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Sociotechnical inquiry approach for innovation in agronomy

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Abstract: Increasing food production and its sustainability is a crucial need due to population growth and environmental concerns. The application of agroecological principles enables to build innovative cropping systems, but their adoption remains limited. Agroecological transition involves complex, multi-dimensional challenges at various levels, from farming to agrifood systems. So far, sociotechnical analyses were conducted to understand historical lock-ins in agriculture, but without giving strong attention on the interactions between farmers and other actors. Based on both farming system research and sociotechnical system studies, and on 4 previously published case studies, the article proposes a new approach called “sociotechnical inquiry approach” (STIA) based on a 5-step methodology. The STIA explicitly considers how agrifood system actors influence farmers’ decisions, and aim at identifying barriers and levers for agroecological transitions at territorial and value-chain scales. A cross-cutting analysis of the 4 case studies show that such an approach is likely to initiate multi-actor innovation processes that transform not only farmers' practices, but also those of a diversity of actors in the agrifood system. Its outputs are thus useful for designing coupled innovations, combining technological, organizational and institutional changes that are usually carried out independently by different actors.

Keywords: sociotechnical analysis, method, innovation, agrifood systems, agronomy, design

1. Context and Purpose

Food production must change to meet the needs of a growing population whilst minimizing impacts on the environment, calling for sustainable agriculture (Tilman et al., 2011). The application of agroecology principles makes it possible to limit the negative externalities of agricultural systems by promoting biological processes, and so reduce chemical inputs. Even if some agroecological practices are proven to be efficient, their application by farmers remains too scarce, as well as their promotion by value chains. Indeed, changes in farmers' practices would require change in agricultural production systems but also reorganizing food systems at territory and value-chain level, to embrace the wholeness and connectivity of systems and scales (Gliessman, 2016). Agroecological transition is therefore a complex problem (Schut et al., 2015) involving multiple levels of agrifood systems (primary production, food distribution and household consumption) and multiple actors, from the value chains and/or territories (Cholez and Magrini, 2023; Pachoud et al., 2022). Researchers supporting these transitions engage with actors in long-term innovation processes, seen as co-evolutionary processes that combine technological, social, economic and institutional changes (Klerkx et al., 2012). The challenge is to consider the interdependencies between agrifood actors at territorial scale (including farmers) in order to (i) understand the conditions for the development of innovations in agrifood systems and (ii) contribute to their design, jointly with agrifood actors.

Past work has extensively applied the Multi-Level Perspective framework (Geels, 2004) to the analysis of technological transitions towards sustainable systems in agriculture (El Bilali, 2019; Elsner et al., 2023). Such studies, from a historical perspective, highlight the current lock-ins limiting sustainable transition, and show that the study of sociotechnical systems, and their interactions with actors and rules, is potentially a major cognitive resource for identifying the barriers to agricultural innovation. Some recent studies carried out by agronomists explicitly link sociotechnical analysis of agrifood systems to cropping, farming and agrifood systems design (Boulestreau et al., 2021, 2023; della Rossa et al., 2020; Della Rossa et al., 2022; Meynard et al., 2017). Indeed, an agronomist seeking to design innovations at plot and farm level has to widen his angle of view, by considering the level of the sociotechnical system and the interdependency between agrifood system actors in agricultural territories. Such analyses are not, however, part of the agronomist's classic know-how. Moreover, the methodological approach in sociotechnical analysis studies is poorly described, limiting its application to other case studies. In this article, we aim to provide agronomists with a methodology based on sociotechnical analyses and encompassing the scale of farming systems, in order to help them innovate further and better with the diversity of agrifood system actors. We propose an original 5-step approach, called "sociotechnical inquiry approach" (STIA), and inspired by 4 published sociotechnical analyses relative to the agricultural and agrifood sector. We show that such an approach has been used to identify the barriers and levers of change at the scale of the territory and/or value chain in which the farming system operates, in order to initiate and steer an agroecological innovation process in agrifood systems.

2. Approach

2.1. A theoretical framework at the crossroads of farming system research and sociotechnical studies

Farming system research (FSR) initially focused on developing and testing innovative sustainable farming systems. However, the adoption of such systems does not depend only on their performance but also on farmers' practices and their drivers (Giller et al., 2015). This led agronomists to redesign cropping and livestock systems tailored to farms' specificities. Moreover, farmers' innovation not only depend on internal factors, but also on external factors such as market dynamics, knowledge access, or institutional support. So, farmers' technical innovations often depend on practices of other agrifood system actors (Wigboldus et al., 2016).

Sociotechnical system studies offer a promising conceptual framework to move from a farmer-centered approach to an agrifood system-wide approach, since it considers farmers as part of larger actors' network that jointly impact agrifood system transitions. According to Geels (2004) sociotechnical systems (STS) are linkages between elements (*i.e.* resources such as artefacts, knowledge or labour) necessary to fulfil societal functions (e.g. agricultural production and consumption). STS shape the context, the rules, and social norms for actors' actions and vice versa. In some cases, different actors form networks with strong interdependencies, because they share values, knowledge, organizations and technologies. This coordination between groups of actors can thus create self-reinforcing mechanisms in technology choices. It creates strong inertia to change and by excluding alternative technologies that could be better for society, it creates lock-in situation (Arthur, 1989). In agrifood systems, technologies are combination of agricultural techniques and/or of processing techniques that achieve an objective, with the material conditions and know-how that make them possible.

We assume that describing and analyzing the interrelations between STS (resources, material aspects), actors (involved in maintaining and changing the system), and rules (which guide actor's perceptions and activities) lead to a deep understanding of the drivers of change of agrifood systems actors, including farmers. On the other hand, FSR helps to characterize in detail technologies, their underlying agricultural techniques, and the drivers of their implementation in farms. Combining both approaches is thus promising to understand the conditions for the development of innovations in agrifood systems and further design multi-actor innovations at the agrifood systems level.

2.2. Methodological approach

Based on the analysis of 4 previously published case studies (Tab. 1) that carried out a socio-technical analysis of agrifood systems, we provided two types of results: (i) a generic socio-technical inquiry approach (STIA), relying both on FSR and STS approaches, that gives methodological guidelines to decipher the complex systemic phenomena that frame agrifood innovation process and (ii) a cross-case analysis of the outputs of the case studies to show how such sociotechnical analysis lead to the identification of barriers and levers to sustainable innovations in agrifood systems.

Table 1 - Description of the case studies (problem under study, inquiry scope -geographical area and studied value-chain(s)), and references.

Case study denomination	Problem under study	Geographical area	Studied value-chains	References
1. Diversification in France	Development of minor crops to improve crop diversification	France	Arable crops	Meynard et al. (2017, 2018)
2. Corsican Clementine	Maintaining the typical characteristics of Corsican clementine	Corsica	Clementine orchards	Belmin et al., (2018a, b)
3. Watershed in Martinique	Reduction of herbicide use in weed management	Galion watershed in Martinique	Sugar cane, banana, market gardening	Della Rossa et al. (2022, 2020)
4. Vegetables in Provence	Soil pest management in sheltered vegetable systems	Provence	sheltered market-gardening	Boulestreau et al., (2023, 2021)

The 4 case studies (Tab. 1) shared common features: (i) they analyze the interactions between STS, actors, and rules, (ii) they study drivers of practices of farmers and other agrifood system actors and (iii) they identify barriers and levers to sustainable agrifood transitions. In order to propose a generic approach, we have chosen contrasting case studies with regard to the problems under study and the inquiry scope (Table 11). The case studies concern innovation processes at the level of agrifood systems; they differ in the scale of the territories concerned and the complexity of the value chains

involved (Tab 1). By comparing and analyzing those approaches, we came up with a generic proposal that grasps the different methods and tools that are useful for identifying barriers and levers to sustainable innovations in agrifood systems and contribute to a further innovation process. The 5 steps emerged as a coherent organization reflecting both the different case studies and the literature.

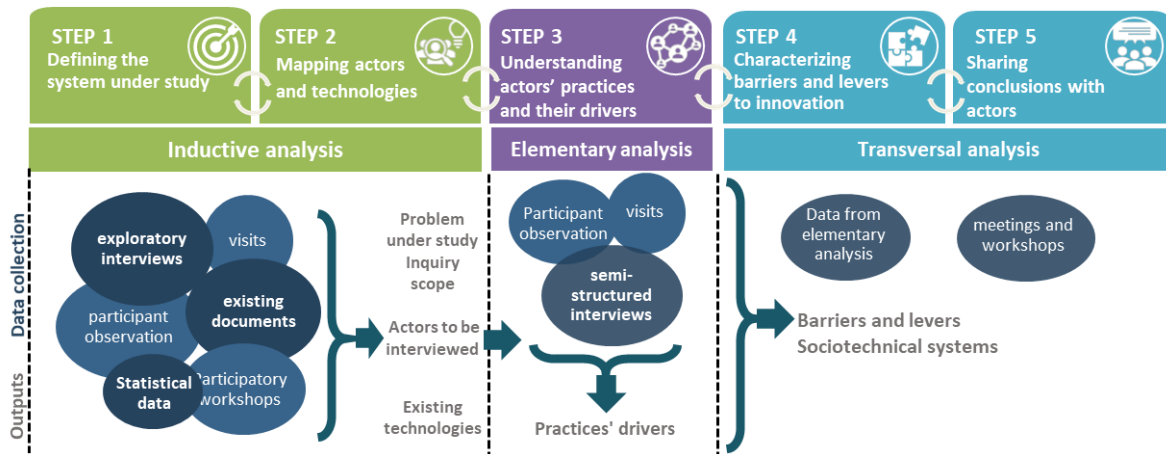
We also cross-analyzed the results of the 4 case studies, iterating between the in-depth analysis of each case study and the comparison with the other case studies. We paid particular attention to (i) the identified STS, (ii) the highlighted lock-ins, (iii) the identified barriers and levers to innovation process and (iv) the contribution of the inquiry approach to the overall innovation process towards sustainable transition.

3. Findings

3.1. The Sociotechnical Inquiry Approach (STIA)

We proposed a sociotechnical inquiry approach (STIA) whose key feature is to characterize the practices, strategies and networks of actors involved in innovation processes, and reveal how the sociotechnical system(s) shape those processes. The STIA is based on 5 steps (Fig. 1): (i) Delimiting the system under study and the inquiry scope (problem under study, concerned territory and value-chain(s)), (ii) Mapping the actors and existing technologies involved in solving the problem or locking it (iii) Understanding the drivers of actors' practices in relation to existing technologies (iv) Characterizing the barriers and levers to the innovation process and (v) Sharing the results with actors.

Figure 1 - Sociotechnical inquiry approach (STIA). The approach is divided in 3 analysis stages (inductive, elementary and transversal analysis) that provide intermediary or final outputs (in brown). It relies on a diversity of data collection methods (in blue).



The first two steps are an immersion phase relying on exploratory interviews with key actors and the collection of existing data (e.g. reports, statistics). The third step is an in-depth elementary analysis, based on semi-structured interviews with agrifood systems actors (including farmers), that aims at characterizing five types of elements related to STS: (1) the previously selected actors and all the drivers that guide their practices, (2) their relationships with other actors (e.g. flows of information, commercial partnerships, alliances or conflicts), (3) the formal and informal rules they follow (regulatory, normative or cognitive rules (Geels, 2004)), (4) the knowledge and (5) technologies they use. The interviews, strongly influenced by FSR methods, aim at characterizing actors' practices, and the driving forces behind practices, including the relationships with other actors that influence them. The last two steps lead to the analysis of the sociotechnical systems and their interactions with actors and rules, mainly based on previously collected data. Step 4 enables to identify barriers and levers to innovation around the problem under study. The objective of the fifth step is not only to present the

conclusions, but also to discuss and revise them if necessary, according to the actors' point of view. The five steps follow a chronological logic. However, the inductive nature of the approach and the complexity of the multiple interactions of STS and actors' networks might imply feedback loops between steps. The STIA, its steps, the data to be collected, the tools and methods of analysis are described in detail in a methodological guide published in French (Casagrande et al., 2023).

3.2. Outputs of the STIA

All case studies identified a dominant STS -i.e. a stable network of actors that favors the development and maintenance of technologies- that results in specialized cropping and farming systems and/or the maintenance of unsustainable technologies (e.g. intensive use of pesticides). Except in case 3, niches- i.e. sociotechnical systems that develop their own dynamics around alternative technologies, diverging from the dominant STS- were identified in each case studies. In addition, the 4 case studies showed one or more lock-ins, that could be intertwined, around specialization in major crops (cases 1 and 4), restrictive crop quality standards (case 2 and 4) and pesticide use (case 3 and 4). Highlighting the lock-ins helped to identify (i) factors that favor the current dominant STS, (ii) barriers to the development of alternative technologies and (iii) how STS, actors and rules interactions shape innovation process. The 4 case studies revealed barriers to the innovation process at different levels (field, farm, value-chain and/or territory). Each of the 4 case studies also identified some levers to overcome the mentioned barriers such as coordinating farmers or actors.

3.3. Contribution of the STIA to the overall innovation process

The STIA outputs helped initiating a multi-actor design process as they contributed to support: (i) the group of actors that will participate in the design process (i.e. forming and managing the group that implement design activities) and (ii) design activities themselves (e.g. understanding of the situation, formulating a design target, exploring and evaluating solutions).

Step 2, 3 and 5 contributed to foster group activities. Indeed, step 2 (mapping actors and technologies) provided a first overview of actors that might be enrolled in design activities (all cases). Step 3 (understanding actors' practices and their drivers) gave information on the current room for maneuver of actors to innovate, which was a selection criterion to choose the key actors for exploring innovative solutions (cases 1, 3, 4). Step 5 (sharing the results of the STIA) was an opportunity to share knowledge among the whole set of involved actors (case 2, 4).

The STIA contributed to further design activities through a better understanding of the situation in each case study, because it provided an analysis of the elements that shape the innovation process. The exploration of solutions was supported by the identification of: (i) existing technologies and/or niches that might contribute to address the problem (step 2, cases 1 and 4), (ii) barriers to be overcome (step 4, all cases) and (iii) existing levers (step 4, cases 1, 3 and 4). Sharing STIA conclusions with the actors (step 5) was an opportunity to discuss and nuance findings, but also to commit actors in future design activities (case 4). In case 3 and 4, serious games, based on data and analysis from the STIA, were developed and used during participatory workshops to facilitate the agrifood actors' understanding of linkages across levels (field, farm, value-chain and territory) and help them find some leeway to unlock the system. The STIA was thought as a preliminary step before designing innovations: respectively innovations across scales (field, farm, territory) (case 3) or coupled innovations (case 1, 4). In case 4, the STIA outputs, embedded within a serious game, led to the design of coupled innovation prototypes that were further refined during additional participatory workshops.

4. Practical and theoretical implications

The diversity of case studies revealed invariants: considering a diversity of actors to understand the problem to solve, identification of dominant sociotechnical systems, and some niches,

characterization of barriers and levers to change. These invariants between the case studies are linked to the highly systemic dimension of the agroecological transition. However, some steps were more important in some cases than in others, depending on the way STIA outputs were used in the research process. This suggests that the inquiry approach is flexible, adaptable and robust. Methodological challenges during implementation included tensions in discussing sensitive topics like pesticide use reduction. The non-normative, inductive nature of the approach could destabilize the researchers conducting the inquiry. The application of STIA might benefit from interdisciplinary collaboration, that could be developed further, especially with social sciences (e.g. to better consider power asymmetries between actors). STIA offers the opportunity to agronomists to enlarge their capacity of supporting innovation processes, by studying how technical innovations are either hampered or supported depending on the inter-relations between farms and other actors of the agrifood systems, and identifying the actors to be involved in future innovation workshops. The STIA outputs could be a first step to fuel the further design of “coupled innovations” (Meynard et al., 2017), i.e. combinations of genetic, agronomic, technological, and organizational innovations that are usually carried out independently by different actors (as it was done in case 4).

In conclusion, STIA results from the combination of FSR and STS approaches and brings together different tools to help agronomists understanding the way sociotechnical systems promote or hinder innovation processes. The main results are the identification of one or more sociotechnical systems concerned by the complex problem under study, and their interrelationships. The approach leads to understand the lock-in mechanisms that prevent changes expected by society. The approach is currently being applied to a larger number of cases, which will make it possible to: (i) verify the relevance and genericity of the approach and overcome methodological difficulties, (ii) analyze the extent to which it has contributed to the exploration of innovations, particularly coupled innovations, and (iii) improve the approach with contributions from other disciplines as part of interdisciplinary research.

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