the
443 agricultural area (Chambre d’agriculture Hautes-Pyrénées, 2012). The definition and implementation of
444 actions are delegated to a consortium involving the water company, the Hautes-Pyrénées Agricultural
445 Chamber and a regional development agency, the Semadour. The implementation of agricultural actions
446 relies on AES co-funded by the EU and the Adour-Garonne Water Agency. In 2014, seven farmers had
447 adopted agri-environmental measures, covering 73 ha in the catchment. The nitrate rates have decreased
448 but are still close to the regulatory standard (SIAEP Tarbes-Nord, 2014).

Table 4: Main characteristics of the drinking water catchments in the six cases

	Allier	Virieu	Oursbellile	Arcier	Ammertzwiller	Val-de-Reuil
Water resource						
Water management	Intermunicipal water utility (SMEA)*	Intermunicipal water utility (SMEAHB) *	Intermunicipal water utility (SIAEP Tarbes-Nord)*	City of Besançon*	Intermunicipal water utility (SIAEP Ammertzwiler-Balschwiller)*	Seine-Eure metropolitan area authority*
Hydrogeological system	Alluvial aquifers (Allier and Loire rivers)*	Perched aquifers**	Alluvial aquifer* (Adour river)	Karst aquifers**	Unconfined aquifer*	Karst aquifer**
Population supplied by the resource	39 900*	9 000 *	12 000*	50 000***	4 500**	40 000*
Share of total drinking water supply	51%*	20%*	100%**	45%***	30%**	67%*
Type of pollution	Nitrates/Pesticides*	Pesticides***	Nitrates**	Pesticides*	Nitrate/Pesticides*	_*
Level of contamination	Moderate*	High***	High**	Moderate*	High*	Low*
Agriculture						
Catchment area	8 300 ha*	115 ha***	396 ha*	10 200 ha*	363 ha**	127 ha***
Agricultural area	6 900 ha* (83%)	97 ha*** (84.3%)	325 ha** (82%)	4 146 ha* (41%)	234 ha* (64.5%)	110 ha*** (86.6%)
Number of farms	118*	10***	19**	72*	30*	7***
Type of farming systems	Mixed crop-livestock farming*	Livestock farming***	Arable crops**	Mixed crop-livestock farming*	Arable crops*	Arable crops***
Share of grassland (% of the agricultural area)	24%*	60%***	3%**	70%*	6%*	9%***
Share of arable crops (% of the agricultural area)	Cereals: 63%* Oleaginous: 9% Others: 4%	Corn: 14%*** Cereals: 13% Oleaginous: 13%	Corn: 88%** Cereals: 4% Others: 5%	Corn: 4%* Cereals: 21% Others: 5%	Corn: 59%* Cereals: 35%	Cereals: 91%***

450

451

452

Sources: Allier: *SMEA, 2013; Virieu: *AE Rhône Méditerranée Corse, 2013a, **DDAF Isère, 2009, ***Chambre d'agriculture de l'Isère, 2012; Oursbellile: *SIAEP Tarbes-Nord, 2013, **Chambre d'agriculture des Hautes-Pyrénées, 2012; Arcier: *Ville de Besançon, 2013, **BRGM, 2005, ***AE Rhône Méditerranée Corse, 2013b; Ammertzwiller: *Chambre d'Agriculture du Haut-Rhin, 2008, **AE Rhin-Meuse, 2009; Val-de-Reuil: *CASE, 2014, **Levinson and Weiss, 2012, ***Safer Haute-Normandie, 2008.

453 The **Arcier** source is located 10 km from the city of Besançon. Between 1998 and 2003, the pesticide
454 rates in the water displayed an upward trend. In 2004, the city decided to undertake the protection of the
455 Arcier source catchment by collaborating with agricultural and non-agricultural stakeholders (Murgue
456 and Afflard, 2013). Because of the importance of the population supplied, the catchment was later added
457 to the list of the “Grenelle” catchments. Most of the 72 farms located in the Arcier catchment are dairy
458 farms producing cheese under the Comté Protected Designation of Origin (PDO) label. Permanent and
459 temporary grassland represents 70% of the agricultural area. The agricultural action program relies
460 mainly on the implementation of AES co-funded by the EU and the Rhône Méditerranée Corse Water
461 Agency. Between 2007 and 2013, approximately 20 farmers adopted agri-environmental measures that
462 covered 808 ha in the catchment. A 27% decrease in pesticide use by participating farmers was observed
463 between 2010 and 2012. Water quality improved between 2004 and 2013 (Ville de Besançon, 2013).

464 The **Ammertzwiler** well, managed by the SIAEP Ammertzwiler and Balschwiller, represents two-
465 thirds of the water resources used for the drinking water supply (AE Rhin-Meuse, 2009). Because of the
466 high nitrate and pesticide pollution levels, the Ammertzwiler catchment was classified in 2009 as
467 “priority” in the Rhin-Meuse water basin management plan. Agriculture dominates land use in the
468 catchment, where 30 farmers own land. While corn represents 59% of the agricultural area, grassland is
469 only 6% (Chambre d’agriculture du Haut-Rhin, 2008). Agricultural actions include the implementation
470 of AES, which are co-funded by the EU, the Rhin-Meuse Water Agency and the Haut-Rhin
471 Departmental Council, and the development of a low-input energy crop (miscanthus). In 2011, the
472 participation of farmers in AES covered 52 ha in the catchment (Ditner, 2014a). The introduction of
473 miscanthus by farmers was supported by subsidies provided by the water supplier and the Rhin-Meuse
474 Water Agency. Moreover, long-term contracts with guaranteed prices were offered to the farmers for
475 supplying the municipal heating system. Sixteen farmers chose to grow miscanthus, the planting of
476 which covered 27 ha in the catchment. Water quality improved significantly between 2009 and 2014,
477 with a decrease in nitrate rates from 45 mg/l to 35 mg/l and a decrease in pesticide rates to levels below
478 the regulatory standard (Ditner, 2014b).

479 The four wells located in the **Val-de-Reuil** catchment are used to supply two-thirds of the population of
480 the metropolitan area Seine-Eure (40 000 inhabitants). The pollution rates of the water resource are well
481 below the regulatory standards (CASE, 2014). However, the metropolitan authority responsible for
482 drinking water production and supply initiated a collaborative process with agricultural stakeholders to
483 limit the risk of diffuse pollution from agriculture in the catchment. In 2008, intensive cereal cropping
484 was the main farming system in the area, with seven farmers renting land from a regional public land
485 development agency (Safer Haute-Normandie, 2008). Between 2009 and 2011, the metropolitan
486 authority became the owner of the rented land in the catchment (FNAB, 2014). Through partnerships
487 with multiple local stakeholders involved in organic farming supply chains, including producers’ groups
488 and potential public and private consumers, environmental land leases were established with farmers.
489 Based on the conversion of part of the cereal area and the development of organic produce production,
490 collective action led to the effective development of organic farming in the Val-de-Reuil catchment.

491 Table 5: Collective action process and outcomes in the six cases

	Allier	Virieu	Oursbellile	Arcier	Ammertzwiller	Val-de-Reuil
Regulatory framework	Grenelle	Grenelle ZSCE	Grenelle	Grenelle	Rhin-Meuse management plan	-
Start date	2009	2009	2009	2004	2008	2008
Main stakeholders involved at the collective-choice level	Water utility-Agricultural Chamber*	Water utility-Agricultural Chamber-Rural Land Agency-Farmers*	Private water supplier-Agricultural Chamber-Regional development agency*	City water service department - Agricultural Chamber-Regional plant protection agency*	Water utility-Agricultural Chamber-Farmers*	Metropolitan water service department-Organic farming/supply associations- Farmers*
Contracts (operational rules)	EU AES**	Environmental land leases**	EU AES**	EU AES**	EU AES** Supply contracts***	Environmental land leases**
Measures	Conversion to grassland**	Maintenance/conversion to grassland**	Reduction in input use**	Conversion to grassland/reduction in input use**	Reduction in input use** Miscanthus growing***	Organic farming**
Outcomes						
Farmer participation	3/118** (0.02%)	5/10** (50%)	7/19** (37%)	20/72** (28%)	16/30*** (53.3%)	4/7** (57.1%)
Agricultural area covered	60 ha**	27 ha**	78.5 ha**	808 ha**	79 ha***	110 ha**
Water quality trend	No improvement/deterioration**	Improving trend**	No improvement**	Improving trend**	Improvement***	Maintenance of good quality**

492 **Sources:** Allier: *Interviews, **SMEA, 2015; Virieu: *Interviews, **AE Rhône Méditerranée Corse, 2013a; Oursbellile: *Interviews, **SIAEP Tarbes-Nord, 2014; Arcier: *Interviews, **Ville
493 de Besançon, 2013; Ammertzwiller: *Interviews, **Ditner, 2014a, ***Ditner, 2014b; Val-de-Reuil: *Interviews, **FNAB, 2014.

494 4. Results

495 The comparison of the results of the individual case studies (Appendix G) led to the identification of a
496 set of factors favoring or constraining collective action for drinking water catchment protection in the
497 French context. First, we present the variables influencing the benefits and costs that accrue to the
498 stakeholders involved in collective action (section 4.1.). The second section describes the variables
499 identified as affecting the transaction costs linked to cooperation (section 4.2). The identified second-,
500 third- and fourth-tier variables and their influence on the benefits, costs and transaction costs of
501 cooperation are presented in Table 6 and Table 7.

502 4.1. The factors affecting the benefits and costs of collective action

503 4.1.1. Water suppliers

504 The engagement of water suppliers in cooperation with agricultural stakeholders appears to be driven
505 by the cost of using alternative approaches to enhance drinking water quality (A8.1.1). Water suppliers
506 are more likely to engage in cooperation when the technical options for reducing the pollutant rates in
507 drinking water, such as purification treatment or water blending/dilution, are nonexistent or very costly
508 (Bosc and Doussan, 2009; Abildtrup et al., 2012; Grolleau and McCann, 2012). The SIAEP Tarbes-
509 Nord depends on the Oursbellile catchment for drinking water production and has no other alternative
510 for lowering nitrate rates than cooperating with farmers. In the Virieu, Arcier and Val-de-Reuil cases,
511 the decision of drinking water suppliers to initiate cooperation with agricultural stakeholders for diffuse
512 pollution control was also driven by the high costs of investing in and operating new water treatment
513 units. In the Arcier case, the annual operating cost of a water treatment plant was estimated at 130 000
514 euros, whereas the annual cost of the preventive approach was 40 000 euros (Gouverne, 2013). In
515 contrast, in the Allier case, the low-cost access to drinking water network interconnections for managing
516 water quality reduced the water suppliers' interest in engaging in collective action.

517 Furthermore, the involvement of water suppliers depends significantly on the financial and human
518 resources (A2.1), including technical skills, available to them. Smaller water suppliers may be especially
519 constrained by available resources (Brouwer, 2003; Barraqué and Viavattene, 2009). In the Arcier and
520 Val-de-Reuil cases, the financial resources available to the city of Besançon and the Seine-Eure
521 metropolitan area authority fostered the development of cooperation with agricultural stakeholders.
522 Since technical options such as water purification were favored until recently to limit the pollutant rates
523 in drinking water in France (Becerra and Roussary, 2008), the water suppliers do not usually possess
524 the necessary skills to implement preventive approaches involving agricultural stakeholders. In the
525 Allier, Virieu and Oursbellile cases, the water suppliers' lack of knowledge of farming systems
526 constituted a constraint to the development of cooperation. In Ammertzwiller, the establishment of
527 contracts for the supply of miscanthus was hampered by the absence of legal expertise of the water
528 supplier.

529 In a context where water suppliers may lack financial and human resources, the external support from
530 public agencies (S4.1.1) enhances the suppliers' involvement in collective action (Lubell et al., 2002;
531 OECD, 2013). In the Oursbellile case, the water supplier considered that there was a lack of technical
532 support that could help them to face the complexity of cooperating with farmers to protect water at the
533 source. Cooperation in the Allier, Virieu and Ammertzwiller cases benefited from public support
534 programs. In Allier, the technical support provided by public agencies at the departmental, regional and
535 water basin levels played a crucial role in the emergence of cooperation. In the Virieu case, a network
536 coordinated by the "département" state agency allowed for information pooling and exchange between
537 water suppliers at the Isère "département" level. Furthermore, five water suppliers, including the
538 SMEAHB, pooled their resources and, with the financial support of the Rhône Méditerranée Corse water
539 agency, hired a full-time facilitator.

540 The involvement of water suppliers in collective action also depends on their environmental preferences
541 (A8.2.1), i.e., their preferences for the use of preventive approaches to solve diffuse pollution problems
542 (Barraqué and Viavattene, 2009; Hellec et al., 2013). In Allier, the initial reluctance of water suppliers
543 with regard to protecting source water hindered the emergence of cooperation in the context of the
544 “Grenelle” policy. In the Virieu, Oursbellile and Arcier cases, the economic incentive to engage in
545 cooperation with agricultural stakeholders was reinforced by the importance for the drinking water
546 suppliers to protect water at the source. In the case of Ammertzwiller and Val-de-Reuil, the pro-
547 environmental political stance of the elected representatives responsible for the water utilities was an
548 important factor for the initiation of collective action.

549 4.1.2. Farmers

550 The type of farming systems (A2.2.1) was found to affect the costs associated with farmers’ participation
551 in collective action. Changes in intensive farming systems to protect water quality involve higher costs
552 than those associated with changes in extensive farming systems (Brouwer, 2003; AE Rhône
553 Méditerranée Corse, 2007). The importance of extensive cattle breeding farming systems in the Virieu
554 and Arcier catchments had a positive effect on the involvement of farmers, while the dominance of
555 intensive cereal crop farming in the Allier, Oursbellile and Ammertzwiller catchments was an obstacle
556 to the implementation of actions targeting nonpoint source pollution.

557 Moreover, market conditions for agricultural products (S5.1) influence the economic benefits and costs
558 associated with changes in farming practices and thus affect farmers’ participation in collective action
559 (Bosc and Doussan, 2009; Grolleau and McCann, 2012; OECD, 2013; Barataud et al., 2014a). The
560 presence of economic operators offering outlets for low-input crops or organic products fosters the
561 involvement of farmers in cooperation. In the Allier and Oursbellile contexts, most farmers have supply
562 contracts with agro-industrial cooperatives that include specific requirements on product volumes and
563 quality. The compliance of farmers with these requirements represents a constraint on the adoption of
564 practices in favor of water quality. In contrast, the technical specifications of the Comté and Saint-
565 Marcellin PDO labels limit the use of pesticides and require the use of grass rather than silage for animal
566 fodder. These specifications favored the evolution of farming practices in the Arcier and Virieu
567 catchments. In Val-de-Reuil, the presence of the largest French organic agricultural cooperative
568 facilitated the conversion of cereal producers in the catchment.

569 Depending on the type of farming system and the market conditions for agricultural products, contract
570 incentives (GS5.1) affect the farmers’ adoption of measures targeting nonpoint source pollution
571 (Brouwer, 2003; Lubell, 2004; Grolleau and McCann, 2012). In the Allier and Oursbellile catchments
572 where highly profitable cereal farming is predominant, the financial compensation offered by the EU
573 AES was considered insufficient to cover the costs of contracted measures. As a result, the participation
574 of farmers in AES was low. In contrast, the AES implemented in Arcier to reduce the use of
575 phytosanitary products were evaluated as attractive enough in the local farming context. In Virieu and
576 Val-de-Reuil, the benefits linked to land exchanges and environmental land leases were considered by
577 the farmers to be superior to the associated constraints. In the Ammertzwiller case, the financial
578 compensation and the guaranteed outlet offered by the water supplier for growing miscanthus covered
579 the costs borne by farmers. Some of them considered that although net economic benefits could not be
580 expected from their participation in the cooperative agreement, their willingness to contribute to water
581 quality restoration reinforced the contract incentives.

582 Indeed, the participation of farmers appeared to also be driven by their attitudes towards environmental
583 protection (environmental preferences) (A8.2.2), particularly towards water source protection (Lubell et
584 al., 2002; Brouwer, 2003; Grolleau and Mc Cann, 2012). In the Allier and Oursbellile cases, the low
585 concern of farmers for environmental protection limited their participation in collective action. In Virieu,
586 Arcier and Ammertzwiller, the involvement of farmers was favored by their stronger sensitivity to
587 protecting the water at the source. In Virieu and Ammertzwiller, the agri-environmental programs that
588 had been previously implemented in the catchments contributed to the development of attitudes in favor
589 of environmental protection. In the Arcier catchment, the environmental awareness of Comté cheese
590 producers has been increased by the technical specifications of the PDO label, which include limitations
591 on pesticide use.

592 Table 6: Factors identified as fostering/constraining collective action

First-tier variable	Second-tier, third-tier and fourth-tier variables	Impact on the benefits/costs and transaction costs of collective action	Impact on collective action
Social, economic and political settings (S)	S4 – Other governance systems		
	<i>S4.1 – Larger scale governance systems</i>		
	S4.1.1 – External support from public agencies	External support from public agencies decreases costs	+
	S4.1.2 – Regulatory threat	A regulatory threat increases benefits The absence of a regulatory threat decreases transaction costs	Inconclusive
Resource system (S)	S5 – Markets		
	<i>S5.1 – Market conditions for agricultural products</i>	Favorable market conditions for low-input/organic products increase benefits	+
	RS3 – Size of resource system *		
	<i>RS3.1 – Size of the water catchment</i>	A large water catchment increases transaction costs	-
Governance system (GS)	RS5 – Productivity of system *		
	<i>RS5.1 – Level of water contamination</i>	High levels of water contamination increase benefits and transaction costs	-/+
	RS7 – Predictability of system dynamics *	A high predictability of system dynamics decreases transaction costs	+
	GS5 – Operational rules		
<i>GS5.1 – Contract incentives</i>	An adequate financial compensation decreases costs	+	
GS6 – Collective-choice rules *			
<i>GS6.1 – Autonomy at the collective-choice level</i>	The autonomy of local stakeholders increases benefits and transaction costs	-/+	
GS8 – Monitoring and sanctioning rules			
<i>GS8.1 – Contract enforcement</i>	The implementation of a control system of farming practices decreases transaction costs	+	

593 * Variables identified as crucial for self-organization by users of a common-pool resource (Ostrom, 2009)

594 Table 7: Factors identified as fostering/constraining collective action

First-tier variable	Second-tier, third-tier and fourth-tier variables	Impact on the benefits/costs and transaction costs of collective action	Impact on collective action
Actors (A)	A1 – Number of relevant actors *		
	<i>A1.1 - Number of farmers</i>	A large number of farmers increases transaction costs	-
	A2 – Socioeconomic attributes		
	<i>A2.1 – Resources available to water suppliers</i>	A high level of resources available to water suppliers decreases costs	+
	<i>A2.2 – Farming systems</i>		
	<i>A2.2.1 – Type of farming systems</i>	Intensive farming systems in the catchment increase costs	-
	<i>A2.2.2 – Heterogeneity of farming systems</i>	The heterogeneity of farming systems affects benefits and transaction costs, depending on the type of farming systems and the type of cooperation	-/+
	A5 – Leadership-entrepreneurship *		
	<i>A5.1 - Leadership in the farming community</i>	The involvement of local farm leaders decreases transaction costs	+
	A6 – Norms (trust-reciprocity)/social capital *	Shared norms of reciprocity/trust between water suppliers and agricultural stakeholders decrease transaction costs	+
	A7 – Knowledge of SES *	Shared knowledge of the hydrogeological system decreases transaction costs	+
	A8 – Importance of the resource *		
	<i>A8.1 – Economic importance of the resource</i>		
	<i>A8.1.1 – Economic importance of the resource for water suppliers</i>	High costs of using alternative approaches to enhance drinking water quality increase benefits	+
<i>A8.2 – Environmental preferences of stakeholders</i>			
<i>A8.2.1 – Environmental preferences of water suppliers</i>	A high level of preferences for the protection of water at the source increases benefits	+	
<i>A8.2.2 – Environmental preferences of farmers</i>	A high level of preferences for the protection of water at the source increases benefits	+	

595 * Variables identified as crucial for self-organization by users of a common-pool resource (Ostrom, 2009)

596

597 The level of water contamination (RS5.1) by nitrates and/or pesticides also plays an important role in
598 the stakeholders' incentives to cooperate in drinking water catchment protection (Lubell et al., 2002;
599 Bosc and Doussan, 2009). In the case of the Oursbellille, Virieu and Ammertzwiller catchments, the
600 regular peaks of pollutant rates above regulatory standards stimulated the involvement of both the water
601 supplier and agricultural stakeholders in collective action because of the threat of application of
602 regulatory measures. However, the moderate level of water pollution in the Allier and Arcier cases was
603 identified as a positive factor that allowed cooperation to develop over a longer time frame. The case of
604 the Val-de-Reuil catchment illustrates a situation where the absence of water pollution constitutes an
605 impediment to the agricultural stakeholders' involvement (Garin and Barraqué, 2012). The good quality
606 of the water resource appeared to be an obstacle to the participation of some farmers who questioned
607 the legitimacy of undertaking costly changes in their farming practices in the absence of any observed
608 pollution.

609 The presence of a regulatory threat (S4.1.2) was not found to have a clear-cut effect on farmers'
610 participation in collective action, a finding that differs from previous studies (Abildtrup et al., 2012;
611 Grolleau and McCann, 2012). In the Virieu catchment, the use of the ZSCE procedure as a complement
612 to the "Grenelle" catchment protection enhanced the willingness of farmers to cooperate. In the
613 Ammertzwiller and Oursbellille cases, the threat of activating the ZSCE tool if water quality further
614 deteriorated beyond the regulatory standards was also effective in fostering the farmers' voluntary
615 involvement. However, the choice of not resorting to the ZSCE regulatory threat in the Allier and Arcier
616 cases was perceived as favorable to collective action, as it limited the costs of a potential confrontation
617 with farmers.

618 4.2. The factors affecting the transaction costs of collective action

619 The hydrogeological systems differ in terms of the complexity of their dynamics and response time to
620 measures targeting diffuse pollution. The predictability of resource system dynamics (RS7) affects the
621 costs of defining actions and assessing their impact on water quality (Brouwer, 2003; AE Rhône
622 Méditerranée Corse, 2007; Grolleau and McCann, 2012). In the Virieu, Arcier and Oursbellille cases,
623 the complex dynamics and the low reactivity of the aquifers increased the level of uncertainty about the
624 impact of the measures implemented to protect the catchment. Moreover, in Oursbellille, the absence of
625 visible effects of actions on water quality reduced the farmers' motivation to participate, as noted in
626 other studies (Grolleau and McCann, 2012). In contrast, the short response time of the aquifers in Allier
627 and Val-de-Reuil reduced the costs of defining and assessing the impact of actions on water quality. In
628 Ammertzwiller, the high level of predictability of the hydrogeological system dynamics enhanced the
629 involvement of farmers in collective action.

630 The availability of scientific or expert knowledge (A7) regarding the hydrogeological system and the
631 interactions between anthropogenic activities and water quality affects the capacity of stakeholders to
632 identify pollution sources, the areas to target in the catchment and the relevant actions for limiting
633 nonpoint source pollution (AE Rhône Méditerranée Corse, 2007). In the Oursbellille case, the lack of
634 scientific knowledge regarding the alluvial aquifer increased the costs for defining the actions.
635 Moreover, this lack of knowledge led to a controversy about the farming versus nonfarming source of
636 water pollution, hindering the farmers' involvement in collective action. In contrast, the use of
637 hydrogeological surveys and pollution source assessments in the Arcier, Ammertzwiller and Val-de-
638 Reuil cases facilitated the identification of measures to be implemented. Moreover, sharing the results
639 of these studies with farmers improved their own understanding of the impact of farming practices on
640 water quality, thereby reducing the information collection and processing costs associated with their
641 participation in collective action.

642 The size of the water catchment (RS3.1) was found to affect the development of collective action
643 (Brouwer, 2003; Barraqué and Viavattene, 2009; Bosc and Doussan, 2009; Barataud et al., 2014b). In
644 relation to the number of farms (A1.1), a larger catchment means higher transaction costs for defining
645 and implementing action programs. The large catchment area in Allier and Arcier increased the
646 information costs for defining the actions because of the large number of farms. In the case of Virieu,
647 Oursbellille, Ammertzwiller and Val-de-Reuil, the small size of the catchments limited the negotiation
648 and enforcement costs of agreements.

649 Several studies suggest that the heterogeneity of farming systems (A2.2.2) increases the costs of defining
650 and negotiating the measures for controlling diffuse pollution (Grolleau and McCann, 2012; OECD,
651 2013). Indeed, the homogeneity of the farming systems in Allier and Oursbellile was identified as
652 limiting the costs associated with the definition of actions. However, in the Oursbellile case, the similar
653 orientation of production systems towards intensive corn farming was also perceived as a constraint on
654 the evolution of farm practices due to the higher costs of developing alternative farming techniques and
655 systems within the catchment. Furthermore, the heterogeneity of cattle breeding systems in Virieu
656 appeared to be a factor that enhanced the collaborative land exchange process. The complementarities
657 between the preferences of dairy and meat farms for arable parcels and grassland allowed for the transfer
658 of grassland within the boundaries of the catchment.

659 The analysis highlights the role of trust and social capital (A6) in lowering the costs of reaching
660 agreements and the costs of monitoring and enforcing these agreements (Lubell et al., 2002; Brouwer,
661 2003; Lubell, 2004; Lehmann et al., 2009). Pre-existing links between water suppliers and agricultural
662 stakeholders were found to enhance cooperation. These links may have developed through local social
663 interactions (Barraqué and Viavattene, 2009). In Virieu and Ammertzwiller, the involvement of some
664 farmers in the municipal council was the basis for the development of trust and norms of reciprocity
665 between the farming community and the public water supplier. In contrast, in the Arcier case, the
666 distance between the city of Besançon and the protected watershed initially acted as an obstacle to
667 cooperation. The previous implementation of water quality programs involving farmers and water
668 suppliers also fosters cooperation (Barataud et al., 2014b). In the Ammertzwiller case, the voluntary
669 Agri-Mieux operations implemented in the region since 1997 led to the development of links between
670 the water supplier and agricultural stakeholders. In Allier and Val-de-Reuil, the absence of previous
671 interactions between water suppliers and farmers was identified as a constraint for the development of
672 collective action.

673 The involvement of farming community leaders in collective action (A5.1) was also found to foster
674 farmer participation (Barraqué and Viavattene, 2009). In the Virieu, Oursbellile and Val-de-Reuil
675 catchments, well-respected producers acted as intermediaries between the institutional stakeholders and
676 farmers, thereby limiting the information collection costs for both parties. Similarly, the participation of
677 agricultural representatives in drinking water catchment protection positively impacted cooperation in
678 the Arcier case. In particular, the participation of a farmer, who was also an elected representative on
679 the Agricultural Chamber board and a vice-president of the main agricultural cooperative in the area,
680 had a positive effect on farmers' participation in collective action.

681 The greater autonomy in contract design (GS6.1) associated with contracts established between water
682 suppliers and farmers (environmental land leases and purchase contracts) appeared to have a positive
683 effect on cooperation by allowing for a better adaptation of incentives to the local farming and
684 environmental context (Lehmann et al., 2009; AE Adour-Garonne, 2012). In the Allier and Oursbellile
685 cases, the lower autonomy of the local stakeholders in designing EU AES contracts was a constraint on
686 the match between the measures and compensation and the characteristics of the local context. In
687 contrast, the negotiation of contract terms with farmers in Virieu, Ammertzwiller and Val-de-Reuil was
688 identified as crucial for considering the specificities of local farming systems. However, greater
689 autonomy in contract design comes with higher transaction costs (Abildtrup et al., 2012). In the
690 corresponding cases, the small number of farmers and/or the pre-existing trust between the water
691 suppliers and agricultural stakeholders limited the costs for defining and negotiating contract terms.

692 The implementation of a control system of farming practices (GS8.1) limits the risk of opportunistic
693 behavior of farmers (AE Rhône Méditerranée Corse, 2007; Abildtrup et al., 2012; Grolleau and McCann,
694 2012). Such a monitoring system was in place and identified as effective in reducing the enforcement
695 costs in Virieu, Oursbellile, Arcier and Ammertzwiller. For the EU AES implemented in the Oursbellile
696 and Arcier cases, the control costs are borne by the national public agency in charge of monitoring the
697 implementation of EU Common Agricultural Policy in France. For contracts established between water
698 suppliers and farmers (environmental land leases, purchase contracts), the water suppliers are
699 responsible for monitoring the farmers' practices. In Virieu, the choice of contracting for the conversion
700 of farmland into grassland reduced the control costs compared to the choice of other measures, such as,
701 for example, a reduction in input use. Similarly, in the Ammertzwiller case, the planting and

702 maintenance of miscanthus only required low-cost visual control by the water supplier. Thus, also noted
703 by Abildtrup et al. (2012) and Grolleau and McCann (2012), the type of measure chosen influences the
704 control and enforcement costs incurred by water suppliers.

705 **5. Discussion and conclusions**

706 The cross-case comparative analysis shows that the effectiveness of collective action involving water
707 suppliers and agricultural stakeholders (farm organizations and farmers) aimed to protect drinking water
708 resources depends on a number of interacting conditions related to (i) the characteristics of the
709 hydrogeological system, (ii) the characteristics of the actors involved, (iii) the governance of cooperation
710 and (iv) the economic and policy context of collective action.

711 All the factors considered to be crucial for the self-organization of users of a common-pool resource
712 (Ostrom, 2009) (Table 1) were also identified as playing a role in collective action for water quality
713 management in France, with the exception of the resource unit mobility (Table 6-7). The difference
714 between the benefits and costs of water management in the respective cases of surface streams and
715 groundwater has been analyzed in previous research (Schlager et al., 1994), including studies focusing
716 on cooperative agreements for drinking water protection (Brouwer, 2003). The specific impact of the
717 resource unit mobility could not be captured in this research, as the empirical cases selected do not vary
718 along this dimension: all the cooperation processes involve groundwater bodies.

719 Furthermore, the results highlight the role of other variables in the SES framework as important
720 conditions for successful cooperation to protect drinking water resources. First, the socioeconomic
721 attributes of both drinking water suppliers and farmers were shown to strongly affect the benefits and
722 costs associated with their involvement in collective action. Additionally, market and policy incentives
723 were found to be important in explaining the outcomes of cooperation for the control of diffuse pollution
724 at the catchment level. While the early common-pool resource scholarship has been criticized for
725 overlooking the influence of the policy and market environment on resource management (Agrawal,
726 2001), several studies have since highlighted the role of market incentives (Delgado-Serrano and Ramos,
727 2015; Torres-Guevara et al., 2016) and state policies (Mansbridge, 2014) in local collective action for
728 natural resource governance.

729 In a context where the level of financial and human resources available to drinking water suppliers is
730 limited, their involvement in collective action is dependent on external support from public agencies at
731 higher scales, in the form of funding or technical support. This result is in line with findings from SES
732 studies dealing with community-based drinking water provision (Madrigal et al., 2011; Naiga et al.,
733 2015).

734 For farmers, the benefits and costs associated with collective action depend on the interactions among
735 the type of farming system, the market conditions for agricultural products and the economic incentives
736 provided by contracts. In particular, the match between the incentives provided by contracts and the
737 characteristics of local farming and agro-food systems proves to be crucial for encouraging farmers'
738 participation. Autonomy in contract design enhances the ability to adapt measures to the local agro-food
739 context. While the EU AES have evolved towards greater decentralization and the involvement of local
740 stakeholders, their implementation in the French context is still considered to be constrained by a lack
741 of flexibility in contract design, leading to reduced environmental impacts (ECA, 2011; Kufhuss et al.,
742 2012). Enhancing the local stakeholders' autonomy to adapt the measures and compensation to the local
743 context could improve the effectiveness of cooperation to the extent that higher transaction costs, which
744 may be prohibitive in large water catchments and/or in situations where water suppliers lack the
745 necessary resources, are addressed through adequate public support.

746 In addition to economic costs and benefits, the participation of water suppliers and farmers in collective
747 action appears to be driven by their environmental preferences and more particularly their concern for
748 the preservation of the water resource. Recent SES studies have emphasized the need for taking into
749 account noneconomic values in the analysis of decision-making processes for resource management
750 (Basurto et al., 2013; Villamayor-Tomas et al., 2014; Delgado-Serrano and Ramos, 2015; Partelow and
751 Winkler, 2016). In the agri-environmental field, many studies have shown that farmers' attitudes
752 towards environmental protection affect their participation in conservation programs (G Giovanopoulou

753 et al., 2011; Lastra-Bravo et al., 2015). Our results highlight the importance of strengthening information
754 and advisory policies to modify the stakeholders' attitudes towards environmental protection, as a
755 complementary tool to regulatory and economic incentives (Blackstock et al., 2010; Mills et al., 2018).

756 The results corroborate the insights provided by the literature on cooperative agreements for drinking
757 water management (Lehmann et al., 2009; Abildtrup et al., 2012; Grolleau and McCann, 2012).
758 However, two variables deserving additional investigation are highlighted by the analysis.

759 First, the analysis qualifies the findings of previous studies in which the heterogeneity of farming
760 systems was shown to increase the transaction costs of drinking water catchment protection (Grolleau
761 and McCann, 2012; OECD, 2013). In line with the broader common-pool resource literature (Agrawal
762 and Gibson, 1999; Poteete and Ostrom, 2004), the results suggest that heterogeneity in farming systems
763 may also play a positive role in collective action. While the homogeneity of farm types reduces the costs
764 of defining actions, it increases costs related to the diffusion of alternative farming techniques/systems
765 in settings where intensive farming systems dominate. Furthermore, some forms of cooperation may
766 benefit from complementarities between heterogeneous farming systems, as illustrated by the
767 collaborative land exchange process in the Virieu case. Thus, the impact of the diversity of farming
768 systems on collective action involves trade-offs between benefits and transaction costs, which are
769 contingent upon the type of farming systems and cooperation. These trade-offs would need to be
770 disentangled in future research.

771 Second, the results suggest that the impact of a regulatory threat on voluntary cooperation is not
772 straightforward. Resorting to the ZSCE tool or the threat of activating this procedure induced farmers'
773 cooperation in situations where the level of water contamination was critical in terms of regulatory
774 standards (Virieu, Ammertzwiler, Oursbellile). In contrast, the absence of a regulatory threat positively
775 affected farmers' participation in collective action in settings where water contamination was considered
776 to be moderate (Allier, Arcier). The positive effect of a regulatory threat, stressed in previous studies on
777 drinking water management (Abildtrup et al., 2012; Grolleau and McCann, 2012) as well as in the
778 broader literature about common-pool resource management (e.g., Mansbridge, 2014), may depend on
779 its legitimacy, from the agricultural stakeholders' perspective, in relation to the level of water
780 degradation. This hypothesis calls for future research. Understanding the conditions under which
781 regulatory tools provide (dis)incentives for voluntary collective action would contribute to the design of
782 efficient combinations of policy options.

783 Combining transaction cost economics and the SES framework proved to be useful for explaining the
784 outcomes of collective action for drinking water catchment protection in France. While transaction cost
785 theory was instrumental in the characterization of causal links between SES variables and collective
786 action, the SES framework provided a structure for collecting and analyzing data across the cases
787 (Partelow, 2018).

788 The case study approach adopted in this research allowed for the identification of factors impacting
789 benefits and costs, including transaction costs, which accrue to stakeholders at different stages of the
790 cooperation process. Furthermore, the in-depth qualitative approach used in this study highlighted the
791 interdependencies among the variables affecting collective action (Poteete et al., 2010). However, the
792 results, which were obtained on the basis of a small purposive sample of cases of cooperation, cannot
793 be considered as representative, in a statistical sense, of drinking water catchment protection processes
794 in the French context. In future research, the identified factors could serve as theoretically and
795 empirically informed assumptions to be tested on a larger sample of cases. Furthermore, analyzing cases
796 of collective action in other countries, both inside and outside the EU, would provide insights into the
797 role of factors related to the EU and national institutional contexts.

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1151 **Appendix A: Second-tier variables of a social-ecological system (McGinnis and Ostrom, 2014)**

First-tier variable	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

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1153

1154 **Appendix B: Interviews conducted at the national and river-basin levels in 2013**

1155

1156 At the river-basin level, the representatives from five water agencies were interviewed (representing
1157 five river basins on the six covering the French metropolitan territory). Water agencies are in charge of
1158 the implementation of watershed management plans for reaching the objectives set by the EU Water
1159 Framework Directive. Under the framework of multiyear intervention programs, they levy fees on water
1160 uses and provide financial incentives to public and private stakeholders for sustainable water
1161 management. More particularly, water agencies provide financial and technical support to local
1162 stakeholders engaging in cooperation for protecting drinking water catchments from nonpoint source
1163 pollution.

1164 At the national level, the interviews conducted with representatives of the Ministries of the Environment
1165 and Agriculture allowed for a better understanding of the regulatory and policy context framing
1166 collective action at the drinking water catchment level.

1167 The perspective of agricultural stakeholders was comprehended through interviews held with
1168 representatives of the national network of Agricultural Chambers, the national federation of organic
1169 farmers' groups and the think tank "Saf agr'iDées". The Agricultural Chambers (regional and
1170 departmental public organizations led by representatives of agricultural and other rural stakeholders)
1171 and the organic farmers' groups (regional and departmental associations supporting the development of
1172 organic farming) are the main agricultural organizations involved locally in collective action for
1173 drinking water quality management. The think tank "Saf agr'iDées" is devoted to the study and debate
1174 of evolutions in the agricultural and agro-industrial sectors.

1175 Finally, interviews were conducted with the two main French private water operators in order to
1176 characterize their involvement in local collective action.

1177 Table B.1: List of interviews conducted in 2013 at the national and river-basin levels

Organization	Interviewee	Field of expertise	Type of interview	Date/Location	Duration
Water agencies					
Seine-Normandie	Project coordinator	Agriculture-related water issues	Face-to face	5/17/2013 Nanterre	2:21
Adour-Garonne	Project coordinator	Agriculture-related water issues	Phone	7/16/2013	1:15
Rhône Méditerranée Corse	Project coordinator	Pesticide management	Face-to-face	7/15/2013 Lyon	1:43
	Project coordinator	Drinking water management			
Rhin-Meuse	Head of department	Natural and rural areas	Phone	7/18/2013	2:00
Loire-Bretagne	Head of department	Agriculture and territorial water governance	Face-to-face	10/15/2013 Orléans	2:20
Ministries					
Ministry responsible for the environment	Policy officer	Agriculture and the Water Framework Directive	Face-to-face	6/7/2013 Paris	1:15
Ministry responsible for agriculture	Policy officer	Agri-environmental management	Face-to-face	11/8/2013 Paris	1:07
Agricultural organizations					
National network of Agricultural Chambers (APCA)	Project coordinator	Water management	Face-to-face	5/27/2013 Paris	1:47
National federation of organic agriculture (FNAB)	Project coordinator	Water management	Face-to-face	10/14/2013 Paris	2:56
Think tank Saf agr'iDées	Project coordinator	Environment	Phone	10/21/2013	1:43
Private water operators					
Suez Environnement	Project coordinator	Environmental engineering	Face-to-face	11/8/2013 Paris	1:00
Veolia Eau	Project coordinator	Sustainable development partnerships	Face-to-face	11/12/2013 Paris	1:05

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1179 **Appendix C: List of variables identified as likely to affect collective action for drinking water catchment protection in France (Step 1)**

1180 Table C.1: The characteristics of the resource

First-tier variable	Second-tier variables	Impact on the benefits/costs and transaction costs of collective action	Impact on collective action	References
Resource system (RS)	RS3 – Size of resource system <i>RS3.1 – Size of the water catchment</i>	A large water catchment increases transaction costs	-	Brouwer, 2003 Barraqué and Viavattene, 2009 Bosc and Doussan, 2009 Barataud et al., 2014b
	RS5 – Productivity of system <i>RS5.1 – Level of water contamination</i>	High levels of water contamination increase benefits	+	Lubell et al., 2002 Bosc and Doussan, 2009 Garin and Barraqué, 2012
	RS7 – Predictability of system dynamics	A high predictability of system dynamics decreases transaction costs	+	Brouwer, 2003 AE Rhône Méditerranée Corse, 2007 Grolleau and McCann, 2012
Resource units (RU)	RU1 – Resource unit mobility	Mobile units increase transaction costs	-	Brouwer, 2003

1181

Table C.2: The characteristics of the actors

First-tier variable	Second-tier variables	Impact on the benefits/costs and transaction costs of collective action	Impact on collective action	References
Actors (A)	A1 – Number of relevant actors			
	<i>A1.1 - Number of farmers</i>	A large number of farmers increases transaction costs	-	Brouwer, 2003 Bosc and Doussan, 2009
	A2 – Socioeconomic attributes			
	<i>A2.1 – Resources available to water suppliers</i>	A high level of resources available to water suppliers decreases costs	+	Brouwer, 2003 Becerra and Roussary, 2008 Barraqué and Viavattene, 2009
	<i>A2.2 – Farming systems</i>			
	<i>A2.2.1 – Type of farming systems</i>	Intensive farming systems in the catchment increase costs	-	Brouwer, 2003 AE Rhône Méditerranée Corse, 2007
	<i>A2.2.2 – Heterogeneity of farming systems</i>	The heterogeneity of farming systems increases transaction costs	-	Grolleau and McCann, 2012 OECD, 2013
	A5 – Leadership-entrepreneurship			
	<i>A5.1 - Leadership in the farming community</i>	The involvement of local farm leaders decreases transaction costs	+	Barraqué and Viavattene, 2009
	A6 – Norms (trust-reciprocity)/social capital	Shared norms of reciprocity/trust between water suppliers and agricultural stakeholders decrease transaction costs	+	Lubell et al., 2002; Brouwer, 2003 Lubell, 2004; Lehmann et al., 2009 Barraqué and Viavattene, 2009; Barataud et al., 2014b
	A7 – Knowledge of SES	Shared knowledge of the hydrogeological system decreases transaction costs	+	AE Rhône Méditerranée Corse, 2007
	A8 – Importance of the resource			
	<i>A8.1 – Economic importance of the resource</i>			
	<i>A8.1.1 – Economic importance of the resource for water suppliers</i>	High costs of using alternative approaches to enhance drinking water quality increase benefits	+	Bosc and Doussan, 2009 Abildtrup et al., 2012 Grolleau and McCann, 2012
	<i>A8.2 – Environmental preferences of stakeholders</i>			
	<i>A8.2.1 – Environmental preferences of water suppliers</i>	A high level of preferences for the protection of water at source increases benefits	+	Barraqué and Viavattene, 2009 Hellec et al., 2013
	<i>A8.2.2 – Environmental preferences of farmers</i>	A high level of preferences for the protection of water at source increases benefits	+	Lubell et al., 2002 Brouwer, 2003 Grolleau and McCann, 2012

1183 Table C.3: The characteristics of the governance system

First-tier variable	Second-tier variables	Impact on the benefits/costs and transaction costs of collective action	Impact on collective action	References
Governance system (GS)	GS5 – Operational rules			
	<i>GS5.1 – Contract incentives</i>	An adequate financial compensation decreases costs	+	Brouwer, 2003 Lubell, 2004 AE Adour-Garonne, 2012 Grolleau and McCann, 2012
	GS6 – Collective-choice rules <i>GS6.1 – Autonomy at the collective-choice level</i>	The autonomy of local stakeholders increases benefits and transaction costs	-/+	Lehmann et al., 2009 Abildtrup et al., 2012 AE Adour-Garonne, 2012
GS8 – Monitoring and sanctioning rules <i>GS8.1 – Contract enforcement</i>	The implementation of a control system of farming practices decreases transaction costs	+	AE Rhône Méditerranée Corse, 2007 Abildtrup et al., 2012 Grolleau and McCann, 2012	

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1185 Table C.4: The characteristics of the social, economic and political settings

First-tier variable	Second-tier variables	Impact on the benefits/costs and transaction costs of collective action	Impact on collective action	References
Social, economic and political settings (S)	S4 – Other governance systems			
	<i>S4.1 – Larger scale governance systems</i>			
	S4.1.1 – External support from public agencies	External support from public agencies decreases costs	+	Lubell et al., 2002 AE Rhône Méditerranée Corse, 2007 OECD, 2013
	S4.1.2 – Regulatory threat	A regulatory threat increases benefits	+	Albidtrup et al., 2012 Grolleau and McCann, 2012
	S5 – Markets			
	<i>S5.1 – Market conditions for agricultural products</i>	Favorable market conditions for low-input/organic products increase benefits	+	Bosc and Doussan, 2009 Grolleau and McCann, 2012 OECD, 2013 Barataud et al., 2014a

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1187 **Appendix D: List of interviews conducted at the local level in 2014**

1188 Table D.1: Interviews conducted – Allier and Virieu cases

Type of organization	Organization	Interviewee	Date/location	Duration
Allier				
Water supplier	Syndicat Mixte des Eaux de l'Allier (SMEA)	Facilitator for the non-agricultural action plan	1/30/2014 Yzeure	01:30
Agricultural Chamber	Chambre d'agriculture de l'Allier	Facilitator for the agricultural action plan	1/13/2014 Saint Pourçain sur Sioule	01:17
Territorial state administration	Direction Départementale des Territoires de l'Allier (DDT Allier)	Head of the Environment Department	1/14/2014 Yzeure	01:12
Regional environmental state administration	Direction Régionale de l'Environnement, de l'Aménagement et du Logement - Auvergne (DREAL Auvergne)	Head of the Water and Biodiversity Department	1/23/2014 Clermont-Ferrand	02:08
Regional agricultural state administration	Direction Régionale de l'Alimentation, de l'Agriculture et de la Forêt – Auvergne (DRAAF Auvergne)	Head of the Agriculture and Environment Department	1/23/2014 Lempdes	01:10
Local office of the Loire-Bretagne water agency	Délégation Allier-Loire amont de l'Agence de l'eau Loire-Bretagne	Project coordinator - Agriculture	1/30/2014 Lempdes	02:15
Farmer			1/30/2014 Marcenat	0:55
Virieu				
Water supplier	Syndicat Mixte d'Eau et d'Assainissement de la Haute-Bourbre (SMEAHB)	Director of the water utility	3/24/2014 Le Passage	02:12
Watershed management board	Syndicat Mixte d'Aménagement du Bassin de la Bourbre (SMABB)	Project coordinator – Agriculture and water	3/27/2014 La Tour du Pin	02:09
Agricultural Chamber	Chambre d'agriculture de l'Isère	Head of the Agro-environment Department	3/24/2014 Grenoble	02:00
Rural land Agency Rhône-Alpes	Société d'aménagement foncier et d'établissement rural Rhône-Alpes (Safer Rhône-Alpes)	Director of the agency	3/25/2014 Grenoble	01:17
Farmer			3/26/2014 Virieu-sur-Bourbre	01:05
Farmer			3/26/2014 Blandin	01:30

1190 Table D.2: Interviews conducted – Oursbellile and Arcier cases

Type of organization	Organization	Interviewee	Date/location	Duration
Oursbellile				
Water supplier	Syndicat Intercommunal d'Alimentation en Eau Potable Tarbes-Nord (SIAEP Tarbes-Nord)	President of the water utility board	7/2/2014 Andrest	1:46
Private water operator	Veolia Eau	Coordinator of drinking water protection	7/4/2014 Laloubere	1:10
Agricultural Chamber	Chambre d'agriculture des Hautes-Pyrénées	Facilitator for agricultural action plan	7/1/2014 Vic En Bigorre	1:43
Local office of the Adour-Garonne water agency	Délégation de Pau de l'Agence de l'eau Adour-Garonne	Project coordinator	7/3/2014 Pau	2:00
Farmer			7/2/2014 Oursbellile	1:29
Farmer			7/3/2014 Oursbellile	1:27
Arcier				
Water supplier	Ville de Besançon	Head of the water services department	9/3/2014 Besançon	1:39
Natural area management board	Syndicat Mixte du Marais de Saône (SMMS)	Project coordinator	9/2/2014 La Veze	1:29
Agricultural Chamber	Chambre d'agriculture du Doubs	Extension agent	9/4/2014 Besançon	1:13
Agricultural cooperative	Coopérative Terre-Comtoise	Technical adviser	9/4/2014 Saône	1:05
Farmer			9/2/2014 Saône	0:54
Farmer			9/3/2014 Le Grasterris	1:24

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1194 Table D.3: Interviews conducted – Ammertzwiller and Val-de-Reuil cases

Type of organization	Organization	Interviewee	Date/location	Duration
Ammertzwiller				
Water supplier	Syndicat Intercommunal d’Alimentation en Eau Potable d’Ammertzwiller et environs (SIAEP)	President of the water utility board (also a farmer and mayor of Ammertzwiller)	4/14/2014 Ammertzwiller	02:10
Agricultural Chamber	Chambre d’agriculture du Haut-Rhin	Project coordinator – Environment and innovation	4/15/2014 Sainte-Croix-en-Plaine	01:52
Local office of the Rhin-Meuse Water Agency	Service territorial « Rhin supérieur et Ill » de l’Agence de l’eau Loire-Bretagne	Project coordinator – Water and agriculture	4/17/2014 Rozérieulles	01:35
Farmer			4/16/2014 Ballschwiller	00:59
Farmer			4/16/2014 Ballschwiller	00:58
Val-de-Reuil				
Water supplier	Communauté d’Agglomération Seine et Eure (CASE)	Head of the water services department	5/23/2014 Louviers	01:30
Regional group of organic farmers	Groupement Régional d’Agriculteurs Biologiques de Basse-Normandie	Project coordinator – Water and territory	5/22/2014 Bois Guillaume	01:36
Organic supply chain association	Interbio Normandie	Project coordinator – Organic food systems	5/21/2014 Bois Guillaume	01:32
Local office of the Seine-Normandie water agency	Direction territoriale “Seine-Aval” de l’Agence de l’eau Loire-Bretagne	Project coordinator – Agriculture and aquatic environment	5/22/2014 Louviers	01:23
Farmer			5/21/2014 Val-de-Reuil	01:19
Farmer			5/22/2014 Val-de-Reuil	01:03

1196 **Appendix E: Indicators, data and criteria for the assessment of the variables in case studies**

1197 Table E.1: The characteristics of the resource system

Variable	Definition	Indicator	Data type	Criteria for variable assessment	
Size of the water catchment (RS3.1)	Size of the water catchment	Drinking water catchment area (ha)	Quantitative	Area <1300 ha*	Small
				Area > 1300 ha * Median size of priority drinking water catchments in France (Barataud et al., 2014b)	Large
Level of water contamination (RS5.1)	Level of water contamination	Pollutant rates in the water used for drinking water production (mg/l)	Quantitative	Pollutant rates below regulatory standards (Nitrates: 50 mg/l; Pesticides: 0,1 µg/l)	Low
				Pollutant rates below regulatory standards with an increasing trend	Moderate
				Pollutant rates beyond regulatory standards	High
Predictability of system dynamics (RS7)	Degree to which stakeholders are able to assess the impact of farming practices on water quality	Hydrogeological system's response time to measures targeting diffuse pollution	Qualitative	Short	High
				Long	Low

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1203 Table E.2a: The characteristics of the actors

Variable	Definition	Indicator	Data type	Criteria for variable assessment	
Number of farmers (A1.1)	Number of farmers with land in the drinking water catchment	Number of farmers with land in the drinking water catchment	Quantitative	Number <45 *	Small
				Number >45 *Median number of farmers in priority drinking water catchments in France (Barataud et al., 2014b)	Large
Resources available to water suppliers (A2.1)	Financial and human resources available to water suppliers	Budget devoted to catchment protection (€)	Quantitative	Small/moderate/large	
		Skills-preventive approaches to water pollution control	Qualitative		
Type of farming systems (A2.2.1)	Dominance of intensive/extensive farming systems	Share of grassland in agricultural area in the catchment	Quantitative	Share of grassland <50%	Intensive
				Share of grassland >50%	Extensive
Heterogeneity of farming systems (A2.2.2)	Diversity of types of farming systems in the catchment area	Number of different types of farming systems	Quantitative	1	Low
				2	Moderate
				> 2	High
Leadership in the farming community (A5.1)	Involvement of “farm leaders” in collective action	Involvement of “farm leaders” in collective action	Qualitative	No/Yes	

1204

1205 Table E.2b: The characteristics of the actors

Variable	Definition	Indicator	Data type	Criteria for variable assessment	
Norms (trust-reciprocity)/social capital (A6)	Existence of trust/norms of reciprocity between drinking water suppliers and farmers	Pre-existing links between water suppliers and farmers	Qualitative	No	Absent
				Yes	Present
Knowledge of SES (A7)	Shared knowledge of hydrological system dynamics	Existence of hydrogeological studies/pollution source assessments	Qualitative	No	Lacking
				Yes	Available
Economic importance of the resource for water suppliers (A8.1)	Cost of alternative approaches to water catchment protection	Access to palliative/curative options	Qualitative	Yes	Low
				No	High
Environmental preferences of water suppliers (A8.2.1)	Level of concern for the protection of water at source	Level of concern for the protection of water at source	Qualitative	Low/high	
Environmental preferences of farmers (A8.2.2)	Level of concern for the protection of water at source	Previous implementation of agri-environmental programs	Qualitative	No/yes	No/no: low No/yes: high Yes/no: high Yes/yes: high
		Previous involvement in eco-friendly supply chains	Qualitative	No/yes	

1206

1207 Table E.3: The characteristics of the governance system

Variable	Definition	Indicator	Data type	Criteria for variable assessment	
Contract incentives (GS5.1)	Match between compensation and costs of changing farming practices	Perception of a match between compensation and costs of changing farming practices	Qualitative	No match	No
				Partial match	Partly
				Match	Yes
Autonomy at the collective-choice level (GS6.1)	Autonomy in contract design	Type of contract	Qualitative	EU Agri-Environmental Schemes (AES)	Low
				Environmental land leases/supply contracts	High
Contract enforcement (GS8.1)	Procedures for limiting the risk of opportunistic behavior by farmers	Implementation of a system for monitoring farming practices	Qualitative	Absence/presence	

1208

1209 Table E.4: The characteristics of the social, economic and political settings

Variable	Definition	Indicator	Data type	Criteria for variable assessment	
External support from public agencies (S4.1.1)	Existence of financial/technical support from public agencies at a higher level	Share of total cost funded by public agencies	Quantitative	No financial support and no technical support: Absent Financial or technical support: Present	
		Existence of a technical support program at higher levels	Qualitative		
Regulatory threat (S4.1.2)	Perspective of application of regulatory measures in case of collective action failure	Use of the ZSCE procedure or threat of activating it	Qualitative	No/Yes	
Market conditions for agricultural products (S5.1)	Presence of eco-friendly agro-food supply chains	Presence of agro-food operators offering outlets for low-input/organic products	Qualitative	Absence/Presence	

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1211 **Appendix F: Individual case studies**

1212 **1. The case of Allier**

1213 1.1. Description

1214 In the **Allier** case, ten drinking water catchments were classified as “Grenelle priority catchments” in
1215 2009 because of increasing nitrate and pesticide rates. Approximately 120 mixed crop and livestock
1216 farms have all or part of their agricultural area in the large protection zone (8300 ha) (SMEA, 2013).
1217 Drinking water catchment protection relies on the cooperation between the Syndicat Mixte des Eaux de
1218 l’Allier (SMEA), representing the six intermunicipal water suppliers managing the catchments, and the
1219 departmental Agricultural Chamber. Collective action led to the establishment of an action plan in 2014.
1220 In addition to a free technical support program, EU Agri-Environmental Schemes (AES) were
1221 implemented. In 2015, a total of 71 farmers were involved in the support program, while only three
1222 farmers adopted agri-environmental measures, which covered 60 ha in the protection zone (SMEA,
1223 2015). Water quality did not improve and deteriorated in some catchments.

1224 1.2. The factors identified as fostering/constraining collective action

1225 1.2.1. The characteristics of the resource system

1226 The large size of the protection zone (RS3.1) increased the definition and implementation costs of the
1227 action plan, as there were a large number of farms located in the area (A1.1). The short response time
1228 of the alluvial aquifers (RS7) limited the costs of assessing the impact of changes in farming practices
1229 and the costs of adapting actions. The moderate level of water contamination (RS5.1) was found to
1230 facilitate collective action, as the stakeholders had more time to define actions.

1231 1.2.2. The characteristics of the actors

1232 1.2.2.1. Water suppliers

1233 The low-cost access to resource blending through network interconnections (A8.1) increased the
1234 opportunity costs for water suppliers to engage in cooperation with agricultural stakeholders for limiting
1235 nonpoint source pollution. As drinking water quality was managed until then based on this palliative
1236 strategy, the involvement of the drinking water suppliers in collective action was further limited by their
1237 low concern for the protection of water at the source (A8.2.1) and their lack of skills regarding preventive
1238 approaches to water pollution control (A2.1).

1239 1.2.2.2. Agricultural stakeholders

1240 Despite the large number of farmers, the homogeneity of the farming systems in the Allier catchment
1241 (A2.2.2) limited the costs of defining actions. However, the dominance of intensive farming in the
1242 catchment (A2.2.1) acted as a constraint on the participation of farmers in collective action because of
1243 the high costs associated with changes in such farming systems. Furthermore, the low concern of farmers
1244 for environmental protection (A8.2.2) limited their involvement.

1245 1.2.2.3. Norms (trust-reciprocity)/social capital

1246 In the absence of pre-existing interactions between drinking water suppliers and agricultural
1247 stakeholders, the lack of trust and norms of reciprocity among stakeholders (A6) acted as a barrier to
1248 collective action.

1249 1.2.3. The characteristics of the governance system

1250 The measures implemented through the EU Agri-Environmental Schemes (AES) were considered
1251 insufficiently adapted to the characteristics of the farming systems in the area. The financial
1252 compensation involved was more particularly evaluated as not covering the costs associated with
1253 changes in farming practices (GS5.1). As a result, farmers’ participation in AES was limited. The low
1254 level of autonomy of the local stakeholders in designing contracts in the framework of the EU AES
1255 (GS6.1) was identified as a constraint to adapting the measures and compensation to the characteristics
1256 of the local agricultural context.

1257

1258 1.2.4. The characteristics of the social, economic and political settings

1259 In a context where the drinking water suppliers did not hold any skills or previous experience regarding
1260 water catchment protection, the technical support provided by public agencies at the departmental,
1261 regional and water basin levels (S4.1.1) played a crucial role in the emergence of cooperation.
1262 Furthermore, the public financial aids granted (59% of the total cost of the program between 2014 and
1263 2018) (SMEA, 2013) allowed, among other actions, the hiring of an agricultural technical advisor to
1264 facilitate interactions with the farmers. The choice of not resorting to the ZSCE procedure in the Allier
1265 department was seen by local stakeholders as likely to favor farmers' participation in collective action.
1266 Opting for a voluntary approach without a regulatory threat (S4.1.2) was considered as lowering the risk
1267 of conflict with farmers. Most farmers in the water catchment are under contract with large agro-
1268 industrial cooperatives for the production of seed corn and/or high quality wheat. The restrictions on
1269 fertilization associated with the participation in drinking water protection would affect the capacity of
1270 farmers to fulfil the conditions of the contracts in terms of product volume and quality. Thus, market
1271 conditions for agricultural products (S5.1) did not favor farmers' participation in collective action for
1272 diffuse pollution control.

1273 **Sources**

1274 Préfet de l'Allier, 2012, Arrêté n°3060/12. Délimitation des aires d'alimentation et des zones d'action
1275 prioritaires des 10 captages prioritaires du département de l'Allier pour la mise en œuvre du programme
1276 d'actions. [https://www.smea.fr/wp-](https://www.smea.fr/wp-content/uploads/2018/06/Arr%C3%AAt%C3%A9_pr%C3%A9fectoral.pdf)
1277 [content/uploads/2018/06/Arr%C3%AAt%C3%A9_pr%C3%A9fectoral.pdf](https://www.smea.fr/wp-content/uploads/2018/06/Arr%C3%AAt%C3%A9_pr%C3%A9fectoral.pdf) (accessed 27.02.19).

1278 Syndicat Mixte des Eaux de l'Allier (SMEA), 2015. Contrat territorial de l'Allier (2014-2018), Bilan
1279 annuel 2015.

1280 Syndicat Mixte des Eaux de l'Allier (SMEA), 2013, Contrat territorial des captages prioritaires du
1281 département de l'Allier (2014-2018).

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1284 Table F1a: The factors identified as fostering/constraining collective action in Allier

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Social, economic and political settings (S)	S4 – Other governance systems				
	<i>S4.1 – Larger scale governance systems</i>				
	S4.1.1 – External support from public agencies	Share of total cost funded by public agencies	59% (SMEA, 2013)	Present	+
		Existence of a technical support program at higher levels	Yes (Interviews)		
	S4.1.2 – Regulatory threat	Use of the ZSCE procedure or threat of activating it	No (Préfet de l’Allier, 2012)	No	+
	S5 – Markets				
<i>S5.1 – Market conditions for agricultural products</i>	Presence of agro-food operators offering outlets for low-input/organic products	No (Interviews)	Absent	-	
Resource system (S)	RS3 – Size of resource system				
	<i>RS3.1 – Size of the water catchment</i>	Drinking water catchment area (ha)	8300 ha (SMEA, 2013)	Large	-
	RS5 – Productivity of system				
	<i>RS5.1 – Level of water contamination</i>	Pollutant rates in the water used for drinking water production (mg/l)	Nitrate and pesticide rates below regulatory standards with an increasing trend (2008-2012) (SMEA, 2013)	Moderate	+
	RS7 – Predictability of system dynamics	Hydrogeological system’s response time to measures targeting diffuse pollution	Short (Interviews)	High	+

1286 Table F1b: The factors identified as fostering/constraining collective action in Allier

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Governance system (GS)	GS5 – Operational rules				
	<i>GS5.1 – Contract incentives</i>	Perception of a match between compensation and costs of changing farming practices	No match (Interviews)	No	-
	GS6 – Collective-choice rules				
	<i>GS6.1 – Autonomy at the collective-choice level</i>	Type of contract	EU AES (SMEA, 2015)	Low	-
	GS8 – Monitoring and sanctioning rules				
	<i>GS8.1 – Contract enforcement</i>	Implementation of a system for monitoring farming practices	Control and sanction system associated with EU AES (SMEA, 2015)	Present	°

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1288 Table F1c: The factors identified as fostering/constraining collective action in Allier

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A1 – Number of relevant actors				
	<i>A1.1 – Number of farmers</i>	Number of farmers with land in the drinking water catchment	118 (SMEA, 2013)	Large	-
	A2 – Socioeconomic attributes				
	<i>A2.1 – Resources available to water suppliers</i>	Budget devoted to catchment protection (€)	187 890 € (2014-2018) (SMEA, 2013)	Moderate	-
		Skills-preventive approaches to water pollution control	No (Interviews)		
	<i>A2.2 – Farming systems</i>				
	A2.2.1 – Type of farming systems	Share of grassland in agricultural area in the catchment	24% (SMEA, 2013)	Intensive	-
	A2.2.2 – Heterogeneity of farming systems	Number of different types of farming systems	1 Mixed crop-livestock farming (SMEA, 2013)	Low	+
	A5 – Leadership-entrepreneurship				
	<i>A5.1. – Leadership in the farming community</i>	Involvement of “farm leaders” in collective action	No (Interviews)	No	°
	A6 – Norms (trust-reciprocity)/social capital	Pre-existing links between water suppliers and farmers	No (Interviews)	Absent	-
	A7 – Knowledge of SES	Existence of hydrogeological studies/pollution source assessments	Yes (Interviews)	Available	°
	A8 – Importance of the resource				
	<i>A8.1 – Economic importance for water suppliers</i>	Access to palliative/curative options	Yes (Interviews)	Low	-
	<i>A8.2 – Environmental preferences of stakeholders</i>				
A8.2.1 – Environmental preferences of water suppliers	Level of concern for the protection of water at the source	Low (Interviews)	Low	-	
A8.2.2 – Environmental preferences of farmers	Previous implementation of agri-environmental programs	No (Interviews)	Low	-	
	Previous involvement in eco-friendly supply chains	No (Interviews)			

1290 **2. The case of Virieu**

1291 2.1. Description

1292 The **Virieu** catchments are managed by the Syndicat Mixte d'Eau et d'Assainissement de la Haute-
1293 Bourbre (SMEAHB). They were identified as “priority” in the framework of the Grenelle policy in 2009
1294 because of the noncompliance of the pesticide rates with the regulatory standard (AE Rhône
1295 Méditerranée Corse, 2013a). A ZSCE procedure was also adopted, giving the option to the
1296 “département” state agency to prescribe regulatory measures if voluntary cooperation was not effective
1297 in restoring water quality after three years (SMEAHB, 2014). Grassland represents two-thirds of the
1298 agricultural area in the catchments, where ten cattle breeding farms are located (Chambre d'Agriculture
1299 de l'Isère, 2012). In 2010, the water supplier became the owner of 17 ha of agricultural land within the
1300 catchment through land acquisition and exchange. The establishment of environmental land contracts
1301 (land leases and loan agreements) with five farmers led to the conversion of 27 ha of cropland into
1302 grassland, increasing the share of grassland from 60% to 87% of the agricultural area. The pesticide
1303 rates have shown a tendency to stabilize and decrease (AE Rhône Méditerranée Corse, 2013a).

1304 2.2. The factors identified as fostering/constraining collective action

1305 2.2.1. The characteristics of the resource system

1306 The small size of the drinking water catchment (RS3.1) reduced the costs associated with the definition
1307 and implementation of actions, as there were a small number of farms located in the area (A1.1). The
1308 high level of water contamination (RS5.1) was an important driver of the drinking water supplier's
1309 involvement in collective action. The long response time of the hydrogeological system (RS7) increased
1310 the uncertainty regarding the impact of actions on water quality.

1311 2.2.2. The characteristics of the actors

1312 2.2.2.1. Water suppliers

1313 The high costs of investing in and operating a new water treatment unit (respectively one million euros
1314 and 100 000 euros/year) (AE Rhône Méditerranée Corse, 2013a) as an alternative to participation in
1315 catchment protection (A8.1) favored the involvement of the drinking water supplier in collective action.
1316 The pro-environmental attitude of the elected representatives at the board of the intermunicipal water
1317 utility (A8.2.1) reinforced the commitment to the preventive approach of water pollution control.
1318 However, the small financial and human resources available (A2.1) constituted a constraint on the water
1319 supplier's participation in collective action. Especially, the initial lack of skills regarding collaborative
1320 catchment protection induced delays in the cooperation process.

1321 2.2.2.2. Agricultural stakeholders

1322 The dominance of extensive cattle breeding farms (A2.2.1) reduced the costs associated with changes
1323 in the farming systems, thereby favoring the participation of farmers in collective action. The diversity
1324 of the cattle breeding systems (A2.2.2) enhanced the collaborative land exchange process. The
1325 complementarities between the preferences of dairy and meat farms for arable parcels and grassland
1326 allowed for the transfer of grassland within the boundaries of the catchment. Furthermore, several agri-
1327 environmental programs previously implemented in the area increased the concern of farmers for
1328 protecting the water at the source (A8.2.2). The involvement of farmers was also facilitated by the
1329 intermediary role played by a well-respected retired farmer (A5.1).

1330 2.2.2.3. Norms (trust-reciprocity)/social capital (A6)

1331 The elected position previously held by some farmers at the municipal or intermunicipal levels led to
1332 the development of trust between the drinking water supplier and the farmers. This trust (A6) limited
1333 the negotiation and enforcement costs of environmental land contracts.

1334 2.2.3. The characteristics of the governance system

1335 The benefits linked to land exchanges and environmental land leases (access to grassland in the
1336 catchment, access to arable land outside the protected zone and/or the regrouping of farm parcels) were
1337 considered by the farmers as superior to the costs induced by the conversion from arable into grassland

1338 in the catchment (GS5.1). The negotiation of contract terms between the water supplier and farmers
1339 (GS6.1) allowed for the consideration of the individual farm specificities. The negotiation costs were
1340 limited by the small number of farmers in the catchment and the pre-existing trust between farmers and
1341 the water supplier. The water supplier is responsible for controlling the environmental requirements
1342 included in the environmental land lease contracts (GS8.1). However, the control costs are reduced by
1343 the choice of contracting the easily observable conversion of cropland into grassland.

1344 2.2.4. The characteristics of the social, economic and political settings

1345 Collective action in the Virieu case benefited from public support programs (S4.1.1). Supported by the
1346 Rhône Méditerranée Corse water agency, five water suppliers, including the SMEAHB, pooled their
1347 resources to hire a full-time facilitator. Furthermore, a network coordinated by the “département” state
1348 agency allowed for information pooling and exchange between water suppliers at the Isère
1349 “département” level. The use of the ZSCE procedure as a complement to the “Grenelle” catchment
1350 protection (S4.1.2) favored the participation of farmers in collective action. The conversion of cropland
1351 into grassland is compatible with the evolution of the Saint-Marcellin PDO label technical
1352 specifications, which involve raising the share of grass for animal fodder. Thus, the involvement of
1353 farmers was favored by the local market conditions (S5.1).

1354

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1372 Table F2a: The factors identified as fostering/constraining collective action in Virieu

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Social, economic and political settings (S)	S4 – Other governance systems				
	<i>S4.1 – Larger scale governance systems</i>				
	S4.1.1 – External support from public agencies	Share of total cost funded by public agencies	80% (AE RMC, 2013a)	Present	+
		Existence of a technical support program at higher levels	Information exchange network (Interviews)		
	S4.1.2 – Regulatory threat	Use of the ZSCE procedure or threat of activating it	ZSCE (SMEAHB, 2014)	Yes	+
	S5 – Markets				
<i>S5.1 – Market conditions for agricultural products</i>	Presence of agro-food operators offering outlets for low-input/organic products	Saint-Marcellin cheese PDO supply chain (Interviews)	Present	+	
Resource system (S)	RS3 – Size of resource system				
	<i>RS3.1 – Size of the water catchment</i>	Drinking water catchment area (ha)	115 ha (CA Isère, 2012)	Small	+
	RS5 – Productivity of system				
	<i>RS5.1 – Level of water contamination</i>	Pollutant rates in the water used for drinking water production (mg/l)	Pesticide rates beyond regulatory standards (2005-2011) (CA Isère, 2012)	High	+
	RS7 – Predictability of system dynamics	Hydrogeological system's response time to measures targeting diffuse pollution	Long (Gouverne, 2013a)	Low	-

1374 Table F2b: The factors identified as fostering/constraining collective action in Virieu

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Governance system (GS)	GS5 – Operational rules				
	<i>GS5.1 – Contract incentives</i>	Perception of a match between compensation and costs of changing farming practices	Match (Interviews)	Yes	+
	GS6 – Collective-choice rules				
	<i>GS6.1 – Autonomy at the collective-choice level</i>	Type of contract	Environmental land leases (AE RMC, 2013a)	High	+
	GS8 – Monitoring and sanctioning rules				
	<i>GS8.1 – Contract enforcement</i>	Implementation of a system for monitoring farming practices	Regular monitoring by the water supplier (SMEAHB, 2013)	Present	+

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1377 Table F2c: The factors identified as fostering/constraining collective action in Virieu

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A1 – Number of relevant actors				
	<i>A1.1 – Number of farmers</i>	Number of farmers with land in the drinking water catchment	10 (CA Isère, 2012)	Small	+
	A2 – Socioeconomic attributes				
	<i>A2.1 – Resources available to water suppliers</i>	Budget devoted to catchment protection (€)	32 385 € (2010-2013) (AE RMC, 2013a)	Small	-
		Skills-preventive approaches to water pollution control	No (Interviews)		
	<i>A2.2 – Farming systems</i>				
	A2.2.1 – Type of farming systems	Share of grassland in agricultural area in the catchment	60% (CA Isère, 2012)	Extensive	+
	A2.2.2 – Heterogeneity of farming systems	Number of different types of farming systems	2 Beef and dairy cattle breeding farms (CA Isère, 2012)	Moderate	+
	A5 – Leadership-entrepreneurship				
	<i>A5.1. – Leadership in the farming community</i>	Involvement of “farm leaders” in collective action	Yes (Interviews)	Yes	+

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1382 Table F2d: The factors identified as fostering/constraining collective action in Virieu

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A6 – Norms (trust-reciprocity)/social capital	Pre-existing links between water suppliers and farmers	Yes (Interviews)	Present	+
	A7 – Knowledge of SES	Existence of hydrogeological studies/pollution source assessments	Yes (DDAF Isère, 2009)	Available	°
	A8 – Importance of the resource				
	A8.1 – <i>Economic importance for water suppliers</i>	Access to palliative/curative options	No (AE RMC, 2013a)	High	+
	A8.2. – <i>Environmental preferences of stakeholders</i>				
	A8.2.1 – Environmental preferences of water suppliers	Level of concern for the protection of water at the source	High (Interviews)	High	+
	A8.2.2 – Environmental preferences of farmers	Previous implementation of agri-environmental programs	Yes (Interviews)	High	+
		Previous involvement in eco-friendly supply chains	Yes (Interviews)		

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1384 **3. The case of Oursbellile**

1385 3.1. Description

1386 The Syndicat Intercommunal d'Alimentation en Eau Potable (SIAEP) Tarbes-Nord relies on the
1387 **Oursbellile** catchment for its total drinking water production, for which the supply is delegated to a
1388 private company. In 2009, the catchment was identified as a Grenelle "priority" catchment, as the nitrate
1389 rate regularly exceeded the regulatory standard between 2003 and 2008 (SIAEP Tarbes-Nord, 2013).
1390 Nineteen farmers own parcels in the catchment, with irrigated corn farming representing 88% of the
1391 agricultural area (CA Hautes-Pyrénées, 2012). The definition and implementation of actions are
1392 delegated to a consortium involving the water company, the Hautes-Pyrénées Agricultural Chamber and
1393 a regional development agency, the Semadour. The implementation of agricultural actions relies on AES
1394 co-funded by the EU and the Adour-Garonne Water Agency. In 2014, seven farmers, representing 73
1395 ha in the catchment, adopted agri-environmental measures. The nitrate rates have decreased but are still
1396 close to the regulatory standard (SIAEP Tarbes-Nord, 2014).

1397 3.2. The factors identified as fostering/constraining collective action

1398 3.2.1. The characteristics of the resource system

1399 The small size of the drinking water catchment (RS3.1) had a positive effect on collective action, as
1400 there were a small number of farms located in the catchment (A1.1). The costs of diagnosing farming
1401 practices at the individual farm level and monitoring their evolution were kept limited. However, the
1402 complex dynamics and the low reactivity of the alluvial aquifer increased the level of uncertainty about
1403 the impact of the measures implemented to protect the catchment (RS.7). The high level of water
1404 contamination (RS5.1), with regular peaks of pollutant rates above regulatory standards, stimulated the
1405 involvement of both the water supplier and the agricultural stakeholders in collective action because of
1406 the threat of activating a ZSCE procedure.

1407 3.2.2. The characteristics of the actors

1408 3.2.2.1. Water suppliers

1409 The involvement of the SIAEP Tarbes-Nord in collective action was favored by the absence of access
1410 to curative or palliative options to lower the nitrate rates (A8.1). The high level of concern of the
1411 president of the board of the intermunicipal water utility for the protection of water at the source (A8.2.1)
1412 strengthened this involvement. However, the limited financial resources available and the initial lack of
1413 expertise with regard to agriculture and farming systems (A2.1) constituted a constraint to the initiation
1414 of cooperation with the farmers.

1415 3.2.2.2. Agricultural stakeholders

1416 The high costs associated with changes in intensive corn single-crop farming systems (A2.2.1) were an
1417 obstacle to the implementation of actions targeting nonpoint source pollution. Moreover, the level of
1418 concern of farmers for protecting the water at the source was low (A8.2.2), which further prevented their
1419 participation in collective action. The involvement of local agricultural "leaders" (A5.1) in collective
1420 action had a positive impact on collective action. The homogeneity of the farming systems (A2.2.2)
1421 limited the costs associated with the definition of actions. However, by increasing the costs of
1422 developing alternative farming techniques and systems within the catchment, the similar orientation of
1423 production systems towards intensive corn farming was also perceived as a constraint on the evolution
1424 of farm practices.

1425 3.2.2.3. Norms (trust-reciprocity)/social capital (A6)

1426 According to the interviewed stakeholders, the absence of previous interactions partially explains the
1427 absence of trust between the water supplier and farmers. This lack of trust (A6) did not favor collective
1428 action.

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1432 3.2.2.4. Knowledge of the resource system (A7)

1433 The lack of scientific knowledge about the alluvial aquifer (A7) increased the costs for defining the
1434 actions. Moreover, this lack of knowledge led to a controversy regarding the farming versus nonfarming
1435 source of water pollution, limiting the farmers' involvement in collective action.

1436 3.2.3. The characteristics of the governance system

1437 In a context where the dominant farming system is highly profitable corn farming, the financial
1438 compensation offered by EU AES (GS5.1) was considered insufficient for covering the costs of the
1439 contracted measures. As a result, the participation of farmers in AES was low. The low level of
1440 autonomy of the local stakeholders in designing the AES contracts (GS6.1) was identified as a constraint
1441 to adapting the measures and compensation to the characteristics of the local agricultural context. The
1442 control system implemented in the framework of the EU AES (GS8.1) limited the risk of opportunistic
1443 behavior by the participating farmers.

1444 3.2.4. The characteristics of the social, economic and political settings

1445 The development of cooperation for the protection of the Oursbelille catchment benefited from financial
1446 support by the Adour-Garonne water agency (S4.1.1). However, the water supplier found that there was
1447 a lack of technical and legal support to help them face the complexity of cooperating with farmers. The
1448 threat of activating the ZSCE tool if water quality further deteriorated beyond the regulatory standards
1449 (S4.1.2) was found to be effective in fostering the farmers' voluntary involvement. Nevertheless, the
1450 integration of corn farming into high economic-value agro-food supply chains (S5.1) acted as a
1451 constraint on farmers' participation in collective action.

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1466 Table F3a: The factors identified as fostering/constraining collective action in Oursbellile

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Social, economic and political settings (S)	S4 – Other governance systems				
	<i>S4.1 – Larger scale governance systems</i>				
	S4.1.1 – External support from public agencies	Share of total cost funded by public agencies	50% (SIAEP, 2013)	Present	-/+
		Existence of a technical support program at higher levels	No (Interviews)		
	S4.1.2 – Regulatory threat	Use of the ZSCE procedure or threat of activating it	Threat of activating ZSCE (Préfet des Hautes-Pyrénées, 2013)	Yes	+
	S5 – Markets				
<i>S5.1 – Market conditions for agricultural products</i>	Presence of agro-food operators offering outlets for low-input/organic products	No (Interviews)	Absent	-	
Resource system (S)	RS3 – Size of resource system				
	<i>RS3.1 – Size of the water catchment</i>	Drinking water catchment area (ha)	396 ha (SIAEP, 2013)	Small	+
	RS5 – Productivity of system				
	<i>RS5.1 – Level of water contamination</i>	Pollutant rates in the water used for drinking water production (mg/l)	Nitrate rates beyond regulatory standards (2003-2008; 2013) (CA Hautes-Pyrénées, 2012)	High	+
	RS7 – Predictability of system dynamics	Hydrogeological system's response time to measures targeting diffuse pollution	Long (Interviews)	Low	-

1468 Table F3b: The factors identified as fostering/constraining collective action in Oursbellile

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Governance system (GS)	GS5 – Operational rules				
	<i>GS5.1 – Contract incentives</i>	Perception of a match between compensation and costs of changing farming practices	No match (Interviews)	No	-
	GS6 – Collective-choice rules				
	<i>GS6.1 – Autonomy at the collective-choice level</i>	Type of contract	EU AES (SIAEP, 2013)	Low	-
	GS8 – Monitoring and sanctioning rules				
	<i>GS8.1 – Contract enforcement</i>	Implementation of a system for monitoring farming practices	Control and sanction system associated with EU AES (SIAEP, 2013)	Present	+

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1471 Table F3c: The factors identified as fostering/constraining collective action in Oursbellile

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A1 – Number of relevant actors				
	<i>A1.1 – Number of farmers</i>	Number of farmers with land in the drinking water catchment	19 (CA Hautes-Pyrénées, 2012)	Small	+
	A2 – Socioeconomic attributes				
	<i>A2.1 – Resources available to water suppliers</i>	Budget devoted to catchment protection (€)	83 750 € (2012-2016) (SIAEP, 2013)	Small	-
		Skills-preventive approaches to water pollution control	No		
	<i>A2.2 – Farming systems</i>				
	A2.2.1 – Type of farming systems	Share of grassland in agricultural area in the catchment	3% (CA Hautes-Pyrénées, 2012)	Intensive	-
	A2.2.2 – Heterogeneity of farming systems	Number of different types of farming systems	1 Corn single-crop farming (CA Hautes-Pyrénées, 2012)	Low	-
	A5 – Leadership-entrepreneurship				
	<i>A5.1. – Leadership in the farming community</i>	Involvement of “farm leaders” in collective action	Yes (Interviews)	Yes	+

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1473 Table F3d: The factors identified as fostering/constraining collective action in Oursbellile

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A6 – Norms (trust-reciprocity)/social capital	Pre-existing links between water suppliers and farmers	No (Interviews)	Absent	-
	A7 – Knowledge of SES	Existence of hydrogeological studies/pollution source assessments	No (Interviews)	Lacking	-
	A8 – Importance of the resource				
	<i>A8.1 – Economic importance for water suppliers</i>	Access to palliative/curative options	No (CA Hautes-Pyrénées, 2012)	High	+
	<i>A8.2 – Environmental preferences of stakeholders</i>				
	A8.2.1 – Environmental preferences of water suppliers	Level of concern for the protection of water at the source	High (Interviews)	High	+
	A8.2.2 – Environmental preferences of farmers	Previous implementation of agri-environmental programs	No (Interviews)	Low	-
		Previous involvement in eco-friendly supply chains	No (Interviews)		

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1476 **4. The case of Arcier**

1477 4.1. Description

1478 The **Arcier** source is located 10 km from the city of Besançon. Between 1998 and 2003, the pesticide
1479 rates in the water displayed an upward trend (Ville de Besançon, 2013). In 2004, the city decided to
1480 undertake the protection of the Arcier source catchment by collaborating with agricultural and non-
1481 agricultural stakeholders (Murgue and Afflard, 2013). Because of the importance of the population
1482 supplied, the catchment was later added to the list of the “Grenelle” catchments. Most of the 72 farms
1483 located in the Arcier catchment are dairy farms producing cheese under the Comté Protected Designation
1484 of Origin (PDO) label. Permanent and temporary grassland represents 70% of the agricultural area. The
1485 agricultural action program relies mainly on the implementation of AES co-funded by the EU and the
1486 Rhône Méditerranée Corse Water Agency. Between 2007 and 2013, approximately 20 farmers adopted
1487 agri-environmental measures, covering 808 ha in the catchment. A 27% decrease in pesticide use by
1488 participating farmers has been observed between 2010 and 2012. Water quality improved between 2004
1489 and 2013 (Ville de Besançon, 2013).

1490 4.2. The factors identified as fostering/constraining collective action

1491 4.2.1. The characteristics of the resource system

1492 The large size of the Arcier drinking water catchment (RS3.1) increased the definition and
1493 implementation costs of actions targeting nonpoint source pollution because of the large number of
1494 farmers (A1.1) and other stakeholders in the catchment. Moreover, the complexity of the karstic
1495 hydrogeological system (RS7) increased the costs of defining actions and assessing their impact on water
1496 quality. The level of water contamination by pesticides was moderate (RS5.1), with no peaks beyond
1497 the regulatory standard; providing time for the cooperation process to unfold, this factor favored
1498 collective action.

1499 4.2.2. The characteristics of the actors

1500 4.2.2.1. Water supplier

1501 The willingness of the drinking water supplier to avoid the high costs of investing in and operating a
1502 water treatment unit (A8.1) was a strong driver of the initiation of the cooperation with agricultural
1503 stakeholders. Indeed, the annual operating cost of a water treatment plant was estimated at 130 000
1504 euros, whereas the annual cost of the preventive approach was 40 000 euros (Gouverne, 2013b). The
1505 involvement of the water supplier in collective action was also sustained by the pro-environmental
1506 attitude of the members of the Besançon city council (A8.2.1). The large resources available to the city
1507 (A2.1) were sufficient to cover the costs associated with the collaborative water catchment protection.
1508 More particularly, a facilitator holding agricultural technical skills was hired by the water supplier to
1509 support the cooperation process.

1510 4.2.2.2. Agricultural stakeholders

1511 The dominance of extensive mixed crop-livestock farming (A2.2.1) favored the participation of farmers
1512 in collective action, as changes in farming practices induced limited costs. The involvement of farmers
1513 was also driven by their high level of concern regarding environmental protection (A8.2.2). The
1514 environmental awareness of farmers producing Comté cheese has been increased by the PDO label’s
1515 technical specifications, which include limitations on pesticide use, and by the previous agri-
1516 environmental programs implemented in the area. The participation of agricultural representatives in
1517 drinking water catchment protection positively impacted cooperation. In particular, the participation of
1518 a farmer, who was also an elected representative on the Agricultural Chamber board and a vice-president
1519 of the main agricultural cooperative in the area (A5.1), had a positive effect on farmers’ participation in
1520 collective action.

1521 4.2.2.3. Norms (trust-reciprocity)/social capital (A6)

1522 The Arcier catchment is located 10 km away from the city of Besançon. Moreover, farmers in the area
1523 are not themselves consumers of the drinking water produced from the Arcier source. The absence of

1524 previous interactions between the water supplier and farmers initially acted as an obstacle to
1525 cooperation.

1526 4.2.2.4. Knowledge of the resource system (A7)

1527 The completion of a hydrogeological study (A7) contributed to reducing the high level of uncertainty
1528 regarding the potential impact of actions aiming at improving water quality. Additionally, the sharing
1529 of the results with all stakeholders, including farmers, increased the stakeholders' level of concern
1530 regarding the protection of water at the source.

1531 4.2.3. The characteristics of the governance system

1532 The implementation of the EU AES leaves little room for local stakeholders to choose the measures
1533 targeting diffuse pollution and the corresponding financial compensation for farmers (GS6.1). However,
1534 given the local agricultural context characterized by the dominance of extensive dairy farming, the
1535 financial compensation provided by the AES contracts was considered sufficient to cover the costs
1536 associated with the required changes in farming practices (GS5.1). The incentives provided by AES
1537 contracts favored the adoption of measures by farmers. The control system implemented in the
1538 framework of the EU AES (GS8.1) reduced the risk of opportunistic behavior of contracting farmers.

1539 4.2.4. The characteristics of the social, economic and political settings

1540 Collective action benefited from the financial support provided by the Rhône-Méditerranée Corse water
1541 agency (S4.1.1). The absence of a regulatory threat (S4.1.2) was identified as favoring the voluntary
1542 commitment of farmers to cooperation. By limiting the use of phytosanitary products and requiring the
1543 use of grass rather than silage for animal fodder, the technical specifications of the Comté cheese PDO
1544 label (S5.1) favored the evolution of farming practices in the Arcier catchment.

1545

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1562 Table F4a: The factors identified as fostering/constraining collective action in Arcier

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Social, economic and political settings (S)	S4 – Other governance systems				
	<i>S4.1 – Larger scale governance systems</i>				
	S4.1.1 – External support from public agencies	Share of total cost funded by public agencies	50% (AE RMC, 2013b)	Present	+
		Existence of a technical support program at higher levels	No (Interviews)		
	S4.1.2 – Regulatory threat	Use of the ZSCE procedure or threat of activating it	No (Préfet du Doubs, 2012)	No	+
	S5 – Markets				
<i>S5.1 – Market conditions for agricultural products</i>	Presence of agro-food operators offering outlets for low-input/organic products	Comté PDO cheese supply chain (Ville de Besançon, 2013)	Present	+	
Resource system (S)	RS3 – Size of resource system				
	<i>RS3.1 – Size of the water catchment</i>	Drinking water catchment area (ha)	10 200 ha (Ville de Besançon, 2013)	Large	-
	RS5 – Productivity of system				
	<i>RS5.1 – Level of water contamination</i>	Pollutant rates in the water used for drinking water production (mg/l)	Pesticide rates below regulatory standard with an increasing trend (1998-2003) (Ville de Besançon, 2013)	Moderate	+
	RS7 – Predictability of system dynamics	Hydrogeological system's response time to measures targeting diffuse pollution	Long (BRGM, 2005)	Low	-

1564 Table F4b: The factors identified as fostering/constraining collective action in Arcier

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Governance system (GS)	GS5 – Operational rules				
	<i>GS5.1 – Contract incentives</i>	Perception of a match between compensation and costs of changing farming practices	Match (Interviews)	Yes	+
	GS6 – Collective-choice rules				
	<i>GS6.1 – Autonomy at the collective-choice level</i>	Type of contract	EU AES (Ville de Besançon, 2013)	Low	°
	GS8 – Monitoring and sanctioning rules				
	<i>GS8.1 – Contract enforcement</i>	Implementation of a system for monitoring farming practices	Control and sanction system associated with EU AES (Ville de Besançon, 2013)	Present	+

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1567 Table F4c: The factors identified as fostering/constraining collective action in Arcier

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A1 – Number of relevant actors				
	<i>A1.1 – Number of farmers</i>	Number of farmers with land in the drinking water catchment	72 (Ville de Besançon, 2013)	Large	-
	A2 – Socioeconomic attributes				
	<i>A2.1 – Resources available to water suppliers</i>	Budget devoted to catchment protection (€)	230 350 € (2004-2013) (AE RMC, 2013b)	Large	+
		Skills-preventive approaches to water pollution control	Yes (Interviews)		
	<i>A2.2 – Farming systems</i>				
	<i>A2.2.1 – Type of farming systems</i>	Share of grassland in agricultural area in the catchment	70% (Ville de Besançon, 2013)	Extensive	+
	<i>A2.2.2 – Heterogeneity of farming systems</i>	Number of different types of farming systems	1 Mixed crop-livestock farming (Ville de Besançon, 2013)	Low	°
	A5 – Leadership-entrepreneurship				
	<i>A5.1. – Leadership in the farming community</i>	Involvement of “farm leaders” in collective action	Yes (Interviews)	Yes	+

1568

1569 Table F4d: The factors identified as fostering/constraining collective action in Arcier

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A6 – Norms (trust-reciprocity)/social capital	Pre-existing links between water suppliers and farmers	No (Interviews)	Absent	-
	A7 – Knowledge of SES	Existence of hydrogeological studies/pollution source assessments	Yes (BRGM, 2005)	Available	+
	A8 – Importance of the resource				
	A8.1 – <i>Economic importance for water suppliers</i>	Access to palliative/curative options	No (Gouverne, 2013b)	High	+
	A8.2 – <i>Environmental preferences of stakeholders</i>				
	A8.2.1 – Environmental preferences of water suppliers	Level of concern for the protection of water at the source	High (Interviews)	High	+
	A8.2.2 – Environmental preferences of farmers	Previous implementation of agri-environmental programs	Yes (Ville de Besançon, 2013)	High	+
		Previous involvement in eco-friendly supply chains	Yes (Ville de Besançon, 2013)		

1570

1571 **5. The case of Ammertzwiller**

1572 5.1. Description

1573 Managed by the SIAEP Ammertzwiller and Balschwiller, the **Ammertzwiller** well represents two-
1574 thirds of the water resources used for drinking water (AE Rhin-Meuse, 2009). Because of the high nitrate
1575 and pesticide pollution levels, the Ammertzwiller catchment was classified in 2009 as “priority” in the
1576 Rhin-Meuse water basin management plan. Land use is dominated by agriculture in the catchment,
1577 where 30 farmers own land. While corn represents 59% of the agricultural area, grassland only counts
1578 for 6% (Chambre d’agriculture du Haut-Rhin, 2008). Agricultural actions include the implementation
1579 of AES, co-funded by the EU, the Rhin-Meuse Water Agency and the Departmental Council, and the
1580 development of a low-input energy crop (miscanthus). In 2011, the participation of farmers in AES
1581 covered 52 ha in the catchment (Ditner, 2014a). The introduction of miscanthus by farmers was
1582 supported by subsidies provided by the water supplier and the Rhin-Meuse Water Agency. Additionally,
1583 long-term contracts with guaranteed prices were offered to the farmers for supplying the municipal
1584 heating system. Sixteen farmers, representing 27 ha, chose to grow miscanthus in the catchment. Water
1585 quality improved significantly between 2009 and 2014, with a decrease in nitrate rates from 45 mg/l to
1586 35 mg/l and a decrease in pesticide rates to levels below the regulatory standard (Ditner, 2014b).

1587 5.2. The factors identified as fostering/constraining collective action

1588 5.2.1. The characteristics of the resource system

1589 Due to the threat of activating a ZSCE procedure, the high level of water contamination (RS5.1), with
1590 regular peaks of pollutant rates above regulatory standards, was the initial driver of the involvement of
1591 both the water supplier and agricultural stakeholders in collective action. The small size of the water
1592 catchment (RS3.1) had a positive impact on cooperation because of the small number of farmers in the
1593 catchment (A.1.1). The short response time of the unconfined aquifer (RS7) reduced the costs for
1594 assessing the impact of actions on water quality, which strengthened the willingness of farmers to
1595 participate.

1596 5.2.2. The characteristics of the actors

1597 5.2.2.1. Water supplier

1598 Despite the low-cost access to water dilution for lowering the pollutant rates in drinking water (A8.1),
1599 the strong environmental preferences of the members of the board of the intermunicipal water utility
1600 (A8.2.1) favored the involvement of the water supplier in collective action for protecting the water at
1601 the source. Because of the support provided by the Rhin-Meuse water agency and the Haut-Rhin
1602 department council (S4.1.1), the small financial resources available to the water supplier (A2.1) did not
1603 constitute a constraint on cooperation. However, the supplier’s lack of legal expertise increased the costs
1604 of establishing the miscanthus supply contracts with farmers.

1605 5.2.2.2. Agricultural stakeholders

1606 The dominance of intensive field crop farming in the Ammertzwiller catchment (A2.2.1) was a
1607 constraint on farmers’ participation in collective action because of the high costs potentially induced by
1608 changes in such farming systems. However, the involvement of farmers was favored by their pro-
1609 environmental attitude (A8.2.2), which had been developed in the framework of the agri-environmental
1610 programs previously implemented in the area. The leadership role (A5.1) played by the president of the
1611 water utility board, also a farmer and the mayor of Ammertzwiller, also favored farmers’ participation
1612 in collective action.

1613 5.2.2.3. Norms (trust-reciprocity)/social capital (A6)

1614 The pre-existing social links between the drinking water supplier and farmers reduced the costs of
1615 negotiating and enforcing the miscanthus supply contracts.

1616 5.2.2.4. Knowledge of the resource system (A7)

1617 The availability of hydrogeological surveys and pollution source assessments reduced the costs
1618 associated with the definition of the relevant actions to be implemented.

1619 5.2.3. The characteristics of the governance system

1620 The financial compensation and the guaranteed outlet offered by the water supplier for growing
1621 miscanthus covered the costs borne by farmers (GS5.1). Some of the farmers considered that while no
1622 net economic benefits could be expected from their participation in the cooperative agreement, the
1623 contract incentives were strengthened by their willingness to contribute to water quality restoration
1624 (A8.2.2). The autonomy of local stakeholders (GS6.1) in designing the miscanthus supply contract
1625 allowed the consideration of the characteristics of the local farming systems. The low-cost visual control
1626 of the planting and maintenance of miscanthus by the water supplier (GS8.1) was effective in reducing
1627 the risk of opportunistic behavior of farmers.

1628 5.2.4. The characteristics of the social, economic and political settings

1629 The miscanthus project benefited from the financial support provided by the Rhin-Meuse water agency
1630 and the Haut-Rhin departmental council (S4.1.1). Additionally, the experimental project status granted
1631 by the water agency allowed the drinking water supplier to cover the miscanthus planting costs incurred
1632 by farmers. The threat of activating the ZSCE procedure if water quality further deteriorated beyond the
1633 regulatory standards (S4.1.2) favored the voluntary participation of farmers in collective action. The
1634 high profitability of intensive cereal farming in the area (S5.1) was not identified as a constraint on the
1635 involvement of farmers, as the drinking water supplier offered an alternative outlet for the low-input
1636 miscanthus development.

1637

1638 **Sources**

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1651

1652

1653 Table F5a: The factors identified as fostering/constraining collective action in Ammertzwiller

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Social, economic and political settings (S)	S4 – Other governance systems				
	<i>S4.1 – Larger scale governance systems</i>				
	S4.1.1 – External support from public agencies	Share of total cost funded by public agencies	65% (Ditner, 2014b)	Present	+
		Existence of a technical support program at higher levels	Experimental project status (CA Alsace, 2013)		
	S4.1.2 – Regulatory threat	Use of the ZSCE procedure or threat of activating it	Yes (CA du Haut-Rhin, 2008)	Yes	+
	S5 – Markets				
<i>S5.1 – Market conditions for agricultural products</i>	Presence of agro-food operators offering outlets for low-input/organic products	No (Interviews)	Absent	°	
Resource system (S)	RS3 – Size of resource system				
	<i>RS3.1 – Size of the water catchment</i>	Drinking water catchment area (ha)	363 ha (AE Rhin-Meuse, 2009)	Small	+
	RS5 – Productivity of system				
	<i>RS5.1 – Level of water contamination</i>	Pollutant rates in the water used for drinking water production (mg/l)	Noncompliance (pesticide) (2003-2008) Increasing trend (nitrates) (1993-2009) (CA du Haut-Rhin, 2008)	High	+
	RS7 – Predictability of system dynamics	Hydrogeological system's response time to measures targeting diffuse pollution	Low (CA du Haut-Rhin, 2008)	High	+

1655 Table F5b: The factors identified as fostering/constraining collective action in Ammertzwiler

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Governance system (GS)	GS5 – Operational rules				
	<i>GS5.1 – Contract incentives</i>	Perception of a match between compensation and costs of changing farming practices	Partial match (Interviews)	Partly	+
	GS6 – Collective-choice rules				
	<i>GS6.1 – Autonomy at the collective-choice level</i>	Type of contract	Supply contract (SIVOM d' Ammertzwiler/ Bernwiller, 2011)	High	+
	GS8 – Monitoring and sanctioning rules				
	<i>GS8.1 – Contract enforcement</i>	Implementation of a system for monitoring farming practices	Monitoring by the water supplier (SIVOM d' Ammertzwiler/ Bernwiller, 2011)	Present	+

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1658

1659 Table F5c: The factors identified as fostering/constraining collective action in Ammertzwiller

First-tier variable	Second, third and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A1 – Number of relevant actors				
	A1.1 – Number of farmers	Number of farmers with land in the drinking water catchment	30 (CA du Haut-Rhin, 2008)	Small	+
	A2 – Socioeconomic attributes				
	A2.1 – Resources available to water suppliers	Budget devoted to catchment protection (€)	28 000 € (2009-2010) (Interviews)	Small	-
		Skills-preventive approaches to water pollution control	Lacking (Interviews)		
	A2.2 – Farming systems				
	A2.2.1 – Type of farming systems	Share of grassland in agricultural area in the catchment	6% (CA du Haut-Rhin, 2008)	Intensive	-
	A2.2.2 – Heterogeneity of farming systems	Number of different types of farming systems	1 Field crops (CA du Haut-Rhin, 2008)	Low	°
	A5 – Leadership-entrepreneurship				
A5.1. – Leadership in the farming community	Involvement of “farm leaders” in collective action	Yes (Interviews)	Yes	+	

1660

1661

1662 Table F5d: The factors identified as fostering/constraining collective action in Ammertzwiller

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A6 – Norms (trust-reciprocity)/social capital	Pre-existing links between water suppliers and farmers	Yes (Interviews)	Present	+
	A7 – Knowledge of SES	Existence of hydrogeological studies/pollution source assessments	Yes (CA du Haut-Rhin, 2008)	Available	+
	A8 – Importance of the resource				
	A8.1 – <i>Economic importance for water suppliers</i>	Access to palliative/curative options	Yes (CA du Haut-Rhin, 2008)	Low	°
	A8.2 – <i>Environmental preferences of stakeholders</i>				
	A8.2.1 – Environmental preferences of water suppliers	Level of concern for the protection of water at the source	High (Interviews)	High	+
	A8.2.2 – Environmental preferences of farmers	Previous implementation of agri-environmental programs	Yes (Interviews)	High	+
Previous involvement in eco-friendly supply chains		No (CA du Haut-Rhin, 2008)			

1663

1664 **6. The case of Val-de-Reuil**

1665 6.1. Description

1666 The four wells located in the **Val-de-Reuil** catchment are used to supply two-thirds of the population of
1667 the metropolitan area Seine-Eure (40 000 inhabitants). The pollution rates of the water resource are well
1668 below the regulatory standards (CASE, 2014). However, the metropolitan authority responsible for
1669 drinking water production and supply initiated a collaborative process with agricultural stakeholders to
1670 limit the risk of diffuse pollution from agriculture in the catchment. In 2008, intensive cereal cropping
1671 was the main farming system in the area, with seven farmers renting land from a regional public land
1672 development agency (Safer Haute-Normandie, 2008). Between 2009 and 2011, the metropolitan
1673 authority became the owner of the rented land, which covered 110 ha in the catchment (FNAB, 2014).
1674 Through partnerships with multiple local stakeholders involved in organic farming supply chains,
1675 including producers' groups and potential public and private consumers, environmental land leases were
1676 established with farmers. Based on the conversion of part of the cereal area and the development of
1677 organic produce production, collective action led to the effective development of organic farming in the
1678 Val-de-Reuil catchment.

1679 6.2. The factors identified as fostering/constraining collective action

1680 6.2.1. The characteristics of the resource system

1681 The small size of the catchment (RS3.1) limited the negotiation and enforcement costs of environmental
1682 land leases with farmers. The good quality of the water resource (RS5.1) appeared to be an obstacle to
1683 the participation of some farmers who questioned the legitimacy of undertaking costly changes in their
1684 farming system for preventing diffuse pollution. The short response time of the aquifer (RS7) reduced
1685 the costs of assessing the impact of actions on water quality.

1686 6.2.2. The characteristics of the actors

1687 6.2.2.1. Water supplier

1688 The decision of the drinking water supplier to initiate cooperation with agricultural stakeholders for
1689 maintaining the good quality of the resource was driven by the high costs of investing in a water
1690 treatment unit (A8.1). The pro-environmental political stance of the elected representatives leading the
1691 metropolitan water service (A8.2.1) was also an important factor for the initiation of collective action.
1692 The large financial resources available to the Seine-Eure metropolitan area authority (A2.1) favored the
1693 cooperation process, which involved a costly farmland acquisition operation.

1694 6.2.2.2. Agricultural stakeholders

1695 The low level of concern of some farmers for the protection of the water at the source (A8.2.2)
1696 constituted an initial barrier to their involvement in collective action. A well-respected cereal producer
1697 in the catchment played a leadership role (A5.1) in convincing most farmers to participate in the
1698 cooperation process. The homogeneity of farming systems in the catchment (A2.2.2) decreased the costs
1699 for defining and enforcing the environmental land lease contracts.

1700 6.2.2.3. Norms (trust-reciprocity)/social capital (A6)

1701 The absence of previous interactions between the water supplier and farmers was identified as a
1702 constraint for the development of collective action.

1703 6.2.2.4. Knowledge of the resource system (A7)

1704 The completion of a hydrogeological survey at the beginning of the collaborative process was useful for
1705 identifying the vulnerable areas in the catchment, thereby reducing the costs of defining relevant actions
1706 to prevent potential diffuse pollutions.

1707 6.2.3. The characteristics of the governance system

1708 The autonomy of local stakeholders in designing the environmental land lease contracts (GS6.1) was
1709 found to have a positive effect on cooperation. The duration of the contracts (9 years) and the lower
1710 level of land rent were considered by farmers as benefits outweighing the extra costs associated with the

1711 change in farming systems (GS5.1). The public organic certification agency is in charge of monitoring
1712 farming practices (GS8.1); therefore, the water supplier does not bear any control costs.

1713 6.2.4. The characteristics of the social, economic and political settings

1714 Covering 54% of the total cost of the project, the financial support provided by the Seine-Normandie
1715 water agency, the Haute-Normandie region and the Eure department (S4.1.1) facilitated the cooperative
1716 process. The project also benefited from the experimental project status granted by the Seine-Normandie
1717 water agency. The absence of a regulatory threat (S4.1.2.) was identified as having a positive impact on
1718 the farmers' voluntary involvement in collective action. Finally, the presence of the largest French
1719 organic agricultural cooperative in the area (S5.1) facilitated the conversion of cereal producers in the
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1734

1735 Table F6a: The factors identified as fostering/constraining collective action in Val-de-Reuil

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Social, economic and political settings (S)	S4 – Other governance systems				
	<i>S4.1 – Larger scale governance systems</i>				
	S4.1.1 – External support from public agencies	Share of total cost funded by public agencies	54% (FNAB, 2014)	Present	+
		Existence of a technical support program at higher levels	Experimental project status (Interviews)		
	S4.1.2 – Regulatory threat	Use of the ZSCE procedure or threat of activating it	No (Interviews)	No	+
	S5 – Markets				
<i>S5.1 – Market conditions for agricultural products</i>	Presence of agro-food operators offering outlets for low-input/organic products	Organic cereal cooperative (Interviews)	Present	+	
Resource system (S)	RS3 – Size of resource system				
	<i>RS3.1 – Size of the water catchment</i>	Drinking water catchment area (ha)	127 ha (Safer, 2008)	Small	+
	RS5 – Productivity of system				
	<i>RS5.1 – Level of water contamination</i>	Pollutant rates in the water used for drinking water production (mg/l)	No pollution by nitrates/pesticides (CASE, 2014)	Low	-
	RS7 – Predictability of system dynamics	Hydrogeological system's response time to measures targeting diffuse pollution	Short (Safer, 2008)	High	+

1736

1737 Table F6b: The factors identified as fostering/constraining collective action in Val-de-Reuil

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Governance system (GS)	GS5 – Operational rules				
	<i>GS5.1 – Contract incentives</i>	Perception of a match between compensation and costs of changing farming practices	Match (Interviews)	Yes	+
	GS6 – Collective-choice rules				
	<i>GS6.1 – Autonomy at the collective-choice level</i>	Type of contract	Environmental land leases (CASE and GRAB Haute-Normandie, 2013)	High	+
	GS8 – Monitoring and sanctioning rules				
	<i>GS8.1 – Contract enforcement</i>	Implementation of a system for monitoring farming practices	Organic farming label monitoring system (CASE and GRAB Haute Normandie, 2013)	Present	°

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1741 Table F6c: The factors identified as fostering/constraining collective action in Val-de-Reuil

First-tier variable	Second-tier, third-tier and fourth-tier variables	Indicators	Indicator values (Sources)	Variable assessment	Impact on collective action
Actors (A)	A1 – Number of relevant actors				
	<i>A1.1 – Number of farmers</i>	Number of farmers with land in the drinking water catchment	7 (Safer, 2008)	Small	+
	A2 – Socioeconomic attributes				
	<i>A2.1 – Resources available to water suppliers</i>	Budget devoted to catchment protection (€)	1 200 000 € (2008-2014) (Interviews)	Large	+
		Skills-preventive approaches to water pollution control	Yes (FNAB, 2004)		
	<i>A2.2 – Farming systems</i>				
	<i>A2.2.1 – Type of farming systems</i>	Share of grassland in agricultural area in the catchment	9% (Safer, 2008)	Intensive	°
	<i>A2.2.2 – Heterogeneity of farming systems</i>	Number of different types of farming systems	Mostly corn single-cropping (Safer, 2008)	Low	+
	A5 – Leadership-entrepreneurship				
	<i>A5.1. – Leadership in the farming community</i>	Involvement of “farm leaders” in collective action	Yes (Interviews)	Yes	+
	A6 – Norms (trust-reciprocity)/social capital	Pre-existing links between water suppliers and farmers	No (Interviews)	Absent	-
	A7 – Knowledge of SES	Existence of hydrogeological studies/pollution source assessments	Yes (Safer, 2008)	Available	+
	A8 – Importance of the resource				
	<i>A8.1 – Economic importance for water suppliers</i>	Access to palliative/curative options	No (CASE, 2014)	High	+
	<i>A8.2 – Environmental preferences of stakeholders</i>				
<i>A8.2.1 – Environmental preferences of water suppliers</i>	Level of concern for the protection of water at source	High (Interviews)	High	+	
<i>A8.2.2 – Environmental preferences of farmers</i>	Previous implementation of agri-environmental programs	No (Interviews)	Low	-	
	Previous involvement in eco-friendly supply chains	No (Interviews)			

1743 **Appendix G: The variables affecting collective action for drinking water catchment protection**

1744

1745 Table G.1: The characteristics of the resource system (RS)

		Allier	Virieu	Oursbellile	Arcier	Ammertzwiller	Val-de-Reuil
Variable	Definition						
Size of the water catchment (RS3.1)	Size of the water catchment	Large (-)	Small (+)	Small (+)	Large (-)	Small (+)	Small (+)
Level of water contamination (RS5.1)	Level of water contamination	Moderate (+)	High (+)	High (+)	Moderate (+)	High (+)	Low (-)
Predictability of system dynamics (RS7)	Degree to which stakeholders are able to assess the impact of farming practices on water quality	High (+)	Low (-)	Low (-)	Low (-)	High (+)	High (+)

1746 (-) Negative influence on collective action; (+) Positive influence on collective action; (o) No influence on collective action

1747

1748 Table G.2: The characteristics of the actors (A)

		Allier	Virieu	Oursbellile	Arcier	Ammertzwiller	Val-de-Reuil
Variable	Definition						
Number of farmers (A1.1)	Number of farmers with land in the drinking water catchment	Large	Small	Small	Large	Small	Small
		(-)	(+)	(+)	(-)	(+)	(+)
Resources available to water suppliers (A2.1)	Financial and human resources available to water suppliers	Moderate	Small	Small	Large	Small	Large
		(-)	(-)	(-)	(+)	(-)	(+)
Type of farming systems (A2.2.1)	Dominance of intensive/extensive farming systems	Intensive	Extensive	Intensive	Extensive	Intensive	Intensive
		(-)	(+)	(-)	(+)	(-)	(o)
Heterogeneity of farming systems (A2.2.2)	Diversity of types of farming systems in the catchment area	Low	Moderate	Low	Low	Low	Low
		(+)	(+)	(-)	(o)	(o)	(+)
Leadership in the farming community (A5.1)	Involvement of “farm leaders” in collective action	No	Yes	Yes	Yes	Yes	Yes
		(o)	(+)	(+)	(+)	(+)	(+)
Norms (trust-reciprocity)/social capital (A6)	Existence of trust/norms of reciprocity between drinking water suppliers and farmers	Absent	Present	Absent	Absent	Present	Absent
		(-)	(+)	(-)	(-)	(+)	(-)
Knowledge of SES (A7)	Shared knowledge of hydrological system dynamics	Available	Available	Lacking	Available	Available	Available
		(o)	(o)	(-)	(+)	(+)	(+)
Economic importance of the resource for water suppliers (A8.1)	Cost of alternative approaches to water catchment protection	Low	High	High	High	Low	High
		(-)	(+)	(+)	(+)	(o)	(+)
Environmental preferences of water suppliers (A8.2.1)	Level of concern for the protection of water at the source	Low	High	High	High	High	High
		(-)	(+)	(+)	(+)	(+)	(+)
Environmental preferences of farmers (A8.2.2)	Level of concern for the protection of water at the source	Low	High	Low	High	High	Low
		(-)	(+)	(-)	(+)	(+)	(-)

1749 (-) Negative influence on collective action; (+) Positive influence on collective action; (o) No influence on collective action

1750

1751 Table G.3: The characteristics of the governance system (GS)

		Allier	Virieu	Oursbellile	Arcier	Ammertzwiller	Val-de-Reuil
Variable	Definition						
Incentives (GS5.1)	Match between compensation and costs of changing farming practices	No	Yes	No	Yes	Partly	Yes
		(-)	(+)	(-)	(+)	(+)	(+)
Autonomy at the collective-choice level (GS6.1)	Autonomy in contract design	Low	High	Low	Low	High	High
		(-)	(+)	(-)	(o)	(+)	(+)
Contract enforcement (GS8.1)	Procedures for limiting the risk of opportunistic behavior by farmers	Present	Present	Present	Present	Present	Present
		(o)	(+)	(+)	(+)	(+)	(o)

1752 (-) Negative influence on collective action; (+) Positive influence on collective action; (o) No influence on collective action

1753

1754 Table G.4: The characteristics of the social, economic and political settings (S)

		Allier	Virieu	Oursbellile	Arcier	Ammertzwiller	Val-de-Reuil
Variable	Definition						
External support from public agencies (S4.1.1)	Existence of financial/technical support from public agencies at a higher level	Present	Present	Present	Present	Present	Present
		(+)	(+)	(-/ +)	(+)	(+)	(+)
Regulatory threat (S4.1.2)	Perspective of application of regulatory measures in case of collective action failure	No	Yes	Yes	No	Yes	No
		(+)	(+)	(+)	(+)	(+)	(+)
Market conditions for agricultural products (S5.1)	Presence of eco-friendly agro-food supply chains	Absent	Present	Absent	Present	Absent	Present
		(-)	(+)	(-)	(+)	(o)	(+)

1755 (-) Negative influence on collective action; (+) Positive influence on collective action; (o) No influence on collective action

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