From the obstacles of specialisation to the opportunities of diversification for a pesticide-free region

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The Saffré area is a 5,800 ha drinking water catchment. Its stakeholders are committed to pesticide-free farming by 2040. A research project has been undertaken to contribute to this objective. It has highlighted not only the territory's strengths – a large proportion of grassland areas and farms are already using organic farming methods – but also the threats it is facing. Grassland areas are declining in favour of crops that consume more pesticides, and the cyclical downturn in demand for organic products is slowing down conversions. To break free from the limitations of long and specialized value chains, some farms are innovating by diversifying their outlets through direct sales, or by diversifying their production by developing crop-livestock complementarities. These innovations will be valuable in helping to achieving a pesticide-free territory by 2040.

Keywords: socio-technical system, value chain, milk, organic farming, lock-in, innovation

1. Introduction

The use of pesticides has been one of the pillars of agricultural intensification. In Europe, this use grew rapidly in the second half of the 20th century, before becoming a major source of social concern, not least because of pesticides' proven negative impact on the environment and human health. A large proportion of aquatic environments, both surface water and groundwater, are increasingly contaminated (Joassard et al., 2020). Since the 1990s, European and national public policies have sought to limit the impact of pesticides by encouraging the de-intensification of agriculture, but to no real avail (Jacquet and Jouan, 2022). The Ecophyto plan, launched in France in 2008, aimed to halve the use of pesticides within 10 years, yet 15 years after its launch, the expected results have not been achieved; use has increased or, at best, stagnated. This difficulty in reducing the use of pesticides can be explained primarily by the specialisation of production systems, which began in the 20th century and has led to increased pressure from pests and weeds (Guichard et al., 2017, Hossard et al., 2017, Ministère de la Transition Écologique et de la Cohésion des Territoires, 2024).

Drinking water catchment areas (AACs), i.e. all areas where water infiltrates to supply a drinking water catchment, are particularly concerned, as drinking water standards require compliance with a regulatory concentration threshold of 0.1 µg.l^{-1} per molecule and 0.5 µg.l^{-1} for the total of all molecules. The Grenelle Environment Forum in 2007, followed by the Environmental Conference in 2013, designated 1,000 "priority" water catchments among those most threatened by diffuse pollution, with the obligation to implement a water resource protection programme. Despite this, at least one molecule is detected at 90%

of water quality monitoring points in France, and the concentration exceeds the potability threshold in almost two-thirds of cases (OFB, 2023). Drinking water resources are threatened by pesticides or their metabolites in one-third of the country (Descrozaille and Potier, 2023).

The Saffré catchment, in Loire-Atlantique, is one of the drinking water catchments classified as a priority in 2008, under the Grenelle Environment Forum. It is managed by the Atlantic'eau water syndicate and supplies water to around 45,000 people. Pesticide residues have been detected in the water, particularly from agricultural sources. To improve this situation, in 2016 the elected members of Atlantic'eau adopted a motion aimed at "no longer detecting pesticides in the water collected in Saffré". This motion was the starting point for a consultation process that culminated in 2021 in the signing of a charter entitled "Bassin de Saffré, tous innEAUv'acteurs". This charter, co-signed by the local authorities in the basin, the Chamber of Agriculture and a local farmers' association, sets the objective of moving towards pesticide-free famring in the basin by 2040.

This mixed farming crop-livestock area is typical of the west of France: on 8,300 hectares, 5,800 hectares of Utilised Agricultural Area (UAA) are farmed by 105 farms, more than nine tenths of which have a livestock production unit. Dairy cattle predominate, with meadows accounting for more than half of the UAA. Meadows, maize and wheat together account for more than 90% of the UAA. As in the rest of the department, a quarter of the farms (20% of the UAA) are certified in Organic Farming (AB).

Starting in 2021, an action-research approach, deployed as part of the BeCreative research project bringing together scientists and local stakeholders, has been launched in the Saffré basin to help achieve the ambitious objectives of the charter. In view of the large number of farms already using organic farming methods in the area, we hypothesised that the obstacles to pesticide-free farming are essentially socio-technical rather than purely technical, similar to the obstacles to crop diversification described by Meynard et al (2018). Arable farming systems in France have gradually become simpler and specialised in the production of a limited number of crops: soft wheat, maize, barley, oilseed rape, etc. This specialisation of production systems has been accompanied by Research and Development efforts focused on these crops, and a specialisation of the sectors guaranteeing their commercial value. This coordinated development of farms and the upstream and downstream players with whom they form a system is now a barrier to crop diversification. The availability of varieties and other inputs is limited for minor crops due to limited research efforts, agricultural advisors lack references to support producers and value chains offer limited or non-existent outlets (Meynard et al., 2018).

Similarly, achieving the goal of a pesticide-free region by 2040 does not simply mean spreading the practices of organic farms to all the other farms in the region. It means first and foremost understanding why these other farms use pesticides, which in part relates to their interactions with other stakeholders – particularly those in the sectors in which they operate –, and the opportunities these stakeholders offer to enhance the value of produce from pesticide-free farming. The Multi Level Perspective is a theoretical framework can facilitate an understanding of the functioning of stakeholder systems. A socio-technical system corresponds to a stable network of stakeholders, their practices, their knowledge, the technologies they use, their collective representations, and the standards and rules they set for themselves (Rip and Kemp 1998). It is shaped by the innovations that have spread through it, and selectively supports the practices and artefacts that are consistent with its functioning. According to the principle of increasing returns to adoption, the more a technology is adopted by a large number of players, the more attractive and effective it becomes (network and learning effects, economies of scale, collective representations, synergies with other technologies; Casagrande et al., 2023). An understanding of the socio-technical systems in the Saffré basin therefore appeared to be a prerequisite for multi-stakeholder coordination work, which would make it possible to achieve the objective of a pesticide-free region.

2. The approach implemented

Three approaches were combined to provide input for the design phase of technical or organisational innovations that would allow the move towards pesticide-free farming in the Saffré catchment area (Figure 1). First, the future of the area without pesticides was sketched out using the Co-click'eau approach (Chantre et al., 2016), to specify the problem to be solved in the Saffré catchment area. An innovation track (Salembier et al., 2021) was then carried out to identify existing innovations (inside and outside the area) that could help to solve the problem. Finally, a socio-technical diagnosis (Casagrande et al., 2023) was performed to reveal the stakeholder systems affected by the problem, and perceptions these stakeholders have of the innovations identified by the innovation track. This combination of three approaches led to the formulation of design targets aimed at the various socio-technical systems highlighted, each of which will be the subject of design workshops starting in the winter of 2024.

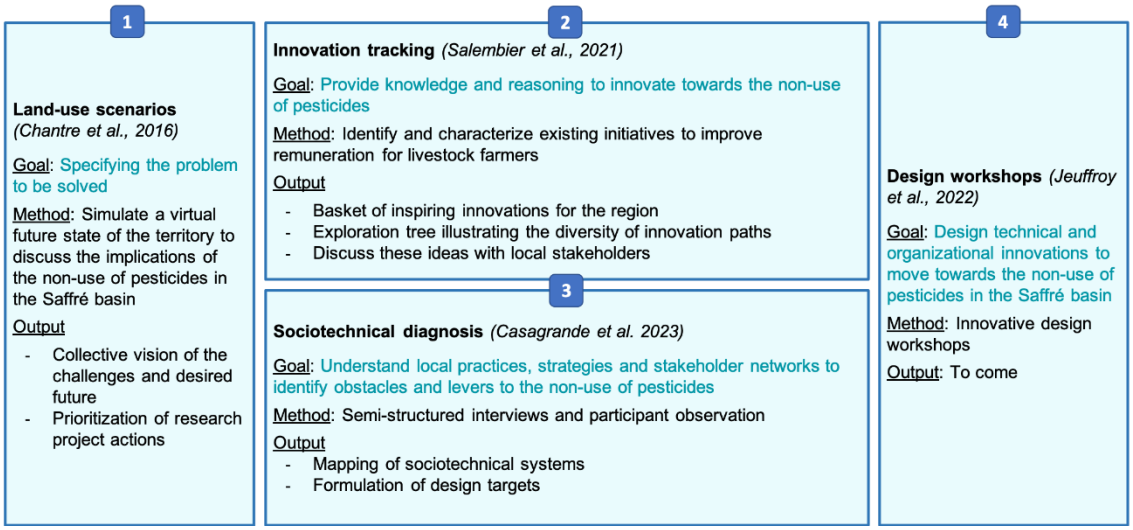

Figure 1: Overview of the combination of approaches implemented in the Saffré basin

3. Specify the problem to be solved on the basis of scenarios

Reducing the use of pesticides requires a wide range of local stakeholders to innovate in a variety of areas, in line with their activities. In the participatory spirit of the "Tous innEAUv'acteurs" charter, two workshops, bringing together eleven participants, were offered to farmers from the basin. The aim was to work together to define the problem to be solved, based on a simulation of prospective scenarios, using the Co-click'eau approach (Chantre et al., 2016).

The first workshop, held in December 2021, aimed to describe trends in agricultural development in the region, either observed in the recent past or anticipated in the near future, based on the participants' expertise.

Following this initial workshop, the research team translated the anticipated trends into a scenario for changes in land use and farming practices in the Saffré basin up to 2040. A trend towards a decline in livestock farming has been reflected by projecting, for the Saffré catchment area, a 2% reduction in grassland areas observed over the last five years (from 2015 to 2019) in the bocage Angevin agricultural region that encompasses the area, based on data from the French Land Percel Identification System (RPG - Géoservices, 2023). Progress towards the objective of no pesticides use, set out in the "all innEAUv'actors" charter has been reflected by projecting the 10% annual increase in organic farming areas observed over the same period for the département as a whole(Agence Bio, 2021). This scenario

results in a reduction in the share of currently dominant crops (grassland, maize and wheat) in favour of crops frequently found in organic farming systems (particularly cereal-legume intercrops and alfalfa).

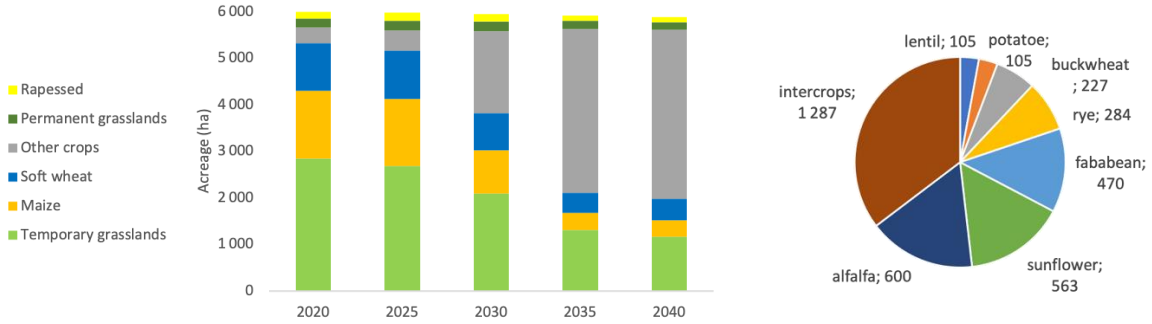

Figure 2: Trend scenario for land use change in the Saffré basin and details of the "Other crops" category for the year 2040

In addition to the use of pesticides, the performances of this scenario has been characterised by a range of indicators: nitrogen balance, greenhouse gas emissions, milk and meat production, stocking rates per hectare, self-sufficiency in total nitrogen and in fodder units for livestock systems, workload and profitability. The non-use of pesticides is achieved by 2035, but at the cost of a loss in profitability of around 15% on average across the region. However, this result conceals considerable variability, depending on the technical orientation of the farms. Profitability remains stable for farms that continue with livestock farming, while it falls by more than 25% for farms that specialise in the production of cash crops. This result illustrates the difficulty of doing without pesticides in cropping systems without grassland or manure, and in systems where the price premium for organic products does not compensate for the yield loss due to reduced weed control and lower nitrogen availability.

This scenario was not intended to be predictive in any way, but rather to provide a virtual future state of the area so that the implications of the non-use of pesticides in the Saffré catchment area could be discussed, with a view to guiding and prioritising the subsequent actions of the research project. On the basis of the simulation results, a second workshop was organised and participants were asked to express their views on how the project could contribute to achieving the objectives of the "all innEAUv'actors" charter. The simulation results highlighted one of the region's strengths in terms of moving towards the pesticide-free farming: the high proportion of grasslands in the farmland. However, this asset is threatened by a trend towards the decline of livestock farming, which has been underway for several years. This observation, discussed during the second workshop, can be approached from two angles: how can this trend be halted? Or how can we deal with this unfavourable trend? The research team gave the participants a list of questions based on these two approaches, with the opportunity during the workshop to add other questions to it. Participants were asked to mark with blue stickers the questions that should be given priority in the research project, and with green stickers the questions that should not be given priority because they had already been addressed elsewhere (Figure 3).

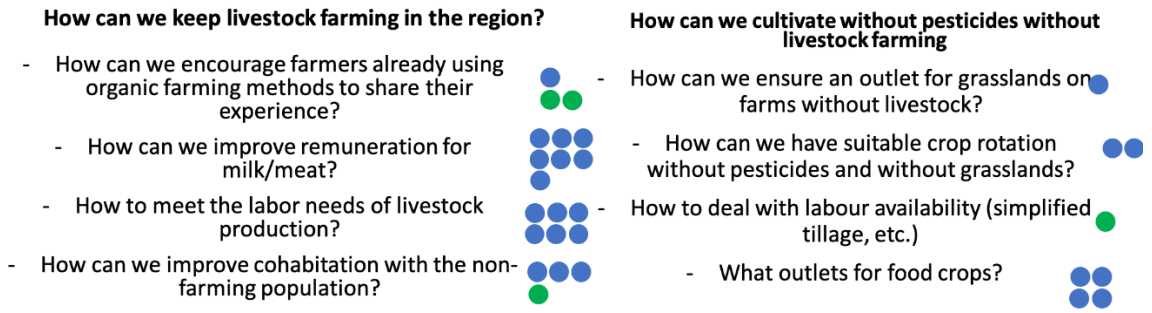

Figure 3: Saffré basin farmers' prioritisation of the issues to be addressed by the research project, to contribute to the objectives of the "all innEAUv'actors" charter (blue stickers: issues identified as priorities; green stickers: issues identified as already addressed elsewhere)

Following this vote and subsequent discussions, strong priority was given to actions likely to encourage the maintenance of livestock farming. A strong attachment to livestock farming, an integral part of the region's identity, was expressed. The source of the problem was felt to be the unsatisfactory remuneration received for the products produced, which would make it difficult to take over farms when farmers retired. As a result, the remaining farms are expanding, developing the production of cash crops to the detriment of grassland. The problem to be solved in order to achieve the objectives of the "all innEAUv'actors" charter has therefore been reformulated as follows: "How can we do without pesticides in the Saffré basin, while maintaining grasslands through better remuneration for farmers?

4. Understanding the determinants of stakeholder practices through interviews

In order to understand how socio-technical systems impact or even block the implementation of innovations, and to identify the stakeholders to involve to support innovation, it seems necessary to gain a better understanding of the stakeholders concerned by the problem to be solved, their practices, and the way in which they interact in networks (Casagrande et al., 2023, Meynard et al., 2018).

In our study a first series of exploratory interviews was therefore conducted with professional agricultural organisations operating in the area: the Chamber of Agriculture, the organic farmers interest group (GAB) and the centres for initiatives to promote agriculture and the rural environment (CIVAM). The aim of these interviews was to identify the stakeholders concerned by the problem to be solved, so that they could be contacted for a second series of in-depth semi-structured interviews. Around twenty organisations were identified and contacted, including those involved in plant health sales and advice, downstream players in the dairy and meat sectors, and distributors (Table 1 and Figure 5). It should be noted that farmers in the area were not approached for interviews, even though they were stakeholders in the problem to be solved. Atlantic'eau had in fact identified that they were over-solicited, and participant observation at events attended by farmers was a preferred way to complete the understanding of this group of stakeholders gained from the scenario workshops in which around ten of them had taken part.

Table 1: Stakeholders involved in the problem of avoiding the use of pesticides by maintaining livestock farming in the Saffré basin, as encountered during the second series of semi-structured interviews.

PLANT HEALTH SALES AND ADVICE	MILK COLLECTION AND PROCESSING	MEAT COLLECTION AND PROCESSING	DISTRIBUTION
2 cooperatives	2 cooperatives	1 slaughterhouse	5 supermarket chains
3 traders	2 private dairies	1 cutting plant	
2 advisory structures			
1 phytosanitary firm			

An innovation track (Salembier et al., 2021) was carried out in parallel with the first series of exploratory interviews in order to provide input for the second series of semi-structured interviews. The aim was to identify initiatives that were part of the solution to the problem of pesticide use, consisting of maintaining livestock farming. This search was largely based on previous work analysing the grey literature on the

dairy sector (Barbe et al., 2020, Diaz et al., 2021). The initiatives identified by these studies have been classified according to an exploration tree (Quinio et al., 2022) illustrating the diversity of ways to improve farmers' remuneration (Figure 4).

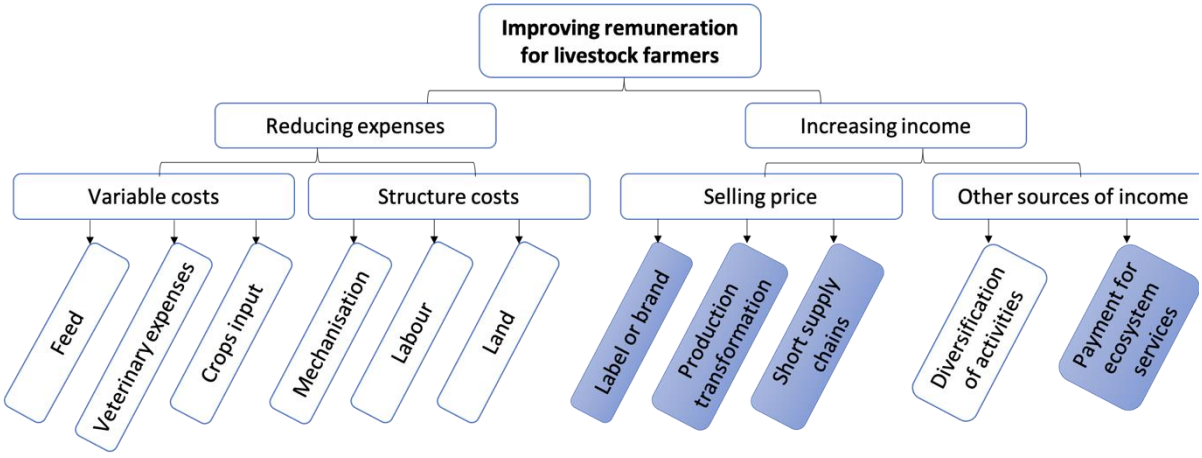

Figure 4: Exploration tree for ways of improving farmers' remuneration (after Barbe et al., 2020, Diaz et al., 2021). The blue highlighting identifies the ways proposed to respondents to gather their perceptions.

A second series of around twenty semi-structured interviews was conducted with the stakeholders identified above. After an introduction presenting the "tous innEAUv'actors" charter and its objectives, a first series of questions aimed to understand the activities of the stakeholders interviewed and to identify the other players with whom they interacted. A second series of questions sought to gather their perceptions on pesticide-free farming and maintaining livestock farming. Some of the ways identified by the above-mentioned innovation track to improve farmers' incomes were proposed to the interviewees to gather their reactions, in the spirit of the "revealing technologies" proposed in the sociotechnical diagnosis method (Casagrande et al., 2023). The ways mentioned in the interviews were: 1) increasing selling prices by means of brands and labels; 2) integrating processing or marketing on farms to capture added value; and 3) diversifying farmers' sources of income through public support.

5. Identification of obstacles to pesticide-free farming, linked to sector specialisation

The information gathered from interviews and observations at local events has been summarised in the form of a map showing the position of stakeholder groups, from production to consumption, according to their distance from the objectives of the "tous innEAUv'actors" charter (Figure 5). For the sake of simplicity, the map presented here focuses on the dairy sector. However, the dairy, meat and cash crop sectors are highly interconnected. For example, specialist dairy farmers have to deal with players in the meat industry to get value from their calves and cull cows, which are "co-products" of milk production, and with players in the cash crop industry to buy inputs for the production of the forage crops that they grow for their own needs.

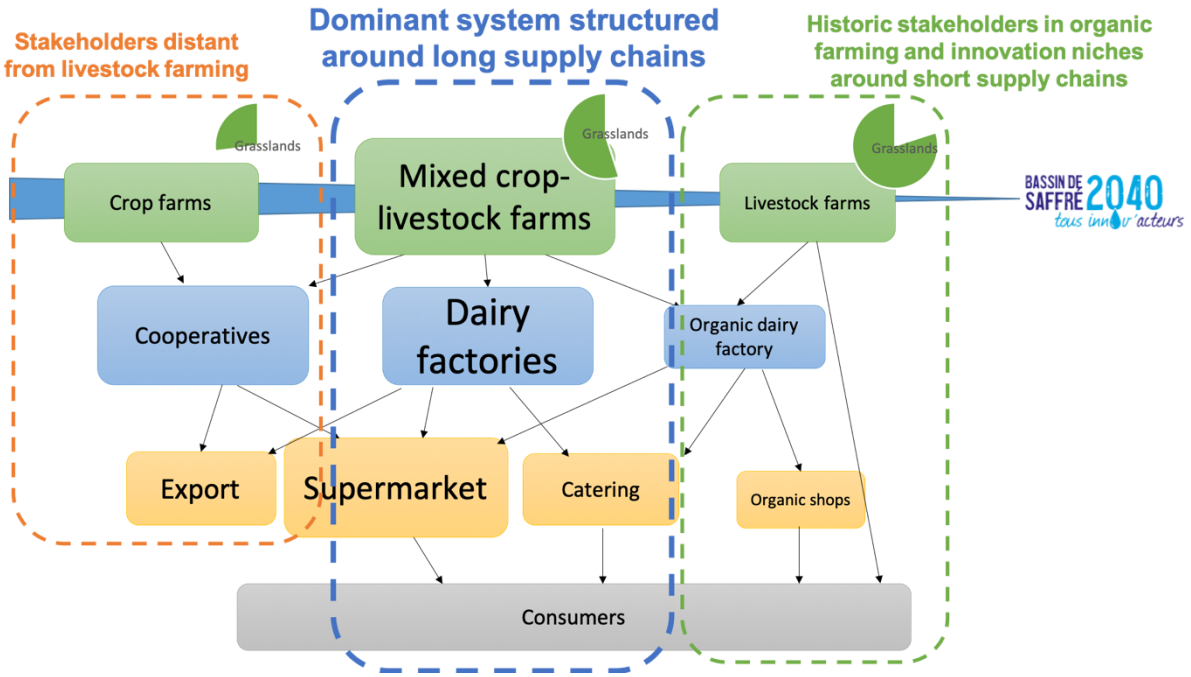

Figure 5: Simplified map of the socio-technical systems identified in the Saffré basin. In green, production; in blue, collection and processing; in yellow, distribution; in grey, consumption.

The first socio-technical system identified (centre of Fig. 5) corresponds to the dominant, most stable system, organised around conventional or organic farms, whose forage area combines grassland and maize. It is structured by players organised into long supply chains. The milk produced by most of the farms in the Saffré basin is collected by six dairies, which either process the milk themselves or sell it to processors. These players operate on a national or even international scale, far beyond that of the Saffré basin. The milk collected is packaged or processed into dairy products that are sold through supermarkets, or even processed into milk powder for export. The operation of this socio-technical system is closely linked to the specialisation of the French Granf Ouest: the Pays de la Loire, Brittany and Basse-Normandie regions account for more than half of France's dairy cattle population and produce more than half of all milk collected (Agreste, 2022). This concentration allows for economies of scale at every link in the chain, reducing production costs and the prices offered to consumers. This socio-technical system has easily integrated organically produced milk into its activities, with limited technical changes for farmers (compared with what conversion to organic farming implies for cash crop farming systems), identical processing and packaging processes to conventional milk, the same distribution channels, and a limited cost differential for consumers. As a result, the production of organically produced milk grew strongly between 2000 and 2020, and its consumption doubled nationally between 2015 and 2020. More recently, organic products have faced a consumer crisis. The inflationary context has led consumers to cut back on their food spending, and organic products, considered more expensive or even 'luxury', have been particularly hard hit, with a 4.6% drop in consumption between 2021 and 2022 (Agence bio, 2023; Bellon, 2023). This drop in consumption has led to excess production compared to demand; the dairies we met had downgraded as much as 30 to 40% of organic milk batches to conventional channels. This has also had an impact on the prices paid to producers: between 2020 and 2023, the price of conventional milk at national level rose by 35%, while the price of organic milk remained stable. In April 2023, producers were even being paid less for organic milk than for conventional milk (Agreste, 2023). This situation illustrates the inability of the dominant system described above, which is driven by the downstream sector, to promote and make attractive organic modes of production, which use no pesticides.

Alongside this dominant socio-technical system, we were able to distinguish a socio-technical system grouping together the historical players in organic farming (right, Figure 5). A cooperative dairy, collecting

only organic milk, is based in the Saffré basin. In addition, several farms, which have been organic for a long time and where grasslands make up the bulk of the forage area, stand out for marketing part of their production through short distribution channels, even though they remain connected to the long distribution channels for most of their production. One farm processes milk into cheese. Another farm sells meat directly to markets and catering establishments, using the services of a local cutting plant. This same farm has recently developed lentil production, making the most of the complementarity between crops and livestock. The presence of grassland in the rotations makes it easier to manage lentil weed cover. A cooperative for the use of agricultural machinery (CUMA) provides access to the equipment needed for sorting and packaging. These players are affected in very different ways by the crisis in demand for organic produce. At national level, between 2021 and 2022, sales of organic products fell by more than 8% in specialised shops, while they rose by 4% in short distribution channels and by 18% in mass catering. At a meeting of organic farmers in the Saffré basin, those who marketed their products via short distribution channels expressed satisfaction at the better value they were getting for their products, as well as at the renewed sense of purpose they were gaining from contact with consumers. They did, however, mention the time constraints involved in taking on processing or marketing activities in addition to production, as well as the limited potential volume of this niche market.

We have also identified a socio-technical system of players who are gradually distancing themselves from livestock farming (on the left in Figure 5). Several traders operate in the Saffré basin, collecting crops (maize, wheat, etc.) and supplying inputs to farms. While only four farms in the basin specialise in cash crop farming, livestock farming has become of secondary importance for others. As farms have expanded, they have increased their arable acreage and reduced the proportion of grassland in their crop rotation, so that their cows' rations are based more on maize, and milking has been automated. Of particular note is the recent creation of a methanisation unit in the Saffré basin, bringing together four farms. Although this unit is based on the use of livestock effluents, the sale of energy has nevertheless prompted one of the farms to stop livestock farming in favour of silphia production for energy purposes. The farms in this socio-technical system are dependent on the use of herbicides to manage weeds in cropping systems without grassland. Several initiatives have been taken in the Saffré basin to promote mechanical weeding: financial assistance from Atlantic eau, technical support from the GAB and services provided by CUMAs. Despite these incentives, the use of mechanical weeding is limited by time constraints on large farms with limited manpower.

6. Identifying the levers offered by diversification of production or outlets

Through the motivations expressed by the players, the socio-technical diagnosis revealed levers for working on subjects in line with the objectives of the "tous innEAUv'actors" charter.

For example, within the system of stakeholders distancing themselves from livestock farming, several farmers expressed curiosity about robotics as a potential lever for facilitating the use of mechanical weeding despite the lack of manpower. In the same socio-technical system, several cooperatives expressed interest in developing and structuring channels for diversification crops that could help manage weeds in rotations without grassland. To fuel these initiatives, it is planned to organise a workshop bringing together farmers and cooperatives to discuss herbicide-free weed management in systems without livestock.

On the other hand, several longstanding organic farmers said they were interested in introducing milk processing into their activities in order to earn a better income. The idea of a collective processing facility was raised as a way of overcoming the time constraints on processing. The dairy present in the basin would be able to collect milk from the farms involved and deliver it to a dedicated processing site. In order to develop the outlets offered by short supply chains, the need to initiate a debate on innovative marketing methods that are more in line with consumer needs was raised. To build on the momentum generated by the Saffré basin's organic farmers around adding value to their milk, a workshop will be held in 2024 to

look at setting up a group to provide a collective framework for these discussions. As well as diversifying production, this also means diversifying outlets and sources of income for farms, which can make them more resilient and stable.

Faced with the inability of the dominant system to commercially value pesticide-free products, and in a context where demand is geared towards low-price products, it would seem essential to try to influence consumer behaviour. Atlantic'eau has undertaken several communication initiatives to this end: a Fresque de l'Alimentation (Food Fresco) is to be offered to residents of the basin, and awareness of the links between consumption practices and agricultural practices has been included in the newsletters distributed to residents connected to the drinking water supply.

7. Conclusion

The obstacles and levers to pesticide-free farming in the Saffré basin, a water catchment in the Loire-Atlantique region, were identified by combining a territorial scenario, innovation tracking, and a socio-technical diagnosis. This original approach revealed a specialised system structured around long supply chains, which was unable to sell the milk produced by low-pesticide farming at a level that was attractive to farmers. It additionally revealed the dynamics of innovation, particularly around the diversification of production, but also around levers that are not directly agronomic, such as those relating to the diversification of outlets and sources of income for farms, and consumer behaviour, which will be discussed in further work.

Ethics
The authors declare that the experiments were carried out in compliance with the applicable national regulations.

Declaration on the availability of data and models
The data supporting the results presented in this article are available on request from the author of the article.

Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.
The authors have used artificial intelligence-assisted technologies to translate from French to English.

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Authors' contributions
RB and MD initiated and coordinated the work. RB and CB prepared and led the scenario workshops. BF was responsible for tracking innovations and socio-technical diagnosis, with the support of RB, MD and LLD. MC and MHJ provided methodological support.

Declaration of interest
The authors have no conflicts of interest to declare.

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