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Abstract

A dynamic production of high-quality apples has developed within the Pilat Natural Regional Park thanks to favourable pedoclimatic conditions, the ingenuity of local farmers, but also synthetic chemical input use. We conducted a holistic inquiry to identify the sociotechnical lock-ins that explain the difficulty in producing fruit without synthetic chemical inputs. This was done by investigating a diverse range of actors involved in Pilat fruit production. We characterized a sociotechnical system structured around an agricultural cooperative marketing apples to mass-market retail, as well as niche dynamics. These elements, and their interconnections, have helped us to identify possible sociotechnical transition pathways towards the establishment of fruit production with a decreased dependence on synthetic chemical inputs.

Keywords: Sociotechnical lock-in, synthetic chemical inputs, agroecology, fruit production, innovation, multi-level perspective

1. Introduction

Over the course of the twentieth century, the use of synthetic chemical inputs (SCIs) has become the main crop protection strategy on European farms. These products are used to prevent, eliminate or regulate various pests: fungi, insects, weeds or other harmful organisms (FAO, 2002). Aimed at helping farmers to 'secure' their harvests, the use of SCI was encouraged from the 1960s onwards by agricultural modernisation and development policies (Jacquet et al., 2022), which went hand in hand with the rise of the agro-industry (Aulagnier and Goulet, 2017; Clapp, 2003) and the specialisation of farms and agricultural regions. These transformations have led to the homogenisation of landscapes (Meynard et al., 2018; Schott et al., 2010), and to the enlargement of plots on farms following various land consolidations. These dynamics have limited the natural regulation mechanisms of pests (Rusch et al., 2016), intensifying dependence on the use of SCIs for crop protection. Moreover, soon after the appearance of SCIs, societal concerns over their harmful effects on the environment emerged. Recent studies have highlighted the significance of SCIs' role in environmental pollution, biodiversity loss and their impact on human health (Sanchez-Bayo and Wyckhuys, 2019; Nicolopoulou-Stamati et al., 2016; Wilson and Tisdell, 2001; Cowan and Gunby, 1996).

Various public policy programmes have been implemented to support cutbacks in the use of SCIs. Their limited impact has highlighted the difficulties encountered by farmers in dispensing with SCIs (Bjørnåvold et al., 2022; Lamine, 2011). In France, the national governmental programme *Ecophyto*, which focuses on production practices, has failed to reduce the use of SCIs, mainly because it does not address the interdependencies between stakeholders in agri-food systems, which 'lock in' producers' practices (Guichard et al., 2017). These interdependencies are present both within sectors and across territories. The territorial scale is an interesting one in terms of which to study the diversity of determinants of farmers' practices (Boulestreau et al., 2021; Della Rossa et al., 2020). This scale is also helpful in better understanding barriers to reducing SCIs, which may be of various kinds (technical, organisational, political, etc.). Territories are biophysical, socio-economic and symbolic entities through which stakeholders can engage in collective activities to build viable pathways towards agroecological transition (Pelzer et al., 2020; Vandenbroucke et al., 2020; Wezel et al., 2016).

The aim of this study is to understand factors limiting the transition to SCI-free fruit production systems and territories. In order to do this, we have used the multi-level perspective on sociotechnical transitions (MLP) theoretical framework. Our work focuses in particular on the analysis of agricultural sociotechnical systems, i.e. networks of actors sharing practices, knowledge, technologies, collective representations and formal or informal rules guiding their practices (Rip and Kemp, 1998). We have sought (1) to characterise the sociotechnical systems that influence the use of synthetic chemical inputs in fruit production in the Pilat Rhodanien (situated on the plateaus and along the west side of the Rhône River), and (2) to identify the sociotechnical lock-in processes that explain the difficulty in eliminating the use of synthetic chemical inputs. The study area ranges across the Pilat Natural Regional Park (Pilat)[1], close to major conurbations such as Lyon and Saint-Etienne. The interest of this case study lies in the fact that it includes a diversity of farm productions. It is also an area known for local efforts to develop sustainable agriculture, within a semi-rural, mid-mountain landscape, particularly through the collaborative establishment of a 15-year charter by local elected bodies, non-profit organisations, and citizens. This paper focuses on fruit production, which is widely present in the region. It is also a production which is subject to some of the highest application rates, both nationally, with an average Pesticide Treatment Index (PTI) for apples of 18.5 for organic and 31.5 for non-organic crops (Agreste, 2018), and locally (PTI: 20; Chambre d'Agriculture 42, 2019), despite a clear cutback in the use of SCIs in the Pilat over the past three decades.

2. Materials and method

2.1. Description of the case study

Until the mid- 20th century, stone fruits were most commonly found in Pilat fruit production. A serious epidemic of bacteriosis in the 1980s decimated several orchards and accelerated the specialisation toward apple production. However, conditions in the Pilat — acidic, shallow, sandy soils in particular — are not considered to be conducive to high-yield apple production. On the other hand, these conditions enable the production of high-quality apples: fruits fill up with sugar, giving them a high-quality taste, and a well-balanced content of sweetness and acidity (Pilat Natural Regional Park, 2024). Production has developed with the systematic use of SCIs, encouraged by the planting of orchards in trellised rows and combined with overhead drip irrigation. Vulnerability to climatic hazards is limited by the widespread use of hail protection nets and good access to irrigation water. In 2022, when this study was carried out, almost three quarters of the 511 ha of orchards were used for apple production, while the remaining quarter were devoted to stone fruit (DRAAF AURA, 2022; Pilat Natural Regional Park, 2012).

[1] To learn what constitutes a Natural Regional Park in France, visit: https://www.parcs-naturels-regionaux.fr/en

The structure of the Pilat fruit sector has also changed. Historically, fruit was sold at a well-known wholesale market specialising in fruit, which took place every morning from May to August in Condrieu, in the Pilat Rhodanien. This market closed in the middle of the 20th century, with the arrival of centralised wholesale markets. Today, some farmers sell their production via cooperatives, while others operate independently. Some focus on direct sales, others on mass distribution and/or wholesale markets. Many combine different types of outlets. One of the fruit cooperatives, firmly rooted in the territory, was formed in the 1980s, opening up collective access to markets, mainly wholesale and mass distribution, thanks to coordinated logistics and investment in shared, high-performance infrastructure and tools. While initially this cooperative brought together 34 producers, at the time of the study it grouped 11 producers, of small to medium-sized farms (15 to 35 hectares).

2.2. Approach

Our analysis of these groups of actors is based on the theoretical framework of the multi-level perspective on sociotechnical transitions, developed to describe sociotechnical systems and make transition trajectories intelligible. MLP is characterised by three levels of heuristic and analytical concepts: the sociotechnical landscape, the sociotechnical regime and innovation niches (Geels, 2020, 2002; Geels and Schot, 2007; Rip and Kemp, 1998). The sociotechnical regime encompasses social groups that stabilise current practices (Geels and Schot, 2007; Nelson and Winter, 2004), and in particular certain technologies, understood in the agricultural context as a combination of agricultural techniques, material conditions and know-hows that make their use possible (Casagrande et al., 2023). Technological niches are incubation spaces where radical innovations can emerge and develop through relatively small networks of actors on the fringes of the sociotechnical regime. The sociotechnical landscape represents factors that have an external influence on the ability of actors in the regime and niches to act and/or modify their practices, such as the macro-economy, macro-political developments and underlying cultural models. The concept of sociotechnical lock-in makes it possible to explain the processes of self-reinforcement which favour the use of a dominant technology to the detriment of competing technologies with similar functions, even if the latter would probably perform better in the long run (Liebowitz and Margolis, 1995). This concept has been used to highlight obstacles to the development of agroecological agricultural and food systems (Duru et al., 2015; Lamine, 2011; Magrini et al., 2019; Meynard et al., 2018; Bilali, 2019).

We carried out an analysis of the sociotechnical barriers and leverages to innovation processes in agri-food systems, based on the MLP concepts (Casagrande et al. 2023). Our study was based mainly on surveys and participant observations with a variety of stakeholders: (i) 35 semi-structured interviews, including 3 group interviews, and (ii) 20 participant observations. The stakeholders to be surveyed were identified in collaboration with the Pilat Natural Regional Park agroecology officer, then by using the Snowball method, supplemented by literature and internet searches to diversify the sample (Table 1).

Table 1: Summary of interviews and participant observations by stakeholder category.

FIELD OF ACTIVITY	TYPE OF PLAYER	SEMI-STRUCTURED INTERVIEWS	PARTICIPANT OBSERVATIONS
PRODUCTION	Farmers	8	2
TECHNOLOGY AND TECHNICAL SUPPORT	Technicians and advisers	3	3
	Coordinators of groups of farmers	4	1
	Agricultural equipment suppliers	2	1
MARKET	Fruit cooperative directors	3	0
	Local produce sellers	1	2

	Wholesale market managers	1	0
CIVIL SOCIETY	Members of a citizen group promoting organic farming	1	7
	Manager of a non-profit promoting organic farming	1	0
SOCIO-POLITICAL	Coordinator at a agroecological farming support non-profit	1	0
	Territory ressource managers	5	0
	Anti-pesticide activists	2	1
	Directors of agricultural development non-profits	2	2
	Technician from the Pilat Natural Regional Park	1	1
TOTAL		35	20

The aim of our interviews and participant observations[2] was to characterise the sociotechnical systems and the determinants of the use of SCIs, by studying actor roles, the nature of their activities, norms (including those relating to the use of SCIs), relationships and networks. Our interviews focused on stakeholders' knowledge of the fruit production sector, issues at stake, strategies employed for crop protection and factors enabling or hindering a reduction in SCI use.[3] We also asked stakeholders about their professional activities, their networks and the evolution of their activities in relation to the use of SCI. In the case of farmers, we asked questions about the ways in which they obtain information in order to make decisions about crop protection. We also asked them about their crop protection strategies (approach, practices, technologies used).

In our analysis, we focus in particular on the cooperative described above and its members, as this group seemed to us to form the core of a strong sociotechnical system. We were also interested in the system structured around independent, often diversified and certified organic farms. These operations were run by farmers who are themselves responsible for storing, packaging and marketing their produce, which is sold on the farm, at the market and/or through producers' shops. The analysis of this second group was limited to the elements necessary for a good understanding of the system structured around the cooperative.

[2] Participant observations took a variety of forms: active participation in orchard work, farmers' markets, the *Fête de la Pomme,* the Apple fair in Pélussin and several half-day field trips organised by a non-profit supporting the development of organic farming, as well as political and professional meetings of the fruit industry in the Rhône Valley.

[3] The specific questions were tailored to the type of stakeholder we met. We used data saturation, continuing the interviews until no significant new information emerged, in order to assess when to stop.

3. Results

3.1 Dependence on mass market, a determining factor in the organisation of farmers and the use of synthetic chemical inputs

3.1.1 The cooperative provides access to supermarket and wholesale distribution channels

The interviews showed how forming a cooperative has enabled small and medium-sized farm producers to gain access to supermarket and wholesale markets (pooling of volumes, storage capacity, common resources for sorting, packaging, canvassing and order follow-up). In this way, the cooperative is calibrated to align fruit production with customer expectations in terms of volumes, freshness, sorting, packaging and traceability. The flow of apples needed to meet customer requirements in large, regular volumes is secured for the cooperative by internal rules of procedure stipulating that 80% of cooperative members' sales come from income generated by the cooperative. This agreement further strengthens the link between cooperative members and a single type of market. Indeed, while other markets are available, cooperative members told us that these are inadequate for big volumes, pay less promptly and thus require the multiplication of sales points and more monitoring. With a view to improving their ability to supply regular volumes of quality eating apples and facilitate the processing of large volumes, the cooperative has invested in a high-performance grading machine and cold storage facilities. While these investments have greatly improved the efficiency of their logistics system, they have also resulted in high depreciation costs, which can only be recouped through large, continuous flows of apples. The investments therefore increase the need to secure a return on investment in an efficient and continuous way, and reinforce the dependence on markets chosen by the cooperative.

3.1.2 Pressure to produce large quantities of 'perfect' apples at low cost

Supermarkets and wholesalers, the cooperative's main outlets, have requirements, set out in specifications, which have a direct impact on the cooperative members' farming practices. These involve the supply of large volumes of uniform, graded apples, of well-known varieties with no defects (category I). Faced with competition from fruit imported at low prices from other European countries (Spain, Poland), fruit growers have to sell their produce at a moderate price to remain competitive. However, the pressure in determining the selling price of apples does not stop there: fruit that does not meet customers' desired standards in terms of size, colour or uniformity is reclassified in the sales grade (category II). Intended for processing into juice or compote, these apples are sold at a much lower price, barely covering production costs, according to the growers surveyed. This encourages farmers to protect their apples in order to secure large volumes of the highest grade achievable all of this at the lowest possible cost. Growers consider that these objectives can only be achieved by mobilising SCIs.

According to interviewees involved in retail, these market demands are reinforced by the marketing method and the distance between producers and consumers: "Consumers who go to the market or to the grocery shop are looking for perfect fruit. When it comes to farm store sales, there is more tolerance". Even so, several organic production growers told us that many consumers are critical of non-standard fruit, which they see as imperfect. The growers speculate that these consumer expectations are influenced by the standards of fruit they are used to finding in supermarkets.

Market and cooperative requirements have led growers to specialise in eating apples, with a minor pear and stone fruit production. According to an extension service officer, production specialisation has increased the ecological and financial vulnerability of farms, intensifying the need to protect yields: farmers "have no choice; when you only have one product to make a living, you don't have the right to make mistakes. Farmers are obliged to protect their production" using physical means, such as nets, and SCIs. This illustrates the coherence of a production and marketing strategy that contrasts with those of other producers in the area, who farm exclusively organically and grow a diversity of fruit species, marketed through direct sales, as a means to become more self-sufficient. This production is often complemented with vegetables, laying hens, a herd of cows or mushroom cultivation.

Despite its small size, the cooperative structure enables fruit producers to stand out and face up to international competition. This is done by targeting the high-end market segment. In some cases, this gives them the leeway they need to reconcile financial viability with ecological objectives. A number of leverages are used: negotiations with downstream suppliers, thanks to the manager's relationships with customers; the coordinated planting of varieties with good organoleptic qualities that stand out from those apples more commonly found on supermarket shelves; adherence to specifications that are perceived as more demanding; a distinct and coherent image, linked to the location of Pilat production, and reflected in the marketing strategy and local representation through a well-known event, the Apple Fair. However, neither of these strategies is sufficient to support a complete reduction in SCIs. This is what we will see in the following sections.

3.1.3 Variety choice considered to be a powerful leverage for reducing the use of SCIs without calling the system into question

The apple varieties typically planted in conventional orchards (Gala, Golden) have been selected in particular for their ability to produce high yields. Today, this selection also meets the expectations of consumers for a distinctive "red, yellow or green" colour and familiar names. However, these apples have low resistance levels to climatic variability and fungal pressure. Their cultivation is therefore heavily dependent on the use of SCIs. The cooperative's growers have planted around ten new so-called 'resistant' varieties, which many of them see as an effective way of offering an original range of apples with good organoleptic qualities, while optimising the production system by reducing the need to use SCIs. This leverage completes the panoply used to move in this direction, together with the use of nets, for example, without radically changing the production system. However, surveyed growers wonder about market opportunities for these new varieties and whether consumers will accept varieties with which they are unfamiliar.

3.2 Too few opportunities and too many risks to make the changes needed to reduce doses

3.2.1 Farm vulnerability and crops' perennial nature limit the possibilities for redesigning orchards

The need to secure yields does not encourage growers to change their production systems significantly. This is all the more true given the perennial nature of the crops in question: "yes, but one must be careful, because when crops are planted, it's a decision that is taken for at least the upcoming decade; one mustn't make any mistakes [...] at least as far as the cost of the plant material is concerned. Before marketing new fruit, experimentation is essential, otherwise we run the risk of planting something that won't work". Replanting plots, in order for example to change varieties, diversify species grown, or redesign orchard structure, is therefore considered by the growers surveyed to be particularly risky, if not too risky to undertake. Replanting entails taking several years off production while waiting for the young trees to bear fruit, a long waiting period and a high cost. Some of the fruit growers surveyed are nearing the end of their career, which reduces their willingness to make major changes to their orchards and crop management in order to limit risks, and because of the need to make a quick profit from their work. This pressure is intensified by the difficulty in finding buyers. In addition, several of the producers interviewed regretted the lack of concrete, relevant and well-known examples of viable tree farms demonstrating that it is possible to make a living from pesticide-free production. Fruit farms in the territory that are entirely organic are often perceived as too different to constitute a viable model by the cooperative's members, particularly in terms of their production objectives and markets.

3.2.2 The development of organic farming is limited by profits that are too low, the fragility of the market and unforeseen climatic events

Many of the cooperative's fruit producers are in the process of reducing the use of SCIs, by replacing these treatments with various alternative solutions (e.g. nets, the use of biocontrol, and mating disruption). This is in line with a general trend towards reducing SCI use in fruit production in the Pilat Rhodanien area (Couturier-Boiton, 2009). This search for alternatives is motivated by the need to deal with the cutback in the number of authorised molecules and products — a cutback that has been observed in recent years and which they anticipate will increase in the future — as well as changes in their customers' expectations. Some fruit producers also told us of their concern about the negative impact of SCIs on human health, and of their desire to support biodiversity.

Most of the cooperative's growers have plots dedicated to organic apple production, which they also use as test areas to find effective solutions for reducing SCIs. Several growers have found that the yield of marketable apples from these organic plots is greatly reduced, most often by half the volume. They note that the selling price obtained for these organic apples is generally not enough to cover the higher production costs involved, linked not only to a drop in productivity but also to additional working time and labour requirements. More generally, growers regret that selling prices, for both organic and non-organic apples, had been particularly unpredictable in the months preceding our survey. The price of organic apples fell throughout 2022, regardless of the variety, while the price of non-organic apples rose (FranceAgriMer, 2024). Certifying orchards as organic is therefore seen as risky, given the uncertainty of future production conditions, against a backdrop of climate change and unfavourable trends on the organic market.

3.2.3 Labels have an uneven effect on the use of synthetic chemical inputs

The market channels developed by the cooperative offer added value to produce certified AB (organic production), *Vergers Écoresponsables* and other labels specific to supermarkets also displaying a commitment to the environment. The cooperative structure helps market the labelled apples of its growers by pooling together volumes. The cooperative's administrators simplify the administrative procedures involved in applying for the label(s). However, there are limits to the extent to which labels can encourage more sustainable practices. The specifications seem to contradict the continuing demands of buyers and consumers, who persist in demanding high visual quality and large volumes. During our interviews, it became apparent that the *High Environmental Value* (HVE) labelling scheme implemented by the cooperative members has not led to any significant change in their orchard protection practices. At the same time, organic farming non-profit and certain organic producers believe that the specifications associated with the HVE label are not well known by consumers, who are unable to discern the difference between HVE and AB labels.

3.3 The cooperative : A helpful organisation, set apart from others

The cooperative is not just a tool for marketing produce. It is also a space for technical exchange, socialisation and mutual support which contributes to building a strong professional identity for Pilat fruit producers, but which is also apart from other fruit growers.

3.3.1 An organisation that supports independent functioning

Cooperative members meet every week to discuss the structure’s development, and challenges faced in the orchards. The collective receives technical support from two technical sales representatives, and very occasionally from an independent technician. This organisation allows the cooperative's producers a high degree of technical independence. However, this means that they do not seek advice from other technical support organisations in the area, including those that are specialised in organic production. It also means that they are not linked to other fruit producers in the area. Although some of the orchards are farmed with organic practices, organic agriculture is not a shared preoccupation in the cooperative because of the major differences perceived in commercial and technical strategies. The current structuring of technical support contributes to the compartmentalisation of professional fruit producer groups in the Pilat.

3.3.2 The cooperative, a space for the anchoring of a unique professional identity of fruit producers rooted in the Pilat

The cooperative has built up a unique image linked to the area, enabling it to differentiate its production on the market and in the region. Its name refers directly to the Pilat, while its logo features one of the area's famous sites. A range of colours and distinct lines are printed on the apple crates. Its logo is used on a range of media (cooperative building, website, producers' lorries and clothing). This visual identity marks the cooperative's identity and links it to the territory in the same way as a PGI label (protected geographical indication, this was considered but abandoned to avoid imposing yet another set of specifications). Added to this is the organisation of a renowned event, the Apple Fair.

For over 40 years now, on November 11, the cooperative has organised the annual Pélussin Apple Fair in collaboration with the Pélussin municipality, the Pilat Natural Regional Park and the Pilat apple fraternity (made up of former cooperative growers and relatives of current members). The fair has achieved a high profile, attracting thousands of people. The layout of the festival reflects the central role the cooperative has played in setting it up. The central square in Pélussin is home to stands run by the fraternity, the town hall, INTERFEL (the fresh fruit and vegetable interprofessional organisation), the Pilat Natural Regional Park (all of which offer entertainment, such as tastings, competitions etc.), and a few artisans. These stands surround those of the cooperative fruit producers and two growers who do not belong to the cooperative, all of whom sell apples. Moving further along the streets, one finds stalls run by citizen organisations, artisans, merchants, fairground owners and farmers, most of whom come from the Pilat Rhodanien area. The omnipresence and key position of the cooperative is visible through the placement of its members at the centre of the fair and its logo, visible on the stands of producers and the fraternity. The regional media, press and television, give extensive coverage to the event, featuring the president of the apple fraternity and the director of the cooperative. The festival concludes with the fraternity inducting several political figures. Each year, the festival, and the induction ceremony in particular, reaffirms the presence of a professional group of fruit producers, displaying alliances and anchoring the cooperative’s professional identity in the region and its traditions. As such, it becomes the eponymous image that many elected representatives, residents and visitors have of Pilat fruit production.

The cooperative's producers, on the one hand, and on the other organic fruit producers, working on diversified farms, each have a different approach to their trade, linked to strong values. The former consider that their role is above all to supply the greatest number of people, thanks to the production of large quantities of apples sold at low costs. The latter are committed to excluding the use of SCIs as a means of limiting the impact of their production on their own health, that of consumers and biodiversity. However, the former are far from ignoring the health and biodiversity issues: these objectives are also important to some of the cooperative's fruit producers, who try to reconcile economic viability and ecology. In our surveys, all shared the feeling that they did not have the same production objectives. They expressed openness to the approach of other producers, and sometimes admiration for their expertise. They also criticised the limitations of the other systems: that of producing with SCIs at the cost of health and biodiversity, and of producing too small a quantity of fruit, sold at an unaffordable price.

4. Discussion

In this article, we have identified a group of actors involved in a sociotechnical system organised locally around a fruit cooperative geared towards the supermarket and wholesale sectors. Joining the cooperative enables producers to integrate the sociotechnical system of the fruit production sector. Its small size and the high-end market segment chosen for its production forge its unique character as a 'terroir niche' (Belmin et al., 2018), distinguishing it within a mass market. This organisation provides the flexibility needed to support the development of a wide range of products (in terms of fruit varieties and ecological standards). This would in principle allow certain environmental objectives to be reached. However, these same objectives are cancelled out, given the expectations of the chosen outlets, whose standards are imposed in what is, in effect, an unequal playing field (Chazoule, 2001). The small number of cooperative members facilitates exchanges and nurtures an identity. This helps the social construction of a strong collective, albeit one that is separate from other fruit production sociotechnical systems in the area. Thus, a set of factors contribute to the socio-technical lock-in which maintains a specialization in the production of eating apples and a dependence on SCIs. Factors include regulations and standards (Unruh, 2000), the need to make investments profitable (Tushman and Anderson, 1986; Christensen, 1997), and normative rules that nurture a common sense of responsibility and shared values (Belmin et al., 2018).

Farmers who produce exclusively using organic methods participate in other niche dynamics, more at odds with the dominant regime. Their farm system makes it possible to maintain SCI-free production, but not without difficulty. These farmers rely on a diverse set of productions and smaller volumes of fruit, for which they obtain a higher price-value, notably though direct sales and value-adding processing.

4.1 A current path of transformation (P1) with limits regarding regime change dynamics

Geels and Schot (2007) propose five levels of sociotechnical transition, from reproduction to reconfiguration. These transitions are the result of interactions between niche dynamics and landscape pressures on the sociotechnical regime, which destabilise this regime sufficiently to create windows of opportunity. According to our analysis, the cooperative is currently in a phase of transformation (type P1). Changes within the landscape are moderate and niche innovations are not yet sufficiently developed. The cooperative's actors are modifying their activities in order to incorporate niche innovations and adapt, without changing their fundamental architecture.

4.2. A sociotechnical landscape unfavourable to the deployment of niche dynamics, but which could evolve through a reconfiguration trajectory (P4)

According to Geels and Schot (2007), niche dynamics have strong development potential if they are sufficiently advanced at a time of radical change in the landscape (technological substitution P3). Looking at the recent situation, the signs do not seem strongly favourable for this type of trajectory. While there has been a steady increase in organic production acreage throughout the past decade, the recent crisis in the organic sector has affected fruit production. Organic food sales peaked in 2020 and have been decreasing ever since, with a -4.6% decrease from 2021 to 2022 (Agence Bio, 2022). The organic farming market is currently going through a crisis, in particular due to inflation, and visible in the gap between consumer appreciation of organic farming and purchases (FranceAgriMer, 2019). Recent political changes have weakened the regulatory leverages that encourage the transition to systems that are more economical in the use of SCIs (recent vote by Eurodeputies against a 50% decrease in of SCI use by 2030, a central element of the 'Green Deal'; 10-year authorisation for glyphosate renewed in November 2023). In addition, free market agreements continue to impose price competition from countries with lower production costs.

While recent changes in the sociotechnical landscape appear to be unfavourable to the emergence of niche dynamics, it is conceivable that a reconfiguration trajectory (P4) could take place, with changes that are initially limited, but gradually reconfigure the regime. Transition from the dominant regime would in this case occur through the adoption of 'symbiotic innovations' from the niches, which are taken up by the regime to solve local challenges. In this case, changes take place across several sectors and in the cohabitation of several technologies. This echoes the theories of authors interested in changes emerging from territory dynamics.

4.3 A possible transition to more SCI-efficient systems through coupled innovation

Our results show that production methods adopted by fruit producers are influenced by factors that go beyond the farm scale and concern a diversity of actors within the food-chain and territory (including technical support, farm transfer support, public policy making, etc.). This finding echoes several analyses of the sociotechnical lock-ins limiting agroecological transitions (Vanloqueren and Baret, 2008 and 2004; Collet and Mormont, 2003), and highlights the value of coupled innovations (otherwise referred to as ‘parallel design interventions’), designed collaboratively by actors from sectors that are usually managed separately, such as agriculture and agri-food (Meynard, 2017; Jeuffroy and Meynard, 2021). Even more relevant are innovations that go beyond the technological elements pertaining to cropping systems or food processing, and also encompass organisational and institutional reforms (Casagrande et al., 2023), bringing about not only agronomic, but also socio-economic and institutional changes. Assessing the potential impact of each player could be useful in identifying fruitful opportunities for collaboration.

5. Conclusion

The use of SCIs has enabled the production of a constant and sufficient volume of apples, with optimum control of production costs. It has helped meet the standards expected by supermarket and wholesale customers. The cooperative structure contributes to the viability of this system by offering a commercial and logistical tool, but also a key space for socialisation, technical and administrative support, and the construction of a unique local professional identity. Many of the cooperative's fruit producers would prefer not to use SCIs; several express the wish to dispense with them entirely. However, the cooperative’s sociotechnical system, established over time, has ended up for social, technical and economic reasons, trapped by the same organisational and market issues it was meant to resolve. While niche dynamics help open up future prospects, change will be hard to achieve without the commitment of players across the value chain, within the territory and beyond.

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 authors 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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Declaration of interest

The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

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