Upscaling of more sustainable cropping systems: a framework to analyse and support intermediation processes

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Abstract: The Ecophyto Plan 1 was devised to achieve a 50% decrease of pesticide use in France between 2008 and 2018. Based on available agronomic knowledge, collective expertise showed that reaching such a target at farm level implied in-depth redesigning of the current cropping systems. The DEPHY Network is one of the main policy instruments to support such a redesign process and to contribute to inviting more and more farmers to take up this challenge. To analyse the ways in which intermediation is organized in this network, we developed a framework which we also applied to two farmer-led networks that support farmers in redesigning their cropping systems and that seek to increase farmers' participation in such processes. Grounded in former studies on transition pathways at farm level and in participatory design processes in work system design projects or in open source communities, our framework distinguishes three levels (strategic, experiential and collaborative) to analyse the organization of intermediation. We apply it to the DEPHY Network and then point out the differences that we identify between the 3 networks analysed. Based on this, we make recommendations about the way each level should be addressed in order to support on-farm redesign processes in a large and inclusive network. We finally conclude by highlighting the limits of our framework and the need to test our recommendations.

Key words: intermediary objects, pesticide reduction, sustainable agriculture, cropping systems, participatory redesign, peripheral participation.

Introduction

Since the year 2000, various expert reports in France (CPP, 2002; Momas *et al.*, 2004; ESCo Pesticides, 2005) have pointed out the noxious effects of pesticides on workers' health and on the environment. In 2006, a European Directive[1] invited all the EU Member States to draft National Action Plans for a sustainable use of pesticides. In France the "Ecophyto 2018" plan was launched in 2009. It targeted a 50% decrease of pesticide use "if possible" within 10 years (starting point 2008). The first phase, the Ecophyto 1 Plan (2009-2015), was led by the French Ministry of Agriculture. It was funded by the "tax on indirect pollution" paid mainly by farmers[2]. The plan was divided into 9 themes[3] and 114 actions. During the 2009-2014 period, it costed M€361, of which M€194 came directly from taxes (Potier, 2014).

The objective was ambitious, as the Ecophyto R&D expert report pointed out (Butault & al., 2010). The experts noted that such a reduction in pesticides would require in-depth re-design[4] of cropping systems, and would certainly reduce the total amount of agricultural production. This objective was nevertheless supported by environmental and citizen associations and by networks of farmers who

[1]. The final Directive (2009/128/CE), along with the (CE) n° 1107/2009 regulation, the Directive 2009/127/CE, and the (CE) n°1185/2009 regulation, are together called the "pesticide package", adopted in 2009.

[2] Pesticides sellers, State programs also contribute to the funding of the Plan

[3]. Le 9th theme only appeared in 2011, to address workers' health issues.

[4] Hill & Mac Rae (1995) distinguish different strategies to change farming practices: efficiency, substitution of inputs, and re-design. Also some farmers adopt an efficiency or a substitution strategy, we chose to focus on the network which claim to support redesign processes.

had already developed new practices contributing to limited use of pesticides (Organic Farming associations, Sustainable and Autonomous Farming Network, among others). Representatives of the incumbent players argued however that such an objective would not be achievable and would make French Agriculture less competitive. Many controversies erupted on the targeted reduction, on the best practices to significantly decrease the use of pesticides, and even on the way to promote large-scale adoption of such practices.

While some experts pointed out that this redesigning would require changes in the supply chains, in the input providers' strategies and in the advisory work, such shifts were hardly taken into account in the Ecophyto Plan which mainly targeted changes at farm level. In fact, the DEPHY network was one of the major thrusts of the Plan in terms of ambition (190 groups of about 10 farmers to be involved in a national network, each group being supported by an advisor working half-time) and of funds allocated (around M€18 per year). A mid-term evaluation of the Ecophyto Plan pointed out poor achievement in terms of reduction of pesticide use at national level since 2008. A second plan, the Ecophyto Plan 2 (2015-2025), was launched in 2015 under the aegis of both the Ministry of Agriculture and the Ministry of Ecology. This plan still targets the farmers: the network is supposed to involve 3000 farmers and a new goal is settled to the Plan: it will be accountable for supporting upscaling of the best practices from the DEPHY farms to 30,000 farmers.

It is difficult to know the extent to which the lack of achievement of the first Plan should be attributed to a lack of consideration of systemic barriers. In this paper we chose to pay attention to another issue: how intermediation is organized in the Dephy Network. Various studies (Coquil, 2014; Chantre et al., 2015) have shown that transition pathways at farm level imply in-depth change in farmers' jobs and activity. How is such transformation supported within the network? How is the network organized to support up-scaling processes and such transformation outside of itself? More precisely, how does it support in-depth redesign of cropping systems and create opportunities for large-scale involvement of farmers in such a redesign process? To examine these questions, we developed a specific framework which we present in the next section. We apply it to the Dephy Network and briefly point out the differences that we found between this network and two other farmer-led networks, in the way scaling-up processes are organized. We then discuss its limits and the ways in which it can usefully support intermediation work in transitions towards a more sustainable agriculture.

A framework for analysing intermediation in sustainability transitions

Approaches to and studies of up-scaling processes have often considered them as a dissemination and adoption process (e.g. Rogers 1983). They have tended to focus mainly on the attributes of the technologies and adopters that determine adoption likelihood. Adoption thinking also pays attention to social networks and increasingly looks at how the configuration of social networks influences adoption behaviour (Compagnone, 2014). By contrast, innovation system scholars[5] working on sustainability transitions propose a more systemic approach and point out technological and organizational lock-in and/or system failures within a socio-technical system. Such approaches give a "big picture" of the processes that take place and suggest some relevant levers for policy makers. They often take as a starting point a new technology. They do not really consider the process by which the technology and its use in practice are co-developed at farm level (Béguin & Cerf, 2004; Klerkx et al. 2010; Béguin et al. 2012). But the reduction of pesticide use is rather a withdrawal of a technology. The cropping system redesign does not necessarily rest on new technologies. It rather rests on new insights on the ecological processes and on developing new practices in order to cope with their unpredictability and with the complex dynamics within the cropping system.

Nevertheless, these studies emphasize the role of brokers or intermediation workers (Klerkx & Leeuwis 2009) who create new links between a network of players and technological artefacts in order to stabilize a technological niche and to support scaling up and out processes (Hermans & al., 2013) or anchoring processes (Elzen & al., 2012). Following Meyer & Kearnes (2013), we consider that intermediation is a specific type of practice in processes of change. Intermediation not only creates

[5] Innovation systems studies is a research field grounded in STS and evolutionary economics. The multi-level perspective is a heuristic framework focusing on the interplay of niches, regime, and landscape in a transition process (see Geels & Schot 2010 for details).

links to overcome systemic barriers or to develop anchoring processes, it also contributes to shaping understandings, new practices and new interaction rules among participants involved in a process of change (Steyeart & al., 2007). We therefore chose to understand the ways in which intermediation is organized to support: (i) the co-evolution of the designed cropping systems and of the activity required to manage them; and (ii) the participation of more and more farmers or other stakeholders (experts and knowledge providers, farm implement manufacturers, input providers, supply chain actors, policy makers, researchers, etc.) in the design process[6] in which farmers re-create both the technology and their work activity. But how can we identify the key conditions to be created?

To answer this question, we built a framework which is grounded on existing results on intermediation found in work systems re-design studies (Barcellini et al., 2014) and in studies on participative and collective design in Online Epistemic Communities[7] (Detienne et al., 2012). According to these results we considered that intermediation means: (i) to identify or create a space in which discussions can take place among various stakeholders (where *who* is invited to join the discussion is key!), whether about the transformation intention or the data needed to analyse the work situations (farming systems) to be transformed; (ii) to support the test of innovative farming practices (implementation and analysis) in order to support the co-evolution of the artefact (the cropping system) and the farmer's activity; and (iii) to support the emergence of specific socio-cognitive roles that contribute to discussions about design and use of new cropping systems, and to proposals for rules and mechanisms that can create peripheral participation in a constantly on-going design process.

In our framework we therefore considered three intertwined levels of intermediation in the up-scaling process: a strategic one which is meant to grasp the way the transformative intention is set and discussed over time; an experiential one that addresses the way work activity is represented and supported so that farmers can participate in tests and simulation loops; and an interactive one that specifies the rules and roles which are at work to create inclusiveness and participation of various stakeholders in the design process. We now describe how we chose to acknowledge each level:

1. **Strategic level:** we identified the transformative intention which serves as a seed to the building of the network, and analysed how discussions are organized around it (Who takes part in it? Where does it take place? What makes it change over time?)
2. **Collaborative level**: we focused on the roles and rules that are built during the up-scaling process or created from scratch within the network in order to perform this process. We also paid attention to the way the collective production (whether it be knowledge or cropping systems) is capitalized on by participants, and to the way peripheral participation (inclusion of newcomers) is organized.
3. **Experiential level:** we paid attention to the way intermediation supports relations between design and use in the up-scaling process through the development of intermediary objects or tools (Vinck, 1999). We also identified the discussion spaces that were created to support design-use exchanges. More specifically, we analysed the way scientific knowledge and farmer's experience were translated and shaped in order to support the co-evolution of both the designed cropping systems and the ways of managing them. We also identified the way intermediary objects took on board a given representation of farmers' activity**.**

We applied this framework to various networks to identify how they differ in their way of supporting the up-scaling process while also supporting in-depth re-design of cropping systems that contribute to reducing pesticide use. Box 1 below gives a quick overview of the three networks. We develop a full analysis only of the DEPHY Ecophyto Network, but then point out the differences we found between three different networks.

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[6] The latter point has however not been adequately documented in our analysis and further data need to be collected in order to fully identify the way these players are interested or enrolled to support the shift in farming practices**.**

[7] e.g. communities involved in producing an Open Source Software or an encyclopedic article, for instance in Wikipedia.

Box 1: Three different networks supporting the re-design of cropping systems

The Dephy Ecophyto Network was initiated in 2010 and gradually (from 2010 to 2012) came to involve 190 groups of about 10 farmers. The initiator was the Ministry of Agriculture. The Network was devised as a new policy instrument to support farmers in redesigning their cropping systems in order to reach a 50% reduction of pesticide use. A common indicator, the frequency treatment indicator FTI was defined to measure the reduction. The organization of the network was created from scratch. More details can be found in the next section.

The BASE Network was initiated by a farmer who encouraged other farmers to explore farming practices with a view to restoring and enhancing biological dynamics in the soil (no tillage, direct sowing and conservation agriculture). The network was initiated in the 1990's and now involves about 2000 farmers. It is a loose organization which holds an annual assembly of the participants. A core team proposes some training sessions and expertise for the participants and supports a journal (TCS) and a website (Agricool). Local associations (farmer groups) can emerge but this is not encouraged by the core team even though it does not reject such associations. The reduction of pesticide use is controversial both within the network and outside (opponents are mainly other farmers or agronomists) as no tillage and direct sowing practices are often related to intensive use of glyphosate. The pros and cons of this are discussed mainly in the journal or on the website but also at local levels. Since 2006, participants have been invited to seek practices (mechanical destruction, covering crops, etc.) that target both the enhancement of soil biological dynamics and the reduction of pesticide use.

The RAD-CIVAM Network is part of a national organization that coordinates local associations of farmers who explore new farming systems mainly oriented towards a high level of decisional and technical autonomy (from input sellers and supply chain buyers). Each local association is supported by a facilitator and has to find its own financial support. Local groups as well as R&D projects can contribute to the funding of the national coordination. 0riginally the main driver for designing new farming systems was the quest for autonomy and economic efficiency but since 1994 attention was paid to pesticide use. In 2006, they address a document to the Ministry of Agriculture in which farmers stated their experiences in reducing pesticides use. The network was invited to take part to the round tables organized on the issue of pesticide reduction during the Grenelle de l'Environnement. In the follow-up of this involvement, the RAD-CIVAM chose to design cropping systems that could also meet certain environmental challenges (e.g. less use of pesticides and nitrogen, sustaining of functional biodiversity through landscape infrastructures). They chose to put this to discussion in two different arenas: within farmers' groups that were connected through a dedicated government-funded R&D project; and within the Ministry of Agriculture with the policy makers in charge of the agri-environmental measures (AEM) and more specifically of the ones called AEM "system". The starting point was the establishment of a list of requirements drawn up by farmers and their group facilitators during the R&D project. Facilitation tools were also developed during this phase and used later by other facilitators within the Dephy Network. The RAD-CIVAM encouraged some farmers' groups to participate in the latter network with the intention to upscale their own way of coping with the reduction of pesticide use. The RAD-CIVAM also proposed a new AEM "system"" which it viewed as a way to support farmers in developing less input-dependant and more environment-friendly cropping systems.

Intermediation to support up-scaling processes in the DEPHY Network

The DEPHY Network has three main arenas in which the transformative intention is discussed: the national strategic committee in which representatives of various farmers' associations, co-operatives, advisory and R&D organizations are invited to participate, along with representatives of the State and research organizations or environmental associations; the National Core Team (NCT) which defines the procedures (roles and rules, intermediary objects) to be developed within the network; and a third arena with looser boundaries, the farmers' group at local level which can develop interactions with other local farmers and stakeholders.

The collaboration is driven at national level. In 2010 a classical call for projects was launched, Applicants (farmer groups and their facilitators) were required to fill an application form in which details about the current cropping systems, the levers to reduce pesticides use and the targeted systems had

to be described. A scientific committee composed of experts designated by the Ministry of Agriculture assessed the proposals. After that, the strategic committee decided which groups to support financially[8]. Each farmer group then entered into a contract with the national board and had to commit: (i) to developing the testing phase (i.e. putting the proposal into practice), (ii) to feeding the national database, and (iii) to opening their farms to show their results. Such contracts were under the responsibility of the national core team which was also responsible for developing procedures, tools and knowledge to feed the network, to collect and analyse data, and to report annually to the Ministry of Agriculture and the strategic committee about the way the network intended to meet its target (Ecophyto 1: 50% reduction of pesticide use in 2018, Ecophyto 2: 50% reduction of pesticide use and reaching 30,000 farmers in 2025). In 2016, new contracts are being negotiated with the groups already involved, and newcomers are invited to submit their proposals following a new call (to expand the network from 2000 to 3000 farmers). From scratch, in 2010, specific roles were assigned to the group facilitators (NE) within the network: they have to support the design-implementation process in their group, to collect data to feed the data base, to communicate on the SCEP, and to organize farm visits. To this end, they have a 50% part-time job paid through a contract between their employer and the NCT. After two years, a specific role has emerged called territorial engineer (TE). Some NE and some of the NCT experts have become TE. All have a part-time contract between their employer and the NCT. Their role is to support the NE in facilitating design and implementation processes in their groups, and to check and aggregate the data collected in each group in order to feed the data base. They also discuss with the NCT how to analyse the data and, more generally, they discuss the shape and content of the mediation tools.

Five main tools are currently operational in the network and give some consistency to the experiential level of intermediation. Two of these are primarily dedicated to group facilitators (called network engineers NE) in order to support their interaction with farmer groups for designing and implementing new cropping systems: (i) the “STEPHY guide” which proposes a procedure to diagnose the current cropping system and to support its redesign in order to achieve a certain reduction of pesticide use; and (ii) the “Ishikawa graph” which enables a farmer to visualize the main levers to be activated for each crop in order to reach the target. Three other tools support interaction among all the participants within the network and with other audiences outside:

- A 4-page leaflet which is meant to disseminate information on “SCEP” (SCEP is an abbreviation for a cropping system which is seen as a good example for a 50% reduction of pesticide use). Such SCEP are sorted out statistically from the various cropping systems designed and implemented by farmers within the network. The expertise of NE can also be used to point out which cropping systems they consider to be SCEP;
- On-farm visits that NE have to organize to present what was achieved in the farm network, especially to farmers who are not yet engaged in reducing pesticide use;
- A national database on cropping systems tested in the network (data on crop sequence and crop management of each crop) can include data from experiments conducted on experimental plots or farms. Data are collected on-farm with a shared protocol and are accumulated in the data base. Statistical analysis is applied to identify the SCEPs. The database can also be used for research purposes.

Discussion: what lessons can be drawn?

As the scope of this paper does not allow us to make an in-depth comparison between the three networks that we studied, we would like here to point out some differences that the framework enables us to highlight. In doing so, we will also make some recommendations about the way intermediation can be organized to support re-design of cropping systems in order to reduce pesticide use, with an increasing number of farmers involved in the process.

[8] It combines scientific evaluation criteria and other criteria such as the types of cropping systems, in order to cover the diversity of criteria or the types of advisory organizations involved in supporting the farmers.

We first wish to acknowledge that the intermediation work is differently shaped in the networks. The DEPHY network was developed as a policy instrument to encourage farmers to commit to the Ecophyto Plan, and intermediation work is covered by massive public funding. The other two networks are made up of farmers who are willing to change their cropping systems according to a transformative intention they all share, and who have to seek funds in order to support the intermediation work. But such differences should not play down other issues that our framework enables us to point out.

The first issue is about the way the transformative intention is settled and the way discussions are organized around it. ***We suggest that volunteer farmers' participation can be increased if they share a common motive to change rather than just a quantified target to reach***. Targeting only the reduction of pesticide use does not clearly identify the motive for which a re-design of the cropping system is required (pesticides are only a means within a cropping system). Such motives are much clearer in the other two networks, and discussions within these networks are not about the transformative intention as such but about the means to achieve it. In the DEPHY network many discussions are about the target as such. For example, the NCT is an operational team but the experts who take part in it sometimes endorsed institutional positions[9] to discuss the legitimacy of the target while their role was to discuss the available means to reach it. At local level, the target was discussed less from an institutional point of view than in relation to the room to manoeuvre that existed at farm or supply chain levels (in terms of the required quality for international markets, for example in fruit production systems, in terms of crop diversification and work organization or available market opportunities in arable cropping systems, etc.). As a result, the participants of the DEPHY network share neither a transformative intention nor the means to achieve it.

The second issue is about the way intermediation supports the experiential level. ***We suggest that the development of intermediary objects and experiential spaces needs to support both constructive and productive dimensions of farming activity*.** Constructive refers here to the farmers' ability to explore new ideas and new practices and to be engaged in re-design processes and through trial and error a new cropping system. Productive refers to the way farmers manage the cropping system efficiently in order to reach their productive goals (yield, quality of work, etc.). In the BASE network the intention is clearly to support the constructive dimension. This is achieved by giving a lot of space, in the TCS journal and on the website, to farmers' narratives about successes and failures in experiencing new cropping practices and systems. The core team also creates "experiential platforms" so that farmers can share their experiences regarding a given new practice and assess it jointly (but without necessarily sharing a common experimental protocol). In the RAD-CIVAM network we noticed that they develop tools which can support both productive and constructive dimensions. While farmer' narratives and experiential platforms are key ways to support the constructive dimension, tools are also built to support facilitators in collecting data on such experiences and in supporting the monitoring of the change process in the cropping system. In both cases such tools not only target the farmers already taking part in the network, but are also built to involve newcomers. In the RAD-CIVAM network the development of a AEM "system" was also seen as a means to support farmers in joining the network. This type of tool can however obscure the motive which initially drives the farmers who developed such an AEM and cannot sufficiently support the constructive dimension of the activity: the list of requirements in the AEM "system" mainly defines means or thresholds to commit to, and does not mention all the experiences and the monitoring that enable the farmers to develop new cropping systems in line with these requirements. The same can be said about the SCEP in the DEPHY Network. Moreover, in this network the tools developed are mainly based on available agronomic knowledge. Finally, they give little room to farmers' experiences and the way the constructive and productive dimensions of their farming activity were developed during the re-design process. In fact, in most of the intermediary tools developed in the Dephy Network (except perhaps for

[9] The core team is composed of various crop production experts who mainly belong to technical institutes, cooperatives, and Chambers of Agriculture, i.e. incumbent players whose leaders often contest the targeted objective. In order to limit political discussions on the target and to focus the debates on the knowledge uncertainties or on the facilitation and data-base tools to be developed, the Ministry of Agriculture took the lead after an initial period during which it delegated it to the National Assembly of the Chambers of Agriculture (NACA). Nevertheless, as the leader of the team is hired by the State, he works within the NACA which still has responsibility to develop the network.

the on-farm visit), farmers' activity was represented mainly through a management scheme rather than as a constructive and productive process in which the farmers experienced new ways of coping with the uncertain system dynamics.

Last but not least, the third issue is about farmer's participation within the networks. ***We suggest that collaborative roles should also be taken on by farmers who are experimenting with a new cropping system. Farmers should contribute to shaping the intermediary tools as these are crucial in supporting the co-development of the cropping system and of their activity. We also suggest that new participants need to be enabled to develop both constructive and productive dimensions of their activity while redesigning their cropping systems*.** In the BASE network, the collaborative level is organized by the core team (mainly farmers) to let other participants (mainly farmers) take different roles or to be recognized by the other participants as assuming such roles (experts, boundary spanners between the network and other ones, project leader for promoting a new experiential platform, etc.). Farmers can take part in defining the transformative intention, proposing new practices, testing and implementing them, sharing experiences and building shared designing principles. In the RAD-CIVAM network, the collaboration takes place within a public funded project in which farmers have a key role in defining the brief of requirements, in designing and implementing new cropping systems that comply with the brief of requirements, and in contributing to a reassessment of the practices and thresholds indicated in the brief. But facilitators also have a key role in collecting and analysing data that can support this assessment process and can be used to plead with the Ministry of Agriculture for a AEM "system". The collaboration is organized at project level: the project core team draft a contract and the farmers and the facilitators involved in the project have roles assigned in the design process. The way to support the inclusiveness of newcomers is subject to discussions within the network mainly to identify which intermediary tools (such as an AEM "system" but also videos, on-farm visits, facilitation toolkit, etc.) could support the re-design process for these newcomers. The DEPHY network does not really give farmers much latitude in the way collaboration is organized. For example, during the inclusion-selection process no attention is paid to the way farmers participate in the design of the proposal[10]. Although farmers' group discussions are encouraged to support farmers in their transition pathways towards less pesticide use in their cropping systems, they have no real influence on the way data are collected and analysed within the network in order to produce useful knowledge either for themselves or for newcomers. While they have discussions within their own group about how to implement their new cropping systems, few opportunities are given to groups to meet together, even if there is room for the NE or TE to organize such meetings. Formal roles are assigned to the NE, TE and NCT, but our analysis shows that these roles are assumed differently. More informal roles have emerged, mainly for two purposes: the first is to involve more farmers and other stakeholders locally in discussions about the targeted objective and the means to reach it; the second is to open discussions on the advisory practices that can support on-farm design and implementation of new cropping systems. Finally, such informal roles try to take on board ways of involving newcomers in an open and inclusive process rather than just by SCEP production or on-farm visits. But inclusiveness might have been hindered by the fact that in this network the participants receive funds as soon as they are considered as part of the network (indirectly, whether by funding advice for farmers or by funding the advisory and expert organizations for the other network participants), and the total amount of funds do not allow for the network to expand.

Conclusion

The framework we developed looks at intermediation in sustainability transitions mainly through its ability to support large-scale transformation of cropping practices at farm level. It points to the need to take on board the normative dimension underlying re-design processes (strategic level), the productive and constructive dimensions of the activity developed to re-design and implement new cropping

[10] Most of the proposals were directly written by the advisor with little participation of farmers at this stage of the process. As recommended in the call, the proposals included a diagnosis of each farm's situation at the beginning of the process, and some levers to be combined for achieving a given level of reduction. But most of the time the way farmers participate in the choice of these levers, their analysis of the way they could change their practices and the meaning they gave to change was not addressed in the proposal. Inclusion was therefore based mainly on an evaluation by the scientific committee experts of the credibility of what was written on the proposal regarding the proposed targets and their consistency with the proposed levers and time schedule.

systems (experiential level) and the interactive dimension thereof (collaborative level). By contrasting different networks involved in such intermediation processes, some key attributes for organizing an effective intermediation were established. None of the networks really combine all the attributes we identified.

Our recommendations need to be strengthened by testing them within existing networks if possible. The way we analysed intermediation did not however pay attention to the way it addresses some of the lock-in processes that various studies have pointed out (Cowan and Gunby 1996 for the United States; Vanloqueren and Baret 2009 for Belgium; Lamine 2011 or Fares et al. 2012 for France). We did not identify intermediation work directed towards supply chain actors who are concerned by the potential reduction not only of pesticide sales, but also of production levels, and who are key actors for the development of new crops (for which they do not have markets and conservation silos), or of cultivar mixtures or intercrops (which are used as an efficient lever to reduce pesticide use). Even the Ecophyto Plan which has the largest spectrum of actions does not really address this. As well we did not identify the intermediation work directed towards the exploration of collective solutions (for example by designing collective agro-ecological infrastructures and by organizing crops among farmers). Indeed, the networks we studied address change mainly at an individual level. A question is then how they might adopt a broader approach such as this, and how it might challenge their way of organizing farmers' participation in the whole change process.

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