

Participatory-action research leading to transformation of scientific disciplines' interrelations, research paths, actors' reasoning, and viticultural practices

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Une recherche action participative permet-elle d'affronter la complexité d'une situation en grande tension, en l'occurrence dans le domaine de la viticulture durable ? Telle est la question de ce texte qui nous propose la piste suivante : il faut aller au-delà de la démarche interdisciplinaire pour incorporer dans une recherche en prise avec l'action le processus transformant – du questionnement, des pratiques des chercheurs, des relations entre disciplines et des pratiques des acteurs – que représente la transdisciplinarité. On rejoint ici l'ambition de la revue d'être un lieu, ouvert à la controverse, de réflexivité sur les enjeux contemporains d'une science en société.

La Rédaction

Abstract – Scientific disciplines have been studying the impact of human activities on the planet since 1972 and have developed accurate scenarios. However, they have faced challenges in effecting timely changes. In their pursuit of excellence, these disciplines may have become excessively specialized, isolating themselves from one another and hindering their ability to tackle complex problems. As a solution we could envisage fostering interdisciplinary relationships between these disciplines, or involving society at large. However, both options would require dealing with different systems of evidence, languages, epistemologies, and temporalities. In the field of viticulture, despite numerous projects spanning more than two decades, the global use of harmful pesticides has persisted, leading us down a dead-end. Designing more environmentally friendly viticultural practices and extending beyond agriculture has consequently become an urgent and crucial issue. In this paper I compare the contributions of various disciplines and their relationships with one another in addressing this issue through a series of projects ranging from monodisciplinarity to interdisciplinarity. We also discuss their limitations in resolving the problem at hand. Drawing on ten years of experience in participatory-action research, we propose moving beyond interdisciplinary approaches and embracing a 'transformative' transdisciplinary path. This approach can profoundly transform all stages of research, from formulating questions to generating knowledge and implementing actions. Transformative participatory-action research also impacts relationships between disciplines and between researchers and societal actors, as well as the forms of reasoning involved. I suggest that such an epistemology, while better suited to dealing with complexity, can contribute to a much-anticipated sea change in the world.

Keywords: scientific disciplines / transformation / reasoning / participatory-action research / vine and environment health

Résumé – Une recherche-action participative menant à la transformation des relations interdisciplinaires, des trajectoires de recherche, du raisonnement des acteurs et des pratiques viticoles. Les disciplines scientifiques étudient les impacts des activités humaines sur la planète depuis 1972 et elles ont développé des scénarios précis. Cependant, elles ont rencontré des difficultés pour contribuer aux changements attendus. Dans leur quête d'excellence, ces disciplines se sont vraisemblablement trop spécialisées, s'isolant les unes des autres, ce qui a limité leur capacité à résoudre des problèmes

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complexes. Une question se pose : s'agit-il de revoir les relations entre les disciplines ou d'impliquer la société dans la recherche ? Séparément ou combinées, ces options nécessiteraient de traiter des systèmes de preuves, des langages, des épistémologies et des temporalités tous différents. Dans le domaine de la viticulture, malgré de nombreux projets développés depuis plus de 20 ans, l'utilisation à l'échelle mondiale de pesticides nocifs n'a pas diminué, suggérant que les approches entreprises ne sont pas adaptées aux enjeux. Pourtant, concevoir des pratiques viticoles et, au-delà, agricoles, plus respectueuses de l'environnement, est un enjeu urgent et crucial. Je comparerai les contributions de différentes disciplines scientifiques et leurs relations dans la résolution de ce problème à travers une série de projets allant de la monodisciplinarité à l'interdisciplinarité. Je discuterai également de leurs limites dans la résolution du problème en question, en prenant en compte également les connaissances sur les disciplines et leurs relations lorsqu'il s'agit de traiter le problème des changements de pratiques viticoles, et plus largement, agricoles. En m'appuyant sur dix ans d'expérience en recherche-action participative, je proposerai de dépasser les approches interdisciplinaires et d'adopter une voie transdisciplinaire « transformative ». Cette approche peut transformer profondément toutes les étapes de la recherche, de la formulation des questions à la génération de connaissances, et jusqu'à la mise en œuvre des actions. Cette recherche-action participative a également un impact sur les relations entre les disciplines et entre les chercheurs et les acteurs de la société, ainsi que sur les formes de raisonnement mobilisées. Je suggère que cette épistémologie, mieux adaptée à la prise en compte de la complexité, peut contribuer aux transformations tant attendues en viticulture et plus largement en agriculture.

Mots-clés : disciplines scientifiques / transformation / raisonnements / recherche-action-participative / santé de la vigne et de l'environnement

As scientific disciplines have shown for a long time, the entire planet is endangered, for reasons pertaining both to climate change (IPCC, 2023) and to socio-economic issues (Meadows et al., 1992). Scientists have engaged extensively in research on these issues, with massive funding and even the establishment of dedicated scientific journals. However, the expected changes are not materializing in a timely manner. We question whether scientific disciplines possess the knowledge to effectively tackle such major and highly complex issues. In an interview with the national daily *Le Monde*, Edgar Morin commented: 'Science is ravaged by hyper-specialization'. That being so, would addressing these challenges simply require an interdisciplinary framework connecting them to one another? Or should the research community be more open to society at large, embracing transdisciplinarity and participatory research? Whereas citizen sciences are undeniably gaining momentum, conducting research with stakeholders is still not as straightforward as it may seem (Barbier, 1996). As B. Strasser recently pointed out: 'Are participatory research and transdisciplinarity a democratization of science? The idea is as brilliant as its implementation is opaque' (Strasser et al., 2019). The different formats of participatory sciences do indeed pose challenges to disciplinary boundaries, particularly participatory-action research, as they often involve different systems of evidence, languages, epistemologies, and temporalities. Projects aiming to address these challenges often involve actors and stakeholders from different domains, as well as scientists from different disciplines who need to articulate their own perspectives or knowledge on the same subject. As a result, the nature of interactions, and even an appropriate methodological

framework, are critical for the success of a project¹. As Jean-Paul Billaud (2003) wrote, we are transitioning from 'interdisciplinarity around objects to the object of interdisciplinarity'. To overcome these difficulties, various levers have been dedicated to building bridges (Billaud et al., 2017), establishing common language elements, creating intermediate objects (Vinck, 1999), and defining the functions of intermediary actors responsible for coordinating such projects (Cerf et al., 2017). In fact, foundational experiential narratives on this subject were already laid out nearly three decades ago by René Barbier (1996). Participatory research formats tend to recognize the principle of interdependence (Nicolescu, 2010), and there is even a specific emphasis on 'the prism of transdisciplinarity' (Irwin et al., 2018). But what should transdisciplinarity be at the epistemological level? Does it offer a better understanding of complexity? It has been shown that the participation of actors, and even the public in general, can indeed lead to different approaches to problems, as well as more tangible consequences in the territories where these research projects are conducted, in terms of practical, technical, and sociological results, which is a definite added and concrete value (Strasser et al., 2019; Masson et al., 2021). In the field of sustainable development, transdisciplinary research seems to consider both scientific knowledge and experiential knowledge more fully than do other approaches (Zaccai, 2007; Popa et al., 2015). In a special issue of *Nature*, an actor involved in a project on resilience to climate disruptions stated that 'the final product of co-production is almost

¹ See https://scnat.ch/fr/for_a_solid_science/transdisciplinarity.

intangible' (Williard, 2018). This remark implies sensitivity and emotion that are associated with such projects shared with society, and this is an important dimension to consider in participatory research. From the societal perspective, transdisciplinary research can be seen as a critical and self-reflective research approach that connects societal problems with fundamental scientific questions or queries (Schäpke et al., 2018; Bergmann et al., 2021). Incidentally, this definition suggests that most societal problems are not adequately addressed by the scientific community, and indeed, the gap between science and society, in terms of problem selection, and the perspectives from which they are approached, still persists (Agre and Leshner, 2010). Yet there is a true desire among laypersons to engage with scientific communities and contribute to the future of the planet, as they likely believe that citizen sciences may serve as a lever to influence their environment and their future (Haklay, 2013). It can also be argued that these commitments primarily reflect a search for meaning (Moulin, 2013; Morin, 2000; 2014; 2017).

Despite the development of such projects over the years, recent studies still emphasize the 'need for new structures to foster deeply integrated knowledge between disciplines, and co-produced with non-academic actors' (Irwin et al., 2018). Are they referring to 'outdoor research' compared to 'laboratory research', as described by Guy Paillotin and Bruno Latour (Paillotin et al., 2002)? If structure refers here to a dedicated research institute, then it is likely a misleading path as 'the institutionally discipline-based organization often continues to hinder the establishment of a knowledge dialogue' (Darbellay, 2015). In a special issue of *Nature* titled 'Shared Sciences', an editorial claimed that: 'The best research is produced when researchers and communities work together' (Editorial, 2018). Such a statement can both be encouraging but also potentially amplify the rejection of these practices by the research community. Researchers have even spoken of a nightmare when considering the involvement of society in research choices and actions (Graur, 2007), as if the independence of research were at stake. Yet, let us not forget questions of temporalities which are part of the game. We expect a disjunction between societal problems, often perceived as urgent, or considered too late, and the questions addressed by the scientific community, which, in its standard format, operates within a long-term timescale. We expect research to be forward-looking and to surpass incremental patterns. We expect it to push the boundaries of paradigms, foster the emergence of the new, and potentially prepare us for the unexpected. However, recent studies suggest that research community is far short of these promises (Park et al., 2023).

So, which disciplines should be mobilized, at what time of the project, with what status, and within what systems of evidence? These are all serious questions. The

largest gap is likely to be between the social sciences and biotechnical sciences (Pedersen, 2016). For research on sustainable development, our topic of interest here, B. Latour proposed an idealized framework called 'the parliament of things', prefiguring what participatory sciences resemble today, in order to contribute to 'the coproduction of more comprehensive forms of knowledge and action, among actors, and between disciplines' (Akrich et al., 2006; Latour, 2009; 2018). In practice, if there is one field in which the idea of interdisciplinarity, particularly transdisciplinarity, has made the most progress, it is indeed the environmental sciences, with concepts of centrality, diversity, and even entropy (Wagner et al., 2011). Moreover, beyond sustainable development, transdisciplinarity has also been associated with major societal questions (Mapfumo et al., 2013; Popa et al., 2015). Yet, until now the term has been invoked primarily in relation to projects that involve the participation of non-scientific actors in the research process. This is, admittedly, a somewhat loose definition.

Traditional disciplinary frameworks and their relationships have shown their limitations, and sometimes their blindness, especially when dealing with major global challenges. However, considering that everyone, whether a layperson or a scientist, has both a lack of knowledge and some understanding of reality, it is essential, and valuable, to engage relevant actors in collective reflection. In the field of agriculture, especially in viticulture, I therefore suggest including laypersons, viticultural advisors, educators, and winemakers, as well as researchers from different disciplines, as exemplified in the following case study. In this article I address points illustrated in the introduction regarding the general context of participatory sciences, using the example of the challenges related to redesigning viticultural practices to make them more environmentally friendly and healthier for humans. I illustrate the contributions of various disciplines and their relationships in addressing vine health, on a gradient ranging from monodisciplinarity to interdisciplinarity. I argue for going beyond interdisciplinarity and moving towards transdisciplinarity, but also suggest that this term will gain relevance if the prefix 'trans' signifies transformation, on the following four complementary axes: (1) Transformation involving a shift in the direction of questioning, where complexity leads to the formulation of original questions, often in the 'black holes of knowledge' (Moulin, 2013; Morin 2014; 2017; 2020). These questions are raised both in the scientific community and among societal actors, encouraging their participation in the coproduction of experimental data; (2) Transformation of the relationships between the disciplines involved in such projects, notably by generating scientific knowledge based on raw and quite diverse data they are not used to considering; (3) Transformation of reality through the

actionable knowledge produced for and in the vineyards (Masson et al., 2021); (4) Finally, and most importantly, transformation of the discourse, reasoning patterns, and interrelations of the actors (Masson et al., 2021; Madouas et al., 2023). The discussion considers the strengths and weaknesses of the research paths outlined, particularly with respect to subjectivity, and the positioning/legitimacy of the actors mobilized. I argue that considering transdisciplinarity in this way, with its implications for research projects and for scientific disciplines, would enable us to address global challenges facing the planet and bring about the transformations that are expected in the world.

Environmentally-friendly viticultural practices: from hoped-for transitions to a participatory-action research approach

In this section, without claiming to be exhaustive or criticizing the research choices made, but aiming rather to provide understanding and perspective, I propose examples of questions and projects initiated around global issues in viticulture. These examples illustrate the differences between disciplines' contributions and their relationships in defining a question and addressing it. In particular, I emphasize the consequences of these different approaches on the project's outcomes, the conditions and implications of their transfer, and their potential for actionability. The complexity of reality is represented here by a puzzle reflecting the interweaving of multiple facts, phenomena, embedded timescales, and actors (Box 1).

Vine health through a monodisciplinary path

In a monodisciplinary path, a single discipline raises questions based on its own framework of understanding, references and mode of reasoning, as illustrated with an arrow going from the discipline to a specific piece of the whole (Box 1). Consider the example of fungal diseases in vineyards, caused primarily by downy mildew and powdery mildew. These diseases are predominantly addressed through 'control measures' in both conventional and organic viticulture, accounting for approximately 85% and 14% of the 800,000 ha of vineyards in France, respectively. The remaining vineyard areas are cultivated using biodynamic practices, which take a more holistic approach to the ecosystem. Similar proportions are observed in the world's vineyards, covering 8 million ha. The 'control' of these diseases still involves the use of tons of synthetic (mostly) pesticides, which have been widely criticized for their environmental and human health impacts. Notwithstanding the modification of practices in vine canopy care, such as leaf removal or

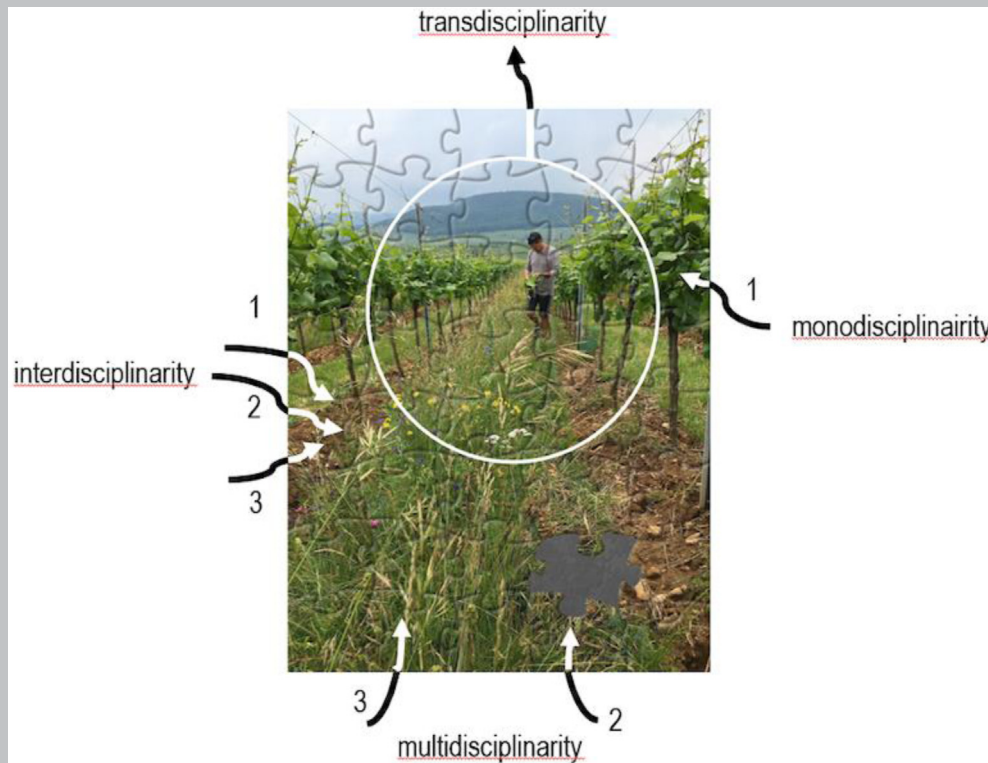
trilling, and the use of lower-impact fungicides, the main focus of research efforts has until now been on a single scientific discipline: genetics. The aim has been to develop new grape varieties by hybridizing centenarians and renowned wine grape varieties with wild vitaceous species that provide disease resistance (Feechan et al., 2013). This monodisciplinary approach is prevalent worldwide². Other monodisciplinary approaches have focused on vine disease protection (Capriotti et al., 2020). The recommended 'solution' is to replace old grape varieties, which are susceptible to diseases yet emblematic and of high quality, with new genetic resources. Such knowledge or innovations can be actionable, yet the shift from centenarians' traditional varieties to these new vine varieties remains an obstacle in winegrowers' thinking. The successful implementation of such innovations depends on the mobilization of stakeholders, their willingness to change, and the applicability of these innovations to pedoclimatic and socio-economic conditions which differ from those found in the dedicated research sites where these plant innovations and related knowledge were produced. Furthermore, questions arise regarding the understanding, adoption, and translation of this knowledge into action by the actors living in this environment, particularly the winemakers themselves. Overall, monodisciplinary approaches are rooted in a now somewhat outdated positivist philosophy in which innovation is always beneficial and will naturally prevail.

Vine health through a pluridisciplinary path

In a pluridisciplinary example, disciplines 2 and 3 operate through their own perspectives and expertise, separately, often focusing on distinct targets. Consider the example of another threat in viticulture: vine decline. This threat has spread at the European and global scales, with 4 to 12% of vines dying each year, sometimes within a span of two months. The prohibition of the systematic treatment of vine pruning wounds with sodium arsenite, a highly toxic substance for humans, appears to have marked the beginning of the emergence of this decline (Bertsch et al., 2009). However, the causality has not been fully established so far. Vine decline calls for an understanding of complexity, perhaps more than any other threat. To this end, the wine industry has undertaken a large-scale project in France (National Vine Decline Plan³), and similar efforts are being made at the European and global levels with dedicated research initiatives. However, so far, the research responses have consisted in mobilizing different scientific disciplines, each of which puts forward its own hypotheses and

² <https://piwi-international.org/fr/>.

³ <https://www.plan-deperissement-vigne.fr/>.

Box 1. Interrelations between scientific disciplines when addressing the complexity of viticulture illustrated with a puzzle.

In this vineyard-plot, we see the culmination of a complete redesign of practices following the participatory action research project called Repère. Underneath the grapevines, herbicides have been abandoned in favor of minimal soil tillage and the acceptance of some weeds. The traditional ground cover between the vine rows, which required frequent mowing (still visible on the left and right sides of the image), has been replaced with wild and local wild-plant-based ground cover that is only mowed once a year (in the center). The pruning method of the vines has been changed to prioritize sap flow and, thereby, favoring more long-term resilience of the vines (according to F. Dall pruning). Finally, the use of synthetic fungicides for disease control, such as powdery mildew and downy mildew, has been abandoned in favor of a project employing biocontrol inspired by biodynamics. This includes the use of plant and mineral-based preparations and moderate doses of copper and sulfur. The arrows illustrate the direction and choices of questions developed by the disciplines, whether from the perspective of the discipline towards a part of the complexity of reality (single puzzle's pieces), or starting from the complexity of reality towards the disciplines (a group of puzzle's pieces). This later illustrates a transdisciplinary approach to participatory action research addressing better the complexity of reality, which addresses questions towards the disciplines (© J.E. Masson. The photo was transformed into a puzzle using www.jigsawplanet.com, freely accessible).

interpretations, particularly in biological science projects. Among the social sciences, only sociology has been involved, and to a very limited extent, at least in the first round. When winemakers' experiential knowledge has been considered, this has been through the lens of agrotechnical disciplines. We have here a pluridisciplinary approach which is expected to generate knowledge that can at least provide a diagnosis, especially if the decline syndrome is multifactorial. However, in the long run a kaleidoscope of knowledge is likely to be produced. The challenge will lie in envisioning how to synthesize this knowledge, as the diversity of knowledge, expertise, and different evidentiary standards among disciplines could make this exercise difficult, even just within the scientific community. Moreover, making this knowledge

actionable and mobilizing winemakers to change their practices, if that is the desired outcome, presents its own set of challenges.

Vine health through an interdisciplinary path

In an interdisciplinary path, the interpretation of reality and its translation into questions remain separate, as in approaches 1, 2, and 3 (Box 1). With these three paths, disciplines interpret/question reality, i.e. arrows go from disciplines to reality. However, in interdisciplinarity path, interactions can be implemented between disciplines, ideally during the construction of a collective project or, more commonly, during the analysis of the data produced, and possibly in dedicated moments fostering reflexivity.

Nonetheless, this remains a construct, and the process largely relies on the skills of the project coordinator, which effectively will provide a framework for initiating and valuing collective reflexivity or not (Cerf et al., 2017). As an example of interdisciplinarity, consider another threat to vines, the *flavescence dorée* (FD), a disease affecting grapevines that is caused by a phytoplasma found in trees and shrubs, and on riverbanks. The phytoplasma is transferred by specific leafhoppers to the vines, where it multiplies and circulates within the plant's vessels. Thereafter, another insect, *S. titanus*, feeds on the infected vines and transmits the phytoplasma to neighbouring vines, causing them to become infected as well (Caudwell, 1957; Malembic-Maher et al., 2020; Kwame et al., 2022)⁴. Over time, this disease has become an epidemic that has spread throughout European vineyards. In France, its spread led to mandatory government decisions requiring the uprooting of infected plants and the spraying of insecticides to eliminate the insect-vector. These mandatory measures disrupted the wine industry, especially because the insecticides used were broad-spectrum products (killing almost all insects), which triggered protest by organic and biodynamic winemakers⁵. The first disciplines mobilized were those in biology. They studied the epidemiological cycle of the disease, the biological interactions between the phytoplasma and its hosts, and management solutions, with a view to generating useful knowledge for the wine industry (Boudon-Padieu, 2002; Chuche and Thiéry, 2014; Oliveira et al., 2019). This knowledge served as a reference for establishing sanitary regulations in close collaboration with the industry. The same disciplines were mobilized at European level. Significantly, the epidemic dimension of FD probably led to collective approaches among wine industry stakeholders, akin to those of a quasi 'state of emergency'. Around the same time, the idea of interdisciplinarity took shape within INRAE (National Research Institute for Agriculture, Food, and Environment), with the implementation of the Sustainable Management of Crop Health (SMaCH) metaprogram. This action was initially undertaken with a view to synchronizing and sharing knowledge among disciplines. Thereafter, a conception of what crop health could mean needed to be defined, especially with regard to dependency on chemical pesticides. In the second phase, disciplines from the social sciences were involved to characterize the socio-anthropological dimension of surveillance that shifted from a delegated mandate to a widespread mobilization of winemakers. Many winemakers meticulously searched for suspicious plants across extensive areas (Malembic-Maher et al., 2023). Finally, in

the third phase, environmental scientific disciplines and, more recently, modelling disciplines were involved (Adrakey et al., 2022; 2023). In this example, in addition to the progressive diversification of disciplines over the long term, there was also a gradual mobilization and diversification of actors to develop a hybrid collective. What was initially considered a vine and biology problem (only) became a territorial problem, at both the sociological and the ecologic levels (Oliveira et al., 2019; Malembic-Maher et al., 2020). This was made possible through the precise project management that ensured synthesis between disciplines, reflecting an interdisciplinary approach quite closely aligned with the model proposed by Jollivet and Legay (2005). Thus far, this sequence suggests that while the disciplines themselves did not undergo transformation during the project, still the precise project coordination ensured a synthesis between disciplines. This example thus represents an interdisciplinary approach that can reasonably be expected to foster collective reflexivity, and may potentially produce more actionable knowledge compared to monodisciplinary or multidisciplinary approaches.

Transdisciplinary approach leading to transformation

Regarding the same issue of pesticide use in viticulture, I illustrate the characteristics of a participatory-action research study that initially started as interdisciplinary, but later became transdisciplinary (Moneyron et al., 2017; Masson et al., 2021). By listening to and legitimizing each actor, and acknowledging the experiential knowledge of winemakers and their parents, as well as the opinions of trainers and advisors in the wine industry and those of a nature conservation association, and last but not least the existing scientific knowledge within the engaged research team, we reached a heterogeneous understanding of reality. This was mainly because the actors had different worldviews, and often disagreed strongly with one another. Relying on an ad hoc epistemological framework, we were able to construct partial consensus on questions that often pointed to 'black holes of knowledge' (Moulin, 2013; Morin, 2014; 2017; 2020). It proved to be the complexity of reality that challenged disciplines and led to the construction of operational interdisciplinarity, where disciplines engaged in dialogue, uncovered interrelations, and even became intertwined. By sequentially diversifying disciplines, the researchers initially involved found themselves lacking knowledge, and challenged. It was not only a matter of mobilizing other disciplines and involving other stakeholders from the region, but also of transforming the research approach more profoundly. This is illustrated in Box 1 by arrows that originate from the

⁴ On Antoine Caudwell, see <https://hal.inrae.fr/hal-02804653/document>.

⁵ <https://france3-regions.francetvinfo.fr/bourgogne-franche-comte/cote-d-or/beaune/retour-emmanuel-giboulot-viticulleur-qui-refusait-pesticides-1732569.html>.

complexity (several puzzle pieces) of reality and point towards disciplines, signifying a transformation in the direction of questions, compared to other approaches. In the section below, I illustrate how this participatory-action research approach became transdisciplinary, where the prefix ‘trans’ signifies transformation. After the initial transformation in the direction of questioning as depicted in **Box 1**, I illustrate the transformation: (1) of research practices for the team involved, and of relationships between disciplines; (2) of viticulture with practical outcomes; and ultimately (3) of actors’ discourse and reasoning.

The transformation of research practices and of the relationships between disciplines

We observed not only that new disciplines were entering into laboratory life, but also that they were being sought out when the project left the laboratory. While initially interdisciplinary relationships guided the project leader, things fundamentally changed during collective workshops aiming at developing a consensus statement on raw data (Masson et al., 2021). Disciplines could no longer draw conclusions from data through their own lens alone, primarily because they discovered that everything was complex and interconnected. As project stakeholders learned to function, at their core, as a complex system, they could understand the data and draw accurate conclusions only within the framework of complexity. This experience led to a transformation of relationships among themselves, and between themselves and all the stakeholders involved. Interconnecting data from humanities and biological sciences was particularly fruitful. This was illustrated in the agro-technical fact sheets (e.g. on plowing, or seeds⁶), as well as in published articles. For example, ceasing the use of herbicides meant incorporating insights from the humanities to address issues of representation. It meant accepting that a few weeds, but not too many, could grow between the vines, thereby moving away from the notion of vineyard rows that had to be ‘clean’, which was the rule in the era of herbicides. It therefore also resulted in a reduction from 6 to 2 of the number of times a plough passed through the rows, and in the sowing of wild-plant seeds in vineyards, despite having fought against them with herbicides for 50 years! Another change was that farmers also reduced the mowing of grassy strips to only once a year, whereas for 50 years the aim had been to keep the grass ‘neat and tidy’. These were astonishing transformations! Each stage of the project was also an opportunity for reflexivity, whether at the individual or collective level. The prefix ‘trans’ meant here that scientific disciplines were invited to transform both

intrinsically and, in their interrelationships, starting from the construction of questions, and especially because stakeholders were involved in what became a team project: ‘our project’ they called it.

The transformation of viticulture

The most salient characteristic of participatory-action research is unquestionably the notion of action. In the context under study here, the production of questions and knowledge through action has led winegrowers to change their viticultural practices. They have given up the use of herbicides, they now cultivate wild plants in the rows between their vines, and they have reduced soil tillage and developed practices to care for the vines. In all these ways, they have shifted away from the logic of fighting diseases and adopted a holistic vision of a viticultural system in which they support their vines’ development, despite diseases and abiotic stresses associated with climate change. These reconceptualizations of viticultural practices on a large scale have gone far beyond the expectations of the Ecophyto plan, a French national plan dedicated to reducing pesticide use by 50% in 2025⁷. They illustrate a transformation of reality at the vineyard scale, as well as a transformation of the timescale: the impacts of these research efforts were tangible as early as 18 months after the initial discussions, whereas the average time for impacts resulting from standard research projects is typically around 15 years (Henaux and Masson, 2021)⁸.

Transformation of the actors’ discourse, their forms of reasoning, and their role in the wine industry

The discourse of all the actors involved in these projects, as expressed during personalized interviews or workshops, was recorded, transcribed, and analysed. This collection was carried out over a long period of time (2013-2019) for the first project group. Here again, we used a new method, textometry, for which we had to receive training. The analysis showed that the discourse of the actors evolved over the long term, around the key words that were prominent at the beginning of the project, in 2013: work, cover crops, and pesticide spraying. During the course of the project, new words emerged, such as organic and biodynamic practices, trials, vintage, and understanding, and around them, a new discourse also took shape (Box 2).

These data indicated, once again, a transformation. Here, it was a transformation of discourse and reasoning

⁶ <https://vitirepere-pnpp.hub.inrae.fr>.

⁷ https://food.ec.europa.eu/system/files/2019-03/pesticides_sup_nap_fra-ecophyto-2_en.pdf.

⁸ www6.inrae.fr/asirpa/.

recognition appears to be the sticking point, almost like a history of unresolved disputes (Ancori, 2005; 2012).

Coming back to agriculture and viticulture, over the past 14 years, in France, 1 billion euros have been invested in the Ecophyto plan to reduce the use of toxic pesticides in agriculture. However, to date, there has been a 12% increase in pesticide usage, instead of the expected 50% decrease⁹. The same stands true in many other countries. Even though some changes have taken place, standard research, training, and advisory regimes have failed to bring about a timely redesign of agriculture on a large scale (Guichard et al., 2017; Sanchez et al., 2023). Let us put this bad story into perspective, while delving even further into the diversification of disciplines that are mobilized in projects characterized by their complexity. Take neurobiology, for example, where we could find explanations for failures and, more importantly, levers for progress. Brain imaging studies have suggested that different regions of the brain are activated, depending on whether people are asked to reduce their environmentally harmful habits or are presented with virtuous practices, or even asked to invent them (Brevers et al., 2021). The illustration with this additional discipline reinforces the idea that, with the notion of transition, standard research, advisory systems and training regimes could not work in the face of major challenges related to harmful agriculture-viticulture practices, as they probably did not bring on line the right brain regions. I hypothesize that with the participatory-action research path depicted here, more relevant brain regions are involved as transformation takes place both in viticultural practices and in the actors' reasoning.

When developing transdisciplinary research-action, we discovered that indicators of transdisciplinarity were lacking. Yet an assessment of the diversity of disciplines mobilized, and the nature of their interrelations may characterize the amplitude of this research. Furthermore, acknowledging and evaluating researchers' contribution and transdisciplinary projects requires appropriate methods. A study of over 18,000 projects, classified as interdisciplinary, showed that the success rate of selection, and therefore the critical financial support, was much lower than for standard projects (Bromham et al., 2016). We infer that this results from an evaluation perspective that also lacks not only interdisciplinarity but also precision regarding the mobilized disciplines and, above all, their relationship formats and the nature of possible outcomes. Similar difficulties arise in the evaluation of scientific articles, and paradoxically these tensions are particularly evident in the case of sustainable development: 'Doing and evaluating interdisciplinary

sustainability research is not an easy path; some days there is no clear path at all' (Editorial, 2018). In terms of mobilization, one could consider the number of participants, the diversity of their worldviews, the duration of collective mobilization, the ability to form multiple project groups, and the complexity of the issues. Yet measurable indicators in these areas remain to be imagined. When it comes to the transformative action of the field of study, and changes in practices, that becomes more feasible.

Regarding the transformation of actors, we can highlight reflexivity and learning (Popa et al., 2015; Madouas et al., 2023), as well as the transformation of practices, as presented here for viticulture, including changes to the links between cultivated and natural spaces, all of which can be specified and evaluated (Moneyron et al., 2017; Masson et al., 2021; Henaux and Masson, 2021). Regarding the nature of existing knowledge, before the start of a participatory project, it neither falls within the same systems of evidence nor belongs to the same epistemological registers, and therefore cannot be assembled to construct a refutable statement, regardless of the format of interdisciplinarity. At best, we remain in a 'negotiation' between the stakeholders of the collective project (Billaud, 2003; Billaud et al., 2017). However, in REPERE participatory-action research, reference models such as the 'Argonaute' or the 'tetrahedron', both of which were collectively designed, allowed us to move away from such 'negotiated' issues. This was because the knowledge was new, collectively produced, within an appropriate epistemological framework, and subjected to both peer evaluation in the scientific field and evaluation by winegrowers through field testing in vineyards (Moneyron et al., 2017; Masson et al., 2021). We nevertheless experienced bigger challenges, with subjectivity appearing more acute in a regime of transdisciplinary participatory-action research. Thus, actors in viticulture called into question the actionability of the knowledge produced, because they were accustomed to the standard formats of knowledge production and transfer that still prevail. For example, the rejection of biodynamic viticulture persists within the wine industry. However, our projects have helped to clarify questions on which partial consensus has been reached, and the answers have been recognized by winegrowers in their diverse viticultural practices, particularly regarding biodynamics (Masson et al., 2021). The challenge of subjectivity also arose when facing the public, which is familiar only with the standard research system or increasingly relies on the vast amount of unverified information available on the internet. Consider again the example of knowledge produced and published on the influence of biodynamic practices on the molecular regulation of vine defences (Soustre-Gacougnolle et al., 2018). These biodynamic practices are heavily criticized by society at large and actors in the wine industry.

⁹ www.francetvinfo.fr/economie/emploi/metiers/agriculture/ou-sont-passes-les-800-millions-deuros-du-plan-anti-pesticides_4876045.html.

Subjective arguments are widely circulated and amplified through internet networks, such as the following comment by an influencer who wrote: ‘How can INRAE spend public money on research on such topics?’ Furthermore, concerning the scientific community, despite a consensus statement published in a top-tier journal, subjectivity has also taken precedence, further challenging this regime of participatory-action research. There have also been brief and curt comments from management, and evaluations from the project leader stating: ‘Your proposal would benefit from being presented to the panel that assesses social science competencies, or being written in a more accessible manner for a panel of biologists’ (of course, symmetrical comments exist from the evaluation by another expert from the social science committee). This example goes along with Darbellay’s observation reporting that: ‘Almost schizophrenic situations are recounted by researchers who play the inter and transdisciplinarity game, while confidently adhering to the institutional displays for the promotion of dialogue between disciplines, and are caught out when the criteria ultimately remain clearly in a purely disciplinary perspective –in relation to evaluation and academic careers’ (Darbellay, 2015). Yet, if everyone, whether a layperson, a winegrower, or any other actor, especially researchers, adhered to the codes of scientific research and the principle of refutation (Popper, 1963), the boundary between a standard regime of knowledge production and the transdisciplinary participatory regime would blur. The idea of ‘negotiating’ results would become obsolete, as would questions regarding the ‘elaboration of truth’ (Billaud et al., 2017).

With respect to actors’ involvement, issues of legitimacy and acknowledgment are often overlooked, as was evidenced by numerous participatory science initiatives, primarily crowdsourcing. Can we truly speak of ‘participatory sciences’, given that their development can also be perceived by society as an instrumentalization of the individuals involved (Calame, 2015; Resnik et al., 2015). Furthermore, there is a genuine question of semantics and ethics, as the term ‘citizen scientist’ is frequently used¹⁰. This is misleading, even if laypersons can participate in a research project, the qualifier ‘scientist’ refers to a specific community. Moreover, knowledge produced becomes scientific only after critical evaluation by peers referring to premises derived from a conceptual or theoretical framework. For a fact to become scientific the principle of falsifiability must prevail, including in participatory research (Popper, 1963). This applies even in situations of participatory-action research in a so-called ‘radical’ mode (Ancori, 2005; 2012), where actors are involved in the formulation of questions and on the production of a consensus

statement. Indeed, the recognition of the latter as a scientific fact relies on researchers and peer evaluation.

We can build collective intelligence to imagine the day after (Billaud and Hubert, 2020), or at least to address questions in their complexity, and thus to meet the expectations of change directed at the research community (Stengers, 2013). Disciplines could then draw on dedicated epistemological frameworks when studying complexity, and could ‘formulate questions in a new way and/or in different registers’ (Billaud et al., 2017) with a view to achieving the necessary transformations to meet global challenges. Yet, disciplines should remain a framework for inventiveness, detached from real time and the contingencies of the present. Hyper-specialization can be an asset if, temporarily, these disciplines contribute to transdisciplinary action research with the idea of productive entropy, as proposed by Foster et al. (2015), and participatory-action research, as outlined here. A ‘dedicated epistemological framework alone does not turn knowledge from experience and the various intelligibilities of the world into scientific knowledge’ (Billaud, 2003); nor can we ‘guarantee that prescribed epistemologies allow us to uncover all the secrets of nature’, as Paul Feyerabend (1979) wrote. In essence, there are undoubtedly several ‘transdisciplinarity’ and ad hoc epistemologies to be built within (and between) the human and experimental sciences, as well as between disciplines and societal actors, and thereby between societal actors too. They can allow us to articulate different forms of reasoning specific to diverse actors, and to reach a consensus on a question –because without a question, there is no knowledge to expect (Bachelard, 2011). In this regard, the precise formulation of consensus questions is one of the first outcomes of the transdisciplinary regime of participatory-action research. And this is a lever to collective mobilization. The resulting new knowledge can be legitimized by the scientific community and lead to widespread adoption of knowledge that is both refutable and actionable in reality, such as the knowledge on vines in the example illustrated in this article and in Masson et al. (2021). Ultimately, I infer that such a transformative research format will require increased diversification and transformation of scientific disciplines. This may lead us to move beyond the deterministic paradigm posed by molecular biology and biology in general, as well as conventional viticulture/agriculture practices, thereby intersecting with the thoughts of E. Morin and H. Atlan (Marks, 2019), addressing society’s expectations regarding ethics, and achieving the world’s awaited transformation.

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¹⁰ www.inrae.fr/sites/default/files/le_citoyen_ce_scientifique.pdf.

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