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Organizing collective innovation in support of sustainable agro-ecosystems: The role of network management

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ABSTRACT

Designing and managing sustainable agro-ecosystems remains a significant challenge for society. This is largely because their expected functions and values are multiple, and diverse networks of actors and institutions control common pool resources at different scales. Networks are expected to play an important role in facilitating collective innovation in agro-ecosystems, through enabling knowledge acquisition and transfer, resource mobilization for effective governance, and cooperation. However, in order to realize their potential benefit networks require effective management. Drawing on case studies located in the peri-urban agro-ecosystems surrounding Montreal (Quebec, Canada) and Paris (France), we analyze four collective innovation initiatives aiming to reduce the negative impacts of agriculture on the environment. For each case, we assess the contribution of network managers to the core tasks of: "Connecting" (initiating and facilitating interaction processes between actors), "Framing" (guiding interactions through process agreement), "Knowledge brokering" (facilitating knowledge transfer and capitalization) and "Exploring" (searching for goal congruency by creating new content). We then pay particular attention to the activities associated with Exploring across our cases and consider the implications for more collective approaches to designing innovation in agricultural landscapes. Our results suggest that, despite heterogeneity in the activities of network managers in each context, network managers devoted efforts across each of the four tasks. Yet, building a shared vision and engaging diverse stakeholders in a common goal over time were reported as challenging. We identify that the network managers tended to set objectives at the outset, and that design processes were often confined to a limited subgroup of actors. While these strategies were viewed as being efficient in the short term, they likely limited the success of the collective enterprise in the long run.

1. Introduction

Defining and creating sustainable agro-ecosystems remains a significant challenge for society. This is largely because their expected functions are multiple (Foley et al., 2005), their values are partly unknown and they are often perceived differently by social actors (Martín-López et al., 2014). Importantly, the design of sustainable agro-ecosystems cannot rely only upon incremental improvement of what exists; it also requires path-breaking innovation in practices, organizations, and in the way we view and manage ecosystems (Biggs et al., 2010). According to Kemp et al. (2007), orchestrating such transitions towards sustainability requires radical changes in the functions of complex social and ecological systems, requiring more open and adaptive forms of governance that are oriented towards learning and experimentation. Shaping desired changes in agro-ecosystems means envisioning and creating new types of agro-ecosystems, which requires a design reasoning, i.e. exploring the unknown, on the basis of knowledge capitalization and the formulation of what is desirable (Hatchuel et al., 2009). This is all the more challenging when considering that knowledge concerning agro-ecosystems is limited and fragmented, their delimitation is unclear, stakeholders often have diverging interests, and there is no single legitimate designer (Berthet et al., 2016).

Diverse networks of actors and institutions at different scales, including autonomous entrepreneurs (farmers) and heterogeneous actors (residents, naturalists, agri-food industry, local authorities, scientists, etc.) result in highly distributed control of agro-ecosystems, necessitating cooperation and network management (Kemp et al., 2007). Networks are recognized as important forms of multi-level governance (Provan and Kenis, 2007; Bodin and Crona, 2009; Saint Ville et al., 2017); they can facilitate collective action (Powell and Grodal, 2005; Lejano and de Castro, 2014) and innovation in agro-ecosystems (Batterink et al., 2010; Klerkx et al., 2010; Bourne et al. 2017). In the

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Table 1
The four main functions of network managers and their related tasks (sources: van Lente et al., 2003; Klijn et al., 2010; Kilelu et al., 2011; Giest and Howlett, 2014).

Connecting	Framing	Knowledge brokering	Exploring
• Initiating and facilitating interaction processes between actors • Fostering cooperation (by removing obstacles, creating incentives) • Activating (i.e., involving and committing) the right players • Sometimes 'deactivating' actors • Articulating options and demands • Resource mobilizing	• Guiding interactions through process agreement • Establishing and influencing the operating rules of the network • Creating and changing network arrangements for better coordination • Facilitating intellectual property rights attribution • Fostering institutional support • Innovation process monitoring and evaluation of outcomes	• Managing and collecting information and knowledge • Facilitating learning processes (feedback mechanisms, experimentation…) • Creating an environment conducive to knowledge exchange and productive interaction	• Creating new content by exploring new ideas • Stimulating variety • Making sense, searching for goal congruency • Supporting strategy development • Altering the perceptions of the network participants • Influencing the actors' values and norms

context of collective innovation, networks have been shown to play important roles in knowledge acquisition and transfer, resource mobilization for effective governance, and cooperation (Bodin and Crona, 2009; Dessie et al., 2013; Reed and Hickey, 2016). However, as noted by Giest and Howlett (2014), such innovation networks are not self-forming or auto-poetic, requiring leadership to enable reciprocal communication flows among heterogeneous actors, build trust and ensure long-term cooperative structures (van Lente et al., 2003; Batterink et al., 2010; Kilelu et al., 2011). Previous research has examined the diverse functions of network leaders in order to unveil their contribution to fostering collective innovation, including the social and organizational aspects of managing collective innovation processes, and the cognitive aspects of social learning and knowledge brokering. However, the contribution of network managers to steering innovative design processes has, to date, received much less attention. Using innovative design theory (Hatchuel et al., 2009) that formalizes design reasoning, this paper seeks to help address this knowledge gap. Drawing on four collectively organized innovation initiatives that aimed to reduce the negative environmental impacts of agriculture in the peri-urban agro-ecosystems surrounding Montreal (Quebec, Canada) and Paris (France), we explore the core role played by network managers in setting up and steering collective action, and in particular, collective design processes in multi-level agricultural systems.

2. Conceptual framework

2.1. The functions of network managers in innovation processes

Boerzel (1998, 254), quoted by Giest and Howlett (2014), defined a social network as 'a set of relatively stable relationships which are non-hierarchical and interdependent, linking a variety of actors who share common interests with regard to a policy and who exchange resources to pursue these shared interests acknowledging that cooperation is the best way to achieve common goals'. However, there are also situations in which there is a clear need for collective action, but the actors involved do not necessarily see their shared interests, at least initially. Such situations are quite common in the field of natural resource management, including agro-ecosystem management (Berthet et al., 2018), where there is often a need to engage initially reluctant actors for the success of the collective initiative. As Klijn et al. (2010, 1065) underline, "interactions within the network may produce sharp conflicts about, for instance, the distribution of the costs and benefits of a solution." The actors involved may also have different perceptions on the nature of the problem(s), the desired solution or the best organizational arrangements to utilize to ensure cooperation, and this can be a major obstacle to achieving meaningful outcomes that satisfy those actors.

Networks have been well studied in the context of innovation processes as an interesting organizational form, beyond market and hierarchy, through which to source knowledge, access new technologies, create value and reach new markets (Smart et al., 2007). Networks have been shown to facilitate the generation and diffusion of knowledge and information about the systems under management (Isaac et al., 2007), the articulation of options and demands for innovation (Klerkx and Leeuwis, 2009), the allocation of key resources for effective governance (Carlsson and Sandström, 2008), a commitment to common rules among actors (Scholz and Wang, 2006), and the resolution of conflicts (Hahn et al., 2006; Bodin and Crona, 2009). Networks are both consciously planned, as actors deliberately interact and attempt to structure these interactions with organizations and rules, and also unplanned, as a result of spontaneous interactions and pre-existing rules (Klijn et al., 2010). However, such networks generally require effective management in order to realize their potential (Giest and Howlett, 2014). According to Giest and Howlett (2014), the role of network managers, whether they be a formal association, a specific individual, an organization or some combination of these, is key to realizing collective outcomes. More specifically, the management strategies of leaders will significantly influence the structure and dynamics of the network (Gage et al., 1990; Meier and O'Toole Jr, 2001).

Previous research has helped to conceptualize the various roles and functions of network managers in realizing collective action (Table 1) [see, for example, Klijn et al., 2010 and Giest and Howlett, 2014]. In the context of innovation networks, such roles and functions have been explored through concepts such as "network brokers" (Hellin, 2012), "systemic intermediaries" (van Lente et al., 2003), "innovation intermediaries" (Howells, 2006; Kilelu et al., 2011; Agogué et al., 2017), "innovation brokers" (Klerkx and Leeuwis, 2009; Batterink et al., 2010) and "innovation champions" (Klerkx and Aarts, 2013). Taken together, these studies identify a diversity of important tasks associated with network management, which we summarize under four broad categories: Connecting, Framing, Knowledge brokering and Exploring (see Table 1), considered both non-exhaustive and non-independent.

While these four functions are complementary, and any network manager may attempt to fulfil them all, there exist various types of manager who will develop some functions over others (Klerkx and Leeuwis, 2009; Kilelu et al., 2011): e.g. knowledge brokers vs. enterprise development support intermediaries.

In the context of collective innovation for sustainable agriculture, the diversity of stakeholders and their divergent views on the values of innovation (which can be non-monetary), as well as the complexity of agro-ecosystems and the difficulty to set clear objectives at the outset of an innovation process, raise crucial network management challenges. In this paper we aim to clarify the contribution of network managers to the four functions of Connecting, Framing, Knowledge brokering and Exploring in agricultural innovation initiatives, and pay particular attention to the importance given to the Exploring tasks using recent advances in design theories (Le Masson et al., 2010; Hatchuel et al., 2018) to help characterize these activities.

2.2. Design theories, a new perspective on innovation

Design theories have become increasingly applied to innovation and

creation in various domains, from engineering to art (Le Masson et al., 2010; Hatchuel et al., 2018). According to Hatchuel et al.,(2018), the literature on innovative design has long been trapped in the opposition between decision theory (e.g., optimization) and creativity theory (e.g., ideation). However, recent advances in design theory show that design does not only derive from decision or from creativity, but rather that it relies on generativity, which can be defined as a systematic model of thought that both creates new objects with desired properties and provides the new knowledge necessary to warrant their existence (Hatchuel et al., 2018). Innovative design is thus different from decision (Hatchuel, 2001): decision consists in selecting the best option(s) among known solutions, whereas innovative design aims to generate alternatives beyond an existing set of solutions. It is also different from creativity (Le Masson et al., 2010), as one may have a very creative idea on an object without having the knowledge to create an object corresponding to this idea. This has direct implications for the steering of innovative design processes: in contrast with problem-solving that involves defining objectives and selection criteria at the outset and that progressively reduces degrees of freedom (Midler, 1995), innovative design requires the progressive revision of objectives and selection criteria and makes it possible to maintain degrees of freedom during the process. Most design projects in agriculture tend to be carried out using a problem-solving approach: such an approach is more convenient as it allows setting evaluation procedures at the outset, organizing and dividing tasks, using available knowledge, etc. In contrast, an innovative design approach allows generating new alternatives, new ideas and new knowledge, but tends to be harder to manage. In this paper we see both approaches as potentially complementary; where innovative design can be used on an ad-hoc basis and then give way to problem-solving.

3. Methods

We adopted an exploratory approach to conducting our comparative case study analysis (Yin, 2009). After identifying 19 potentially suitable cases in Quebec and eight in France, two instrumental case study sites were subsequently selected near Montreal, Canada (QC1 and QC2) and two near Paris, France (FR1 and FR2). Each case was identified as meeting the following selection criteria: (i) operating in a landscape context of intensive agriculture and environmental degradation; (ii) taking a landscape-level approach to innovation; (iii) involving diverse stakeholders with diverging interests in collective action; and (iv) being considered a 'pioneering' and successful project by public authorities. Each of the cases also involved the creation of new governance networks, with many actors, frequent interactions between them, a level of stability over the project lifespan and complex decision making challenges (Klijn et al., 2010) (see Table 2 for summary of each case study and Table 3 for their timeline). In order to facilitate meaningful cross-case comparison, each of the selected cases exhibited core similarities, while also having important differences allowing contrast and cross-case learning.

The first case (QC1) was a catchment-scale project that sought to restore an endemic fish species' habitat, led by two agro-environmental agents working for a farmer union. The second case (QC2) was a river catchment project that aimed to mitigate soil erosion through implementing buffer strips and agroforestry practices for the protection of aquatic ecosystems and water quality, led by a government officer. The third case (FR1) was a project seeking to design and construct a buffer wetland to limit the degradation of drinkable water quality, led by a local NGO and researchers from a public institute, while the fourth case (FR2) involved the development of a hemp supply chain to diversify arable crops, hereby reducing chemical inputs, led by a farmer association (see Table 2). Each of these initiatives aimed to collectively change agricultural practices and/or develop agro-ecological infrastructures to reduce the negative environmental impact of agriculture.

Data collection involved key informant interviews and document analysis, facilitating data triangulation. From November 2015 to May 2016, we conducted 24 semi-structured interviews with key informants (see Table 4). All interviews were audio-recorded and fully transcribed in accordance with McGill's Policy on the Ethical Conduct of Research Involving Human Participants. Document analysis included reviewing project proposals, reports and related policy documents to better understand the local project's objectives, performance and governance arrangements (see Table 4). Our analysis aimed to identify each project's context and origin, the main characteristics and challenges encountered. We analyzed the various systems of actors and the rules they developed to facilitate collective action in support of innovation. We also paid particular attention to the design processes for each intervention. All data coding was conducted manually following a semi-open strategy using the four network management functions: Connecting, Framing, Knowledge brokering and Exploring (see Table 1).

In what follows we draw on our body of evidence to examine the contribution of the network managers involved in each case study to the various network management functions through their self-reported activities and the way that other stakeholders perceived their performance. We present illustrative quotes throughout our analysis to support and contextualize our observations.

4. Results

4.1. Network management: connecting, framing, knowledge brokering and exploring

In what follows, we present the results of our qualitative analysis using the categories of network managers' functions and related activities presented in Table 1.

4.1.1. Case 1: a catchment project to restore an endemic fish species' habitat (QC1)

4.1.1.1. Connecting. The network managers (project coordinators) reported placing a strong emphasis on activities related to this function. Their objective was generally to facilitate the implementation of measures on farms by removing potential obstacles: *"We bring to the producer solutions to the problems that we observe at their place. (…) We tell them: 'It is possible to make a project almost ready-made for you'."* (QC1-A&B). "*We help farmers in their procedure; we can tell them which partner to contact. We make it easy for them.*" (QC1-A&B). They reported being careful not to rush things with farmers: "*They are encouraged to put something in place, and when they are convinced, we try to go further. It's gradual.*" (QC1-A&B) and built a network in which tasks were shared according to the actors' skills. "*Everyone has their place in the project, there is good coordination, a good partnership."* (QC1-M). They aimed to activate the right players for the project: setting up a strong partnership with the local catchment organization to build interventions on river banks, cooperating with agri-environmental extension services in order to change farming practices and collect information about the actions being implemented on farms, as well as with Regional County Municipalities, in charge of cleaning up the streams, to implement solutions for bank erosion control. In addition to bridging actors with complementary skills, the network managers reportedly mobilized influential farmers to disseminate information and awareness among other farmers: "*They are kind of ambassadors, (…) of models*." (QC1-A&B). They established a river catchment advisory committee composed of 12 people: seven farmers and other local partners: a catchment organization, a municipality, an environmental NGO, and agro-environmental extension services to: "… *give its opinion on the projects; it allows us to identify the best techniques for the different works."* (QC1-M). With regard to resource mobilizing, the network managers played an important role in fund-raising, *"We obtain the funding that allows us to stay in the country* (rural landscape) *and that allows us to create this trust [from producers]"* (QC1-A&B).

Table 2
Main characteristics of each case study.

Case	Project implementation period	Location	Environmental and/or agricultural stakes	Nature of the project addressing these stakes	Network managers	Other stakeholders who are part of the network	Governance	Project achievements
QC1	2009 - ongoing	East of Montreal, Quebec, Canada	Surface water pollution due to soil erosion, pesticide and fertilizer transfer; Fish species threatened with extinction	Catchment project (335 km^2)	Two agri-environmental officers from a farmer union	Catchment organization, Agricultural extension services,~200 farmers, public and private funders, local municipalities	An advisory committee composed of 12 people: the 2 coordinators, 7 farmers, a catchment organization, a municipality, 2 agricultural extension services, and an environmental NGO. Meet four times a year	- 23,5 km planted buffer strips - 17 km erosion control zones - 5 km shelterbelt - 560 hydro-agricultural improvements - 1550 ha of soil cover practices - 75% of participation
QC2	1999–2014	South-East of Montreal, Quebec, Canada	Surface water pollution due to soil erosion, pesticide and fertilizer transfer; River eutrophication	Catchment project (555 km^2)	Officer of the Quebec Ministry of Agriculture (MAPAQ)	Catchment organization, agricultural extension services, ~50 farmers, biologist, researchers, public funders, local municipality, Canadian government	Project manager; Cooperative board (5 farmers) Meet five times a year	- 85 km grassland buffer strips (10 m large) - 33 km planted buffer strips - > 900 hydro-agricultural improvements - 86% of participation
FR1	2005–2012 Pilot project currently deployed at a larger scale	South-East of Paris, France	Groundwater pollution due to pesticide and fertilizer transfer; sinking holes; Aquifer providing water to 1.5 million consumers	Pilot catchment project (350 ha)	Water protection NGO	Researchers, 10 farmers, public funders, consulting engineers, local water union, extension services, local municipality	Informal steering committee: Researchers, NGO, farmers, extension services and local municipality. Two meetings/year during analysis phase, then twice per month during works	3 constructed buffer wetlands (total area: ~2 ha)
FR2	2008 - ongoing	East of Paris, France	Farmers express a need for crop diversification	Setup of a hemp supply chain	Farmer association (initially 10 people)	90 to 200 hemp producing farmers, 12 employees of the hemp transformation unit, local authorities, hemp national association, researchers, extension services	Bureau of the firm: 5 associated farmers and the CEO. Meet on weekly basis. Board: 10 associated farmers. Meet every 3 months General meeting with 10 firm shareholders (8 associated farmers and banks): once a year	1000 ha of hemp production in a 40 km radius Hemp transformation unit and supply chain

Table 3
Timeline for each case.

QC1	QC2	FR1	FR2
1987: Local endemic fish species considered as threatened 1998: The main farmer union employs an agent to work on catchment projects 2000: Canadian public policy program to protect endangered species 2002–2009: Various agro-environmental policy instruments to limit water pollution 2004: Endemic fish species considered as endangered 2009: Local farmers asked their farmer union to initiate a catchment project, following the example of a neighboring catchment project (2005–2008) 2009: Pilot project in a small upstream sub-basin 2010: Project pursued with downstream sub-basins 2011, 2014, 2017: Local catchment organization published a water master plan, then updated it 2012: A study from the Environment Ministry of Quebec shows high rates of pesticides pollution in the river 2013: Project led at the whole river catchment scale - the three pre-existing advisory committees merge 2009–2013: Various project achievements related to planted buffer strips, erosion control and soil conservation practices 2014–2016: New initiatives to value biodiversity and wooden areas, and to limit the use of pesticides 2015–2020: Future plan oriented toward communication	1998: A MAPAQ officer presented to local farmers the results of a study on the river eutrophication 1999: He and a group of farmers founded a cooperative aiming to reduce agricultural impacts on water quality at the catchment scale 2002–2010: The cooperative, local extension services and catchment organization implanted > 20 km of planted buffer strips and windbreaks 2007: The MAPAQ officer initiated a project leading to set up a network of 85 km of 10 m-wide riparian buffer strips 2014: Retirement of the MAPAQ officer - the cooperative was dissolved Since 2015: The local catchment organization has supported the riparian planted network's management	1990's: Severe drop in the Paris groundwater supply and alarming pollution rates due to pesticides 1997, 2008, 2014: Three successive groundwater contracts signed by local authorities: water master plans 2001: local governments and users' representatives founded a NGO for the restoration of water quality 2005: This NGO launches a pilot project in a small catchment - Partnership with various researchers 2005–2006: Hydrologists show evidence of pesticide transfers - Farmer awareness raising 2006–2007: Discussion of potential solutions with local stakeholders - Selection of the constructed wetland option 2007: Launching of agro-environmental contracts to improve farmer practices 2008: Geotechnical study 2009: Looking for funding and wetland design contractors. A farmer sold a plot of land to the local water union for the construction of the wetland. 2010–2011: Buffer wetland construction 2012: Inauguration of the constructed wetland 2014: Award from French Ministry of Environment	2007: Two farmers ask consultants to carry out a study on potentialities for crop diversification 2008: They invite all surrounding farmers at a meeting 2009: Ten farmers set up an association to create a hemp supply chain 2009: First contracts with hemp producers 2010: Creation of a private firm for hemp transformation 2011: Move of a German hemp first transformation unit and agreement with the German salesman to keep their European market Since 2011: Active role to develop hemp uses (e.g. partnership with a national association to promote building with hemp) + partnerships with various R&D institutions

Table 4
Information on data collection - people interviewed and documents collected.

Case	Period of data collection	People interviewed	Documents collected
QC1	Nov.-Dec. 2015	Network managers: Two agri-environmental officers from a farmer union (QC1-A&B)[a] Other network members: Catchment organization (QC1-G, QC1-M), Agricultural extension services (QC1-C), farmers (QC1-H&I, QC1-J, QC1-K), public and private funders (QC1-D&E, QC1-N), local municipalities (QC1-F, QC1-L)	Project descriptions submitted to calls for proposals; Project flyers and between newsletters; Presentations of the catchment organization; Water master plan; Technical sheets, detailed documents and project reports on hydro-agricultural improvements; Public policy presentation documents
QC2	Apr. 2016	Network manager: Officer of the Quebec Ministry of Agriculture (MAPAQ) (QC2-B) Other network member: Biologist and agroforestry technician (QC2-A)	Reports and publications on the project; Presentation at the last General Assembly of the cooperative (with maps, pictures, graphs, etc.); Technical and scientific documents related to the project
FR1	Jan. 2016	Network manager: Water protection NGO (FR1-C&D) Other network members: Researchers (FR1-A, FR1-F), farmers (FR1-B – also member of the local water union, FR1-E)	Project presentation documents; communication documents (flyers, newsletters from the NGO); scientific articles and projects; technical documents on ecological engineering
FR2	Jan. 2016	Network manager: A member of the farmer association (FR2-B) Other network member: CEO of the hemp transformation unit (FR2-A)	Project newsletter; hemp producer contract; scientific publications and technical documents on hemp; commercial documents from the hemp transformation unit

[a] Cases and respondants have been anonymized. These codes are used for quotes.

4.1.1.2. Framing. With regard to guiding interactions, the network managers in this case devised some operational rules but did not report particularly seeking farmers' agreement on these. Also, there were not many explicitly agreed upon rules regarding the interactions between the various network actors. These interactions were reported to be mainly informal. Participation in the project was voluntary, and generally, farmers did not pay money for the interventions. "*Depending on the actions and projects, the contribution of the producer is in terms of machinery, work … But if we do not have enough funds to make an intervention, we ask the farmers to contribute, at least in kind, more rarely in money*." (QC1-A&B).

4.1.1.3. Knowledge brokering. With regard to collecting information and knowledge, for each farm-level intervention, the network managers collected data by walking along the streams, taking pictures and GPS waypoints, in order to propose relevant solutions.

They also built partnerships with key actors to get data, in particular with the local catchment organization for hydrological data, with an environmental NGO for data on biodiversity, and with extension services for data on farming practices. In addition, they attended numerous training sessions to update their knowledge: "*We meet other people doing agri-environment actions. (…) We attend training to have more information on an aspect*" (QC1-A&B). Regarding the facilitation of learning processes, the managers in this case put emphasis on transferring the knowledge they gathered through regular field visits, workshops and seminars: *"We kind of play a role of database"* (QC1 A& B). They also published an annual bulletin informing interested actors about the project results and progress, devoting time to awareness raising among farmers, other stakeholders and students.

4.1.1.4. Exploring. With regard to creating new content, the nature of the interventions being planned did not significantly change over the project lifespan. Nonetheless, the managers reported trying to propose solutions that were increasingly multifunctional: "*Initially, we would say: 'it is necessary to raise the producer's awareness (…) to avoid creating erosion'. Today (…) we say: 'can we make the riparian strip more functional: can we make it wider?'*" (QC1-A&B). From 2014 to 2016, the network managers added projects designed to better value biodiversity and wooded areas, and to limit the use of pesticides. With regard to searching for goal congruency, they intended to stimulate collective action: *"Usually we will do connection when we see the problem and we want it to be solved collectively; we will arrange for them to talk to each other. (…) It is more we who bring this collective vision."* (QC1-A&B). A local politician observed: *"[A farmer] immediately put in place measures; it had a snowball effect because people said 'It's nice!' (…) This raised a consciousness. It's still the beginning."* (QC1-L). However, several interviewees stressed the difficulty of building a shared vision: "*The interventions that are made are interesting, but it is not at a large scale yet"* (QC1-G). "*Coordinators work hard, but they have trouble getting people on board; they do not feel concerned"* (QC1-D). A farmer reports: "*People come to see my fields, but they are not interested. They want to cultivate everywhere. Even if they find it nice"* (QC1-K), revealing a difficulty to alter the perceptions of other farmers.

4.1.2. Case 2: agroforestry and soil erosion control to protect aquatic ecosystems (QC2)

4.1.2.1. Connecting. An officer from the Quebec government initiated this catchment project with a group of farmers in 1999. To facilitate interactions and overcome financial obstacles, they founded a cooperative, whose mission was to collect funding and implement measures to reduce agricultural impacts on water quality at the catchment scale, mobilizing 56 out of 65 producers in the region (participation rate: 86%). The network manager was heavily involved in the organization of the project: "*I still had my job [at the Ministry], but I was doing everything: I was preparing meetings, I was in charge of planning, minutes, annual reports, general meetings, etc."* (QC2-B), reporting close proximity with farmers: *"Relations with farmers were more than excellent"* (QC2-B) and collaborating strongly with specialists: "*[QC2-B] was a transmission belt between researchers and farmers*." (QC2-A). To foster cooperation, the project manager worked with people known and respected locally: *"I was working with a pretty straight retired woman who was local. She inspired a great respect; she had been married to a farmer."* (QC2-B) and "*I chose a small local entrepreneur who also worked on the weekends and had the trust of the farmers."* (QC2-B). The manager showed strong leadership to make the project advance despite administrative difficulties: *"If I had followed the norms, nothing would have been done."* (QC2-B). With regard to activating the right players, he sought to involve motivated farmers to make the project advance smoothly: "*I had formed an executive board for my taste with the most leading and collaborating farmers."* (QC2-B). Tasks were shared with a catchment organization and agricultural extension services: *"[Agricultural extensionists] went to the farmers and offered them a range of agri-environmental schemes. I was the provider, the implementer who was doing the planting."* (QC2-A). With regard to resource mobilizing, the project manager and his partners raised funds from government and research institutions and also asked farmers to contribute financially: "*I was going to a farmer's place": I was telling him "there is such a problem at your farm, I propose you for example a 70% subsidy and you pay the remaining 30%".* (QC2-B).

4.1.2.2. Framing. The network manager in this case searched for the best governance options to raise funds, and organize interactions: *"At the beginning we had created an informal organization, a catchment committee (…) that did not have a legal structure. Then we decided with the farmers to found something to be able to intervene, act, and seek funds."* (QC2-B). He set various operating rules, such as requiring that farmers pay for the interventions on their properties, or determining the width of the riparian buffer strips. These rules were partly discussed with the cooperative board; but the project manager was more in a posture of convincing farmers to adopt the measures he devised: *"There was resistance. Some turned me away; (…) sometimes I managed to convince some of them."* (QC2-B). He cared about finding arrangements to avoid blockages: "*We had more than 600 interventions to be done in two years whereas we had lost six months. We worked during winter even if it is not advised; (…) we even paid work in advance to use the budget. It needed a local organization to make it work. But all this was done in agreement [with the funder]….*" (QC2-B). However he was the node through which most framing interactions occurred, and when he retired, the cooperative was dissolved.

4.1.2.3. Knowledge brokering. Along with his specialist colleagues, the network manager committed to gathering knowledge in order to devise solutions that were locally adapted and to assess their impacts: "*I was going on the field very often: I was walking along the streams before visiting farmers*" (QC2-B); "*Many researchers came from a lot of universities. They were mapping from satellite images to see the patterns of surface water flow. They developed software on what to do to get results."* (QC2-B) "*We installed ten water testing stations on the creek."* (QC2-B). "*For monitoring, we solicited ornithologists and scientists. (*QC2-A) "*Soil analyses were done in the 450 fields; we made an inventory, then we made fertilization plans.*" (QC2-B). His colleague biologist was *"working on the ecological history of Quebec. (…) [He was doing] the scientific reconstruction of what was here before replanting, so as to be more relevant than the agronomists who do not know the flora"* (QC2-A). The network manager believed he contributed towards creating an environment conducive to knowledge exchange: "*I kept farmers up to date; I always said that they were the first actors*." (QC2-B).

4.1.2.4. Exploring. The project led to many interventions and its impacts on water quality were visible, partly altering the perceptions of network participants: *"The farmers did not care about the trees and did not want to maintain them; today they are quite proud of it: "it starts to be beautiful", "it is like a bocage, it is concrete""* (QC2-A). However, despite this success, the network manager reported having difficulty building a shared vision among actors: "*The government was financing the loss for the farmers. When farmers no longer had the subsidy, they replanted corn!*" (QC2-A). *"At the final meeting, many people said they would like to do the same. I was hoping the government would realize that if they want to fix the problem, they have to do it. But they say it's too expensive to do that everywhere in Quebec. Everything died while it was a success! There is no political will."* (QC2-B).

4.1.3. Case 3: constructed wetlands to mitigate groundwater pollution from agriculture (FR1)

4.1.3.1. Connecting. The network manager in this case, an NGO dedicated to groundwater protection, defined its main role as facilitating interaction processes between actors: "*[Our] role is to support the actors so that it doesn't break. It is our added value. (…) We*

wanted to go forward, we did not let go. (…) If there is a weakening, if there are questions of the different partners, we bring them together for information sharing and for sustainable collective decision-making." (FR1-C&D). They organized many meetings with the local farmers during the project. However a farmer reported that the environment was not always adapted to facilitate productive interactions: "*We were sometimes under-represented compared to all the public bodies. (…) The first meetings there were about forty actors including only four farmers"* (FR1-E). The frequency of meetings was adapted to the project phases: "*There were one or two meetings a year at that time (in the first three years); then every three months. (…) Afterwards, with the construction site there were meetings every 15 days. (…) In addition there were informal meetings."* (FR1-A). They underlined that they paid attention to informing all stakeholders about project advancement and outcomes. "*At each stage the farmers were invited, as well as the municipality and the water union. It is important to associate them; they always came."* (FR1-C&D). *"At each stage of the process farmers were present. They followed the soil studies, picketing, drilling; they came, watched, and talked. That's why it worked."* (FR1-C&D). The manager reported working to solve conflicts and to make farmers join the project: "*We had a lot of proposals at first, but we did not want to impose them on farmers who had not asked for anything. There have been many consultation meetings with [the researchers], to explain the geological situation, to make them understand. We do not come out like that; we are at their place!"* (FR1-C&D). They bridged actors, for instance farmers and researchers: "*Farmers give their farming practices to [the NGO], so [the researchers] know what products are used. The research is not disconnected from reality. Farmers are also producers of data."* (FR1-C&D). However, some farmers felt that engagement came too late: "*It is important to let the farmers speak, listen to them. There were mistakes initially; a lack of consultation."* (FR1-E). To initiate their project, the network manager first looked for the right players: "*In 2005 we visited many research organizations."* (FR1-C&D). With the researchers, they then defined the original specifications for the constructed wetland, consultant engineers designed the basins and a private firm constructed the wetland. With regard to resource mobilizing, they looked for funding to pay for the studies, the work, and also to buy the field on which the main wetland was constructed. However, the search for funding was made difficult by the innovative aspect of the project: "*The project was not identified by the funders. (…). Some have devised new budget lines to make it cost zero for farmers, on an experimental basis."* (FR1-C&D).

4.1.3.2. Framing. The network manager devoted efforts to create network arrangements. Assisted by the researchers, the NGO organized the procedure for the construction of the wetland (specifications, call for proposals, etc.). A farmer consented to sell land for the construction of the wetland: *"At the beginning, they proposed to rent [the plot of land to me]; (…) we decided to sell it because it would have been complicated to rent it from a management point of view"* (FR1-B). In this case, the network manager arranged for the local water union to buy the plot from the farmer. The manager also proposed some operating rules and tried to reach an agreement with farmers about the management of the wetland: "*We made a tripartite agreement on the valves and the management of the constructed wetland: with the municipality, the farmers and the union.*" (FR1-C&D). The manager did not set up a specific governance structure for the project, instead organizing meetings on an ad hoc basis.

4.1.3.3. Knowledge brokering. The network manager in this case carried out knowledge brokering in close communication with researchers. With regard to collecting information, the researchers gathered considerable technical knowledge on the aquifer's hydrology and also on a constructed wetland they established in another location between 2005 and 2007. Data on the drainage system was crucial for the project and was collected from both farmers and the administration. Concerning the facilitation of learning processes, the researchers participated in > 45 meetings with public stakeholders and/or farmers and undertook routine maintenance visits every two weeks. The manager also relied on farmers for experimenting with farming systems using low chemical inputs. They reported emphasizing knowledge transfer, especially through newsletters and practical guides and even solicited other partners to develop a role-playing game to facilitate the diffusion of innovations. Since the construction of the wetland, many people have visited this pilot project: *"Since 2012, more than 300 farmers visited the site"* (FR1-A).

4.1.3.4. Exploring. Regarding the exploration of new ideas, the network manager and researchers first discussed a variety of potential solutions with farmers: "*The solutions were discussed with farmers in 2007-2008: to close the sinkhole (…); to channel everything; to use the wood where there was the sinkhole as a purifying area (…); to ban pesticides…*" (FR1-A). Yet, they had a solution in mind when they went to see the farmers. A farmer felt that the farmers were not really part of the decisions: "*We have been informed, but we must be heard. We are stakeholders*" (FR1-E), with a social science researcher who followed the project for two years confirming this view: "*They did some co-design a posteriori. (…) It was rather negotiation"* (FR1-F). The innovativeness of the project raised some difficulties and necessitated the creation of new content: "*The project was experimental at all levels, we discovered everything.*" (FR1-C&D). "*This concept [constructed wetland] has been introduced and it had to be clarified to farmers. It was unknown to them; they did not know what it looked like. (…) There was also a problem with the administration: in which category should we place this project?"* (FR1-A). The interviewees were mixed about the extent to which actors' perceptions were altered: *"Initially the farmers did not want the project, they did not ask for it. (…) Today farmers are able to present the project as we do. They are curious to see the results."* (FR1-C&D); in contrast it was reportedly difficult to build a shared vision among the network actors: "*They appropriate the fact of remaking wetlands, but they did not appropriate this constructed wetland as such.*" (FR1-A).

4.1.4. Case 4: the setup of a hemp supply chain to diversify arable crops (FR2)

4.1.4.1. Connecting. This project started in 2007 when a group of farmers asked consultants to study the diversification potential in a region of intensive agriculture, resulting in the proposed production of hemp. Following the study, the farmers organized a public meeting, aiming to initiate interaction processes: "*We invited all the farmers from the north of [the Department]. About a hundred farmers came."* (FR2-B). Ten farmers interested in hemp founded an association; then in 2010, they set up a private firm, bought a piece of land and acquired a hemp transformation unit. Since then, the associated farmers have been organizing the network: "*The associates run the shop. There are employees only for production.*" (FR2-B). These network managers mobilized between 90 and 200 hemp producers. *"Anyone who wants to produce hemp and who said yes at the beginning can do it."* (FR2-B). To foster cooperation, they signed contracts with the producers for four years and took charge of the hemp harvest to facilitate the producers' work. Yet, an interviewee reported weak links with the producers: "*It's still fragile, we do not have the confidence of all farmers yet, we still do not know for sure that they will continue."* (FR2-B). The configuration chosen for the supply chain, a private firm versus a cooperative, likely played a role in this situation: "*We are criticized for having set up a simplified joint-stock company [SAS in French] and not a cooperative, but we did not want to dilute the profitability toward all members (…). Today it is too late, but we would have involved more farmers in production."* (FR2-B). With regard to activating the right players, the associated farmers built a network with hemp producers, local authorities, agricultural extension services, research institutions and a national association promoting hemp in the building sector. The network members had different status in, and contributed differently to, the project: *"There are three circles: the founding partners (who attend the Board meetings), the shareholders (who*

attend the General Assemblies) and the producers who are only attached by a contract. They are suppliers but not investors" (FR2-B). Regarding resource mobilizing, most funding was private: "*Initially, there were the contributions of each associate, then the loans, then the shareholders*" (FR2-B); "*We were granted regional and European subsidies for plant equipment and harvesting, initially, for investment"* (FR2-B) and they aimed to make the supply chain thrive without public funds. To date, their market was essentially for export: "*The association moved a factory that existed in Germany, and bought the network of the German company. So 95% of the fiber goes to Germany."* (FR2-A), but they were trying to develop national and local markets.

4.1.4.2. Framing. Framing was a major concern for the associated farmers. With regard to establishing the operating rules of the network, the firm signed contracts with hemp producers. "*The first contracts were signed in 2009; for 90% the contract was renewed in 2013."* (FR2-B). In particular, the contract defines the amount of hemp fiber and grain that should be provided to the transformation unit each year, stipulating that the farmers have to comply with the firm's specification regarding, for instance, farming practices and delivery planning. An interviewee reported that *"the role of FR2-B [was] to make the specifications for the hemp producers"* (FR2-A). Yet many rules were not completely formalized: "*Sometimes the hemp harvest has to be delayed until late October. Subsequently the farmers have to reorganize their crop rotation. (…) [In case of shortfall they] can be compensated. [Our association] may offer specialized services [for harvest]; but there is no rule"* (FR2-B). *"[Our association] does not decide on the location of the plots and assumes the consequences. But we communicate a lot, for example on the stones [in the fields, which hinder hemp development]*" (FR2-B). "*We got along with the producers and agreed to lower the price a bit.*" (FR2-B). With regard to changing network arrangements, the associates deemed the setting up of a private firm as being more adapted to developing the business: *"At the beginning, the goal of the association was to organize the project, to work together, to communicate; it was good, but not for investment, industrial tools and commercial activity"* (FR2-B). The decision-making process was adapted to the issues of concern; according to the CEO: *"I make some decisions alone, others with maintenance and site managers; otherwise the decisions are made by the bureau when I submit problems"* (FR2-A).

4.1.4.3. Knowledge brokering. The network managers worked to gather as much knowledge as possible to develop the supply chain based on a poorly understood crop system: *"We learn every day about hemp. Every year is different. This year we have small fibers; the straw is sometimes white, sometimes brown. We learn in the field."* (FR2-A), in partnership with researchers: "*We are part of several French and European research programs*." (FR2-A). *"We also work in partnership with the Chamber of Agriculture of the [Department]: observation of plots, setting up of tests, etc."* (FR2-B) *"We are part of several (…) fundamental and applied research programs. We grow varieties for them, we inform them about the yields and we make samples of fiber."* (FR2-A*) "We work with [a technical institute]: we meet every year with a technician with whom we discuss different issues (sowing, fertilizers …). They do tests and observations all year round, everywhere in France"* (FR2-B). As hemp is a minor crop, genetic research has been limited. The project manager reported playing a key role in fostering research building partnerships with researchers and extension services. With regard to learning processes, knowledge transfer to the hemp producers was reported to occur through a newsletter and via meetings, the nature of which evolved over time: "*We organize one meeting a year with the planters. Before it was a 'High Mass'; now we do small basin meetings (…), it facilitates exchanges.*" (FR2-B). However their communication with the hemp producers was reported as being limited: *"We provide little technical advice. There are meetings every year but no personalized advice. (…) During the first meetings we detailed the technical operations, and now we communicate in real time."* (FR2-B). To communicate with other network members, "*[they] have a website and [they] attend trade shows*" (FR2-A).

4.1.4.4. Exploring. Exploration was led at various levels in the project; from the varieties: *"We hope that with genetics we can have earlier varieties"* (FR2-B), to the market: *"We are active in the sector; today hemp is used in plastics. (…) We would like to reach 1 to 2% of the building market. We want to have standardized products to meet the rules and expectations of this market"* (FR2-B), to the supply chain: *"Within 10 years, we should prepare for the future: either increase production and sales capacity, or create a second transformation if it adds value."* (FR2-B). Through the project, the associated farmers reportedly pursued a shared goal: *"With [the association], farmers did not just want to 'feed the planet', but also to 'build the planet'."* (FR2-A), developing a sense of ownership: *"The associates call me often, and propose things. They are passionate, have a sense of belonging to the project: it's their baby! They sweat to set it up and we still sweat!"* (FR2-B). However, despite the project seemingly motivating many farmers, the sense of ownership was not necessarily shared at a larger scale: *"In my opinion, [the hemp producers] look more at the economic profitability of the culture rather than the idea of a collective project."* (FR2-B).

4.1.5. Cross-case comparison

In each of the four cases, the actions of network managers were significant for all network management tasks. Across the cases, the Connecting task appeared to be the focus of a lot of effort, with network managers considering themselves as facilitators. The network managers also played a crucial role in Knowledge brokering: they produced data as well as built partnerships to conduct important studies; they also devoted energy towards transferring this knowledge to other stakeholders, especially to farmers. Their involvement in the Framing task appears to depend on the degree of informality of the relationships within the network. For example, in FR2 where the objective was to set up an economic supply chain, the Framing activity was crucial; while in the three other cases where projects were steered more by institutional actors, this activity was reported to be less central, with relations based on volunteering and negotiation being given priority.

Despite their reported success in mobilizing stakeholders and achieving the implementation of practical solutions (see Table 2), areas requiring further reflection and consideration emerged in each of our case studies. This is particularly true for the Exploring function, broadly involving the collective creation of new content by exploring ideas, sense-making in the search for goal congruency, collective strategy development, altering the perceptions of network participants and influencing the actors' values and norms. In each of the cases presented, despite the heavy involvement of network managers in these activities, challenges and failures reportedly emerged, with implications for the sustainability and longer-term viability of the initiative. While none of the cases reported open conflict or deadlock, difficulties with building congruent goals and a shared vision among network actors emerged as a recurring theme in each case, jeopardizing the involvement of a sufficiently high proportion of concerned actors over the long term.

4.2. Characterizing the exploring strategies adopted by network managers

The preceding analysis has highlighted some of the difficulties experienced by network managers seeking to achieve goal congruency in agricultural landscapes, and to change the perceptions, values and norms of the network actors. We offer two hypotheses to explain this:

1) The exploration of solutions was essentially driven by network managers who then sought to make them accepted by farmers.
2) Objectives were initially set by network managers and only marginally revised afterwards.

4.2.1. A core-periphery organization of the design process

In each of the case studies, the network managers were reported to have built various partnerships in order to capitalize knowledge. In QC1, the coordinators worked with a catchment organization that had produced a water master plan for the catchment, with agricultural extension services and experts from government agencies. In QC2 and FR1, network managers worked closely with researchers. In FR2, the associated farmers collaborated with research and technical institutes and with agricultural extension services. However, the definition and selection of possible agro-environmental solutions to be implemented was ultimately being led by a limited number of core actors, generally selected by the network managers.

In QC1, the coordinators reported they devised the evolution of the project in their planning. For each farm in the catchment, they suggested, prioritized and implemented solutions to the problems identified: e.g. hydro-agricultural improvements such as planted buffer strips, erosion control zones, or windbreaks. Many of the solutions being implemented in the project were designed and proposed by a government program which offered funding to farmers to implement solutions that are thoroughly described in technical sheets devised by government experts: *"To apply to the first component [of the program], it is necessary to present an action listed in the program: shelterbelts, shoreline development, soil conservation works, or interventions promoting biodiversity. There are guideposts, ceilings, a subsidy rate."* (QC1-D&E). The network managers did incorporate views of other actors to some extent, for example they sometimes asked the advisory committee to review and validate their decisions: *"The advisory committee gives its opinion on the projects; it allows to identify the best techniques for the different works"* (QC1-M). They also adjusted their plan according to the farmers' feedback: *"Meetings [with farmers] take place in the winter. We observe if there are problems and we remain attentive to their needs; we adapt a little like this."* (QC1-A&B).

In QC2, the network manager designed most of the solutions implemented. He explained his reasoning for the adapted solutions "*The idea of riparian strips: (…) The width of a mower is 4 m; round trip + 2m of regulation band, that's 4 + 4 + 2 = 10m. It had a practical side for agricultural work.*" (QC2-B) and *"But it's all well and good to put the strips on the surface; if you put the ditches back into the watercourse, there is a problem, hence the idea of cutting the hydrological link between the field and the watercourse."* (QC2-B). Once he had identified the solutions that he considered to be the most adapted to the issue at stake, he aimed to implement them at a large scale. Indeed, he considered that "*farmers prefer[red] ready-made solutions*" (QC2-B).

In FR1, the network manager solicited researchers to determine a solution to mitigate the pollution of groundwater. After analyzing a diversity of options, the researchers proposed to experiment with the construction of a buffer wetland. They first gathered and produced knowledge to elaborate the requirements for this wetland to be efficient, then worked with experts in ecological engineering to design it: *"In 2008 we worked with consultant engineers to transfer our knowledge, to help them size the wetlands (…). They designed the pre-projects and as researchers, we communicated our goals to them."* (FR1-A). Meanwhile, the innovation was proposed to farmers, and a phase of consultation and negotiation began, with the researchers and NGO collecting information from them: *"[Associating farmers] was useful for producing information; they had information on the drainage network."* (FR1-C&D); farmers provided some advice: *"There were some inputs, not the most flashy, but they exist. They raise very relevant questions (for instance responsibility in the event of a fall)"* (FR1-F). They then negotiated some aspects of the project, such as its scope: "*Regarding the location, the farmers refused to do all the basins. It had a cost and what was it for? They said it was enough"* (FR1-B). However, as a researcher observing the project declared: *"They kind of made co-construction a posteriori."* (FR1-F).

In FR2, the network manager (associated farmers) collaborated with researchers and agricultural extension services to produce knowledge adapted to their needs (see part 4.1.4). These experiments and research collaborations concerned primarily hemp production. The hemp producers contributed to some of the experiments, but they did not contribute to designing the supply chain with all decisions being made by the associated farmers. According to an interviewee, the fact that they were contractors of a private firm and not members of a cooperative or an association was clearly a limitation of their involvement in the project design and orientation.

4.2.2. Tensions between objective setting and network building

Our results highlight that in all four cases of collective innovation in agro-ecological systems, project objectives were set at the outset by the network managers, and that their aim was to implement the solutions they had identified initially on the basis of scientific studies. In QC1, the objectives were set during project planning by the network managers: *"Our action plans are defined over three years: we indicate the objectives to be achieved and the different actions to implement. (…) We make a financial arrangement. We set an annual target for which we do not specify the locations, but the quantified objectives: for example, 10 interventions on riverbanks, 5 km of riparian strip, building ponds, etc. And then we seek funding to finance that."* (QC1-A&B). In QC2, the problem was clearly defined by the network manager who devised and selected a range of solutions that he then sought to apply at a large scale: *"I saw that what I was doing was patchwork (…) I started to dream of a project. I thought about a project of continuous wide strips along the streams, on each side."* (QC2-B). In FR1, the solution - a "constructed buffer wetland" - was selected by the network manager and the researchers they had solicited. They then worked to make local farmers accept this solution: *"We did not want to impose this solution. (…) Yes, we had it in mind. Our approach was to share a diagnosis with the farmers. (…) When a diagnosis is shared, the solutions appear more obvious and are more easily appropriated by actors."* (FR1-A). In FR2, once the associated farmers agreed on the objective to set up a hemp supply chain, they tried to progressively solve all of the problems they faced in order to secure their business: *"Our perspective in five years is to strengthen the industrial tool: increase profitability and productivity; control the supply as well as the outlets. Our concern is to make the infrastructure sustainable."* (QC2-B). In all cases, clear objectives with measurable targets were formulated at the outset by the network managers (and sometimes their supporting institutions). Furthermore, these objectives were marginally revised along the project lifespan. The network managers reported devoting significant effort to communication and to the search of funding to develop incentives; but one is left to wonder to what extent co-constructing the projects objectives with all actors could have helped with motivating collective action.

4.2.3. An exploring activity combining problem-solving with temporary innovative design

In some cases, such as in QC1, the exploration of solutions essentially consisted in scouting existing solutions: *"We do not really experiment or compare. But we observe and adapt techniques according to the conditions. We are looking for less expensive and effective solutions."* (QC1-A&B). Nonetheless, occasionally, new technical solutions were sought when the actors faced a new difficulty: *"Sometimes we need to invent new solutions. For example, we wanted to develop a grass bed to replace Phragmites, but the substrate of the pond was very hard; we did not know how to implant the grass bed. So we bought sod."* (QC1-M). In other cases the search for solutions was more exploratory. For instance, in FR1, the project raised brand new questions both for researchers: *"We could not control anything; it was an open sky laboratory."* (FR1-A), and for institutions *"It was a problem for the water policy: in which category would [the infrastructure] fit?"* (FR1-A).

In all cases, the network managers primarily adopted a problem-solving approach, but in some cases they had to temporarily adopt an innovative design perspective, giving more place to the exploration of new solutions. Eventually, we can see that some activities related to the Exploring function in the literature were reported to be successfully

carried out by the network managers in each case, such as “Creating new content by exploring new ideas” and “Supporting strategy development”, but other activities raised difficulties or seemed to be neglected, such as “Making sense, searching for goal congruency”, “Altering the perceptions of the network participants” and “Influencing the actors' values and norms”.

5. Discussion

This research draws from four empirical case studies, operating in similar agro-ecological settings but very different institutional and organizational contexts, to highlight the strategies employed by network managers seeking to achieve collective innovation in agricultural landscapes. Focusing on the various network management tasks, categorized as: Connecting, Framing, Knowledge brokering and Exploring, our results indicate that the actions of managers were significant to collective innnovation outcomes in different agricultural systems. Overall, the Connecting task appeared to be the focus of the most effort in each case. This is in line with the work of Giest and Howlett (2014) who underlined the importance of the network manager seeing the ‘big picture’ in order to identify members that fill a knowledge gap within the network or connect parties that would benefit from working together. The network managers in each case study also placed importance on the Framing tasks, which corresponds to the ability of the managers to set rules and create network arrangements, and thus give actors a platform to interact and exchange knowledge. These tasks are known to be key determinants of network activity and effectiveness (Provan and Kenis, 2007; Kilelu et al., 2011; Hellin, 2012), as they can reduce the complexity and uncertainty of the relationships and make face-to-face communication more likely (Giest and Howlett, 2014). The network managers in each case also played the role of Knowledge broker, yet they focused more on transfers of knowledge from experts (e.g., researchers, technical experts and governmental agencies) to projects managers and farmers than on interactive flows, even though they also collected knowledge and feedback from farmers.

The tasks associated with Exploring appeared challenging in each case, and would benefit from further research and policy attention in order to assess the outcomes of different networked approaches to collective innovation in agricultural landscapes. According to Klijn et al. (2010), strategies for exploring content are necessary to clarify the goals and perceptions of actors (Fisher, 2003; Koppenjan and Klijn, 2004) and to develop solutions that create opportunities for actors to participate. While each initiative led to significant achievements in terms of stakeholder’ engagement and agro-environmental infrastructures (sensu *largo*), the Exploring process was led by a limited number of actors who then worked to make other network actors accept and implement their solutions. Although such an approach can be viewed as being efficient in the short term, we believe it goes some way to explaining the difficulties that the network managers experienced with building shared and congruent goals, likely limiting the impacts of these collective initiatives in the long term. This finding echoes what Klerkx and Leeuwis (2009) called the tensions and paradoxes of innovation brokers, related for instance to embeddedness and impartiality, when their position in the innovation network and their objectives are not fully understood. Further, network managers often adapt their functions to specific contexts (e.g. Kilelu et al., 2011; Klerkx et al., 2010) and focus on particular functions according to the network's position in its transition trajectory (van Lente et al., 2003). For example, following van Lente et al. (2003), in the initial “exploration” phase of a project, key roles for network managers may be to develop visions of the future and make visible a variety of options: the emphasis is thus on Exploring. In the “take-off” phase, key roles may be to activate relevant actors and support niche development: the emphasis is on Connecting and Knowledge brokering. In the “embedding” phase, key roles may be standardization and project management: the emphasis is on Framing. Lastly, in the “stabilization” phase, a key role may be to reflect on new goals: the emphasis returning to Exploring. Future longitudinal research into how the roles of network managers evolve throughout each stage of an agricultural innovation trajectory would be valuable.

As Van Bueren et al. (2003) underline, when confronting wicked problems, it is all the more challenging but necessary to strengthen interactions between network actors. In the cases presented in this paper, the network managers reported making an effort to inform actors about their interdependences, but as Van Bueren et al. (2013 – 211) note “even if actors do acknowledge their interdependency, they find it difficult to engage in joint action.” Our empirical and comparative study underlines the core importance of the Exploring tasks, and that opening these to a greater diversity of stakeholders (e.g., through design workshops, project steering committees, adopting participatory research and appraisal methods, etc.), may contribute to better anchoring innovations within the network (Elzen et al., 2012).

To date, empirical research on the influence of social networks on agricultural innovation systems has rarely been focused on the Exploring task of network management and leadership. Existing studies on social network management have tended to concentrate on innovation diffusion and consider innovation as the result of a process, with less attention paid to how agricultural innovations ‘come to life’ (Knickel et al., 2009; Van Rijn et al., 2012). The literature on innovation intermediaries considers innovation processes, but tends to focus on the roles of demand articulation, network formation and innovation process management (see for instance Klerkx and Leeuwis, 2009; Batterink et al., 2010; Kilelu et al., 2011). As noted by Klijn et al., 2010, the exploring process is sometimes short of creative solutions to satisfy the various actors involved. The exchange and use of knowledge is only part of the role that network managers can play; the envisioning of novel agro-ecosystems, which may have original spatial configurations and new functions, also being key. The comparative research presented in this paper underlines the need for network managers to carefully organize collective exploration processes, in which a diversity of stakeholders set common objectives and collectively explore a diversity of solutions. In each of our case studies, Exploring was reported as being framed primarily as a problem-solving process, adapted from project management thinking which requires objectives and decision criteria to be clear at the outset, making it then possible to identify solutions to implement and share tasks between stakeholders (Le Masson et al., 2010). However, in a context where innovation and systemic approaches are particularly needed, a problem-solving approach may benefit from temporary collective exploration to broaden the range of potential solutions, enabling actors to complexify before simplifying in order to collectively recognize what is being given up and what is being gained by simplifying (Cooksey, 2001). Exploring presents an opportunity for network actors in the agricultural system to ‘open up’ the range of alternatives being considered, better comprehend the agroecosystem in its complexity, and envision new objects of collaboration, thus contributing to more systemic innovation. Recent advances in design theories (Hatchuel et al., 2009; Le Masson et al., 2010) highlight that design requires various cognitive operations, such as knowledge creation, external knowledge integration and knowledge re-ordering, that could be categorized as knowledge management, but also ideation (i.e., generation of ideas); and that these activities are intertwined. Our results suggest that network managers likely have strong skills in terms of knowledge management. Other complementary skills could include creativity enhancement and design process management. Further research on how to better support and enhance the Exploring task as an innovative design process involving a wider range of network actors in different agricultural innovation systems is warranted.

6. Conclusion

Collective innovation initiatives remain crucial to landscape-level approaches to addressing the environmental impacts of agriculture and

better accounting for the complex interactions between and among agricultural system components and other resource systems, such as rivers, aquifers and forests. This paper presents and contrasts four empirical case studies of collective innovation at the agricultural landscape scale to better understand the network challenges raised by such initiatives. Focusing on the roles and strategies adopted by network managers to initiate and steer collective action revealed significant effort to connect actors and enhance trust, and also to capitalize, produce and share knowledge. However, the collective design processes leading to the adoption of specific innovations in response to the environmental problems being considered were of less focus, generally limited to a core group of actors in the network, with farmers (in particular) being considered end-users. Such an approach likely encourages the network manager to focus too quickly on the innovations considered optimal by 'experts'. Involving more diverse network actors, with sometimes highly diverging interests, in a collective agro-ecological design process toward goal congruency is inherently challenging and will require supporting management schemas, skills, tools and methods to realize outcomes that better reflect the complexity of agro-ecosystems.

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Conflicts of interest

None.

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