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► To cite this version:

Anne Merot, Teo Etchepare, Esther Fouillet, Audrey Martinez. Dealing with complexity to reduce pesticides: the case of vineyard cropping systems. 15. IFSA Conference 2024 - Systemic Change For Sustainable Future, Jun 2024, Trapani, Italy. <hal-04732674>

HAL Id: hal-04732674

<https://hal.science/hal-04732674v1>

Submitted on 11 Oct 2024

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Dealing with complexity to reduce pesticides: the case of vineyard cropping systems

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Conference topic: Theme n°1 Transition Pathways: Changing systems of farming, support and governance

Short abstract

Pesticide reduction is a key issue to improve sustainability. Progressive changes in winegrowers' practices are observed to engage deeper and deeper in this transition. However, one difficulty often expressed by winegrowers in interviews is the increasing complexity of management and organisation. This work aims at analysing the evolution of technical and organisational complexity during the pesticide reduction process in vineyard systems. In this work, we assessed the evolution of the technical and organisational complexity of the vineyard cropping system by calculating 3 structural and functional indicators. Interviews were performed in 6 French wine-growing regions. The analysis showed that the three indicators evolved with pesticide reduction. Our results revealed that as pesticide use decreased, functional complexity increased while structural complexity decreased.

Key-words: transition, grapevine, labour, trajectory, system, hierarchy

Purpose

To address current climatic, socio-economic, and environmental issues, cropping systems are evolving rapidly. Pesticide reduction is one of these major issues that brings farmers to modify their cropping systems since negative impacts on human health, environment and biodiversity (IPBES, 2016; Jacquet et al., 2022) have been shown these last decades. Until now, research efforts to reduce pesticides have largely focused on the way to gain in efficiency in the use of existing methods and products or on the development of substitutive methods for pest and disease control without necessarily changing the way pest and disease control is reasoning (Fouillet et al., 2022 and 2023). Thus, research studies propose numerous solutions to significantly reduce pesticides until -30 to -40% compared to the average regional use without reported losses in yield or productivity (Jacquet et al., 2022). However, the issue is so important that a limited pesticide reduction associated to a weak ecological process (Jacquet et al., 2022) is not sufficient. Moving from a curative crop protection approach based on the use of synthetic pesticides to a more preventive approach based on prophylaxis, ecological processes and biological control is now required at farm scale. In turn, this can lead to an increase in the complexity of the cropping system. In parallel, more significant modifications in farm structure, farm organization, and crop management may also be necessary (Darnhofer et al. 2005) to allow the implementation of these levers (Merot et al., 2019). The conditions to favour this change of paradigm are largely questioned. It can be hypothesized that farmers have to find the balance between taking the biological advantages of complexity related to biodiversity (Duru et al. 2015) and simplifying the system's structure (e.g., number of fields and number of plants grown) and management (number of field interventions) to optimize production factors. In this

work, we propose to analyse the evolution of technical and organisational complexity during the pesticide reduction process in vineyard cropping systems.

Design/Methodology/Approach

Complexity definition and assessment: Complexity refers to a system having many components and interactions that are difficult to define and understand (Flood and Carson 1993). The system's complexity increases with the number of components (i.e., structural complexity) and the number of interactions between these components (i.e., functional complexity) (Cadenasso et al. 2006; Lamanda et al. 2012). Assessing complexity requires assessing both the structural and the functional diversity as proposed by Merot and Wery (2017). In this work, we focused on the technical and organisational complexity of the vineyard system. We calculated six indicators proposed by Merot et Wery (2017) in the case of the conversion towards organic farming (Figure 1 – i) vineyard area, ii) number of plots and iii) difficult plots, iv) number of technical management sequences, v) number of interventions per plot and year, vi) number of management indicators). The vineyard area informs on the structural complexity and the two others on functional complexity. These three indicators were calculated every year and stepped all over the pesticide reduction process on a minimum period of 10 years.

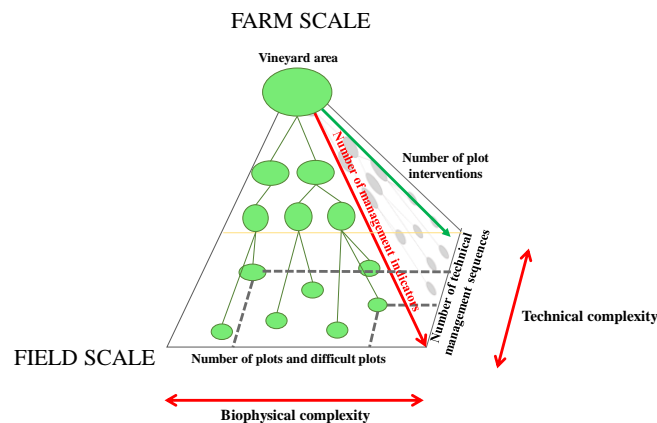


Figure 1: Representation of the vineyard system from plot to farm scale as a hierarchical system combining technical and biophysical components and positioning of the 6 complexity indicators calculated in this work

Data acquisition and farm studied: We interviewed 27 winegrowers in six main wine-growing regions in France spread in various pedoclimatic and production contexts. The winegrowers were more or less advanced in the pesticide reduction process. Each interview consisted in a semi-directive survey (2-3h) on the actual vineyard system completed by a retrospective discussion. The information collected was related to i) the plots' characteristics, ii) the cultural practices and the decision-making process to implement these practices in the various plots in the vineyard. Changes were caught over a period of a minimum of 10 years. We used mapping of the plots and chronologic representation (Figure 2) to collect data during the interviews.

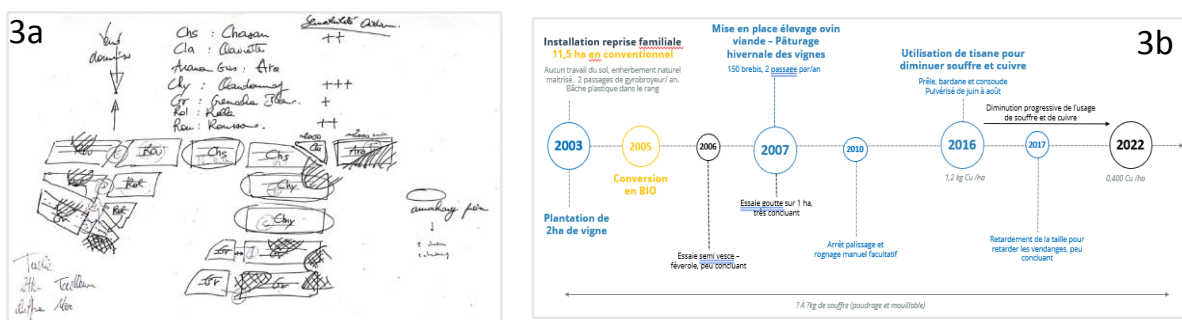


Figure 2: Tools used to synthesise data: 3a) mapping of the plots and 3b) chronologic representation

Indicators calculation: All the data collected let to characterize the intensity of pesticide use and complexity over time. The treatment frequency index was chosen to assess the intensity of pesticide use as it is widely used and accepted in France to assess pesticide reduction (Guichard et al., 2017). TFI was calculated according to the following equation (1):

$$TFI = \sum_{p,t} \left(\frac{Dose_{sprayed}(p,t)}{Dose_{recommanded}(p,t)} \right)$$

Eq(1): Calculation of the TFI (Fouillet et al., 2023) for a given year at the vineyard scale. The TFI equals the sum of the TFI per treatment t and product p , where one treatment corresponds to one product p sprayed and one date of application. The TFI per treatment t and product p is calculated as the dose sprayed per product p ($Dose_{sprayed}_{p,t}$) for each treatment divided by the recommended dose for a product p for the targeted pest ($Dose_{recommended}_{p,t}$).

The pesticide reduction in a vineyard was calculated as the annual TFI divided by the regional TFI. The regional TFI was provided by the French Ministerial Statistical Service for Agricultural Data. Then we calculate the six complexity indicators from Merot and Wery (2017). The vineyard area was directly available with the survey. A deep analysis of the interactions from plot to farm scale between biophysical and technical components of the vineyard system following an HPD analysis (Merot and Belhouchette, 2019) to calculate the number of technical management sequences and the number of management indicators.

Analysis: Each vineyard studied presented specificities in the vineyard area and plot cutting in the landscape that are more linked to the regional context than the farmers' choices. To compare data from different regions and contexts, we normalized the complexity indicators by the number of plots. Linear mixed modelling was performed to test the significance of the relationship between complexity indicators and pesticide reduction. The analyses were conducted in R (R core team, 2021) using the "lme4" package (Bates et al., 2015).

Findings

In this manuscript, we propose to present only three of the six complexity indicators to give an overview of the results. The choice of the three indicators is not motivated by any scientific reasons except to cover a diversity of indicators in nature and components of the system.

Indicator description: Among the vineyard systems and over the period studied, the vineyard area varied from 1ha to 120ha (Figure 3). The data corresponding to the little areas (around 1-2ha) corresponded to farmers that just beginning their agricultural activities 10-15 years ago and that increased vineyard area during the period studied. The number of technical management sequences varied between 0.1 and 1.16 (Figure 3a). This means that in some vineyards most of the plots are conducted the same way with very low diversity in the technical management sequences. On the opposite, some vineyards presented a strong diversification of the technical sequences between plots with more than one technical sequence per plot. The number of management indicators to implement practices varied from 0.1 to 1.7 indicators per plots (Figure 3b). This important variation showed that some farmers have a dense decision-making process that included largely the plot characteristics.

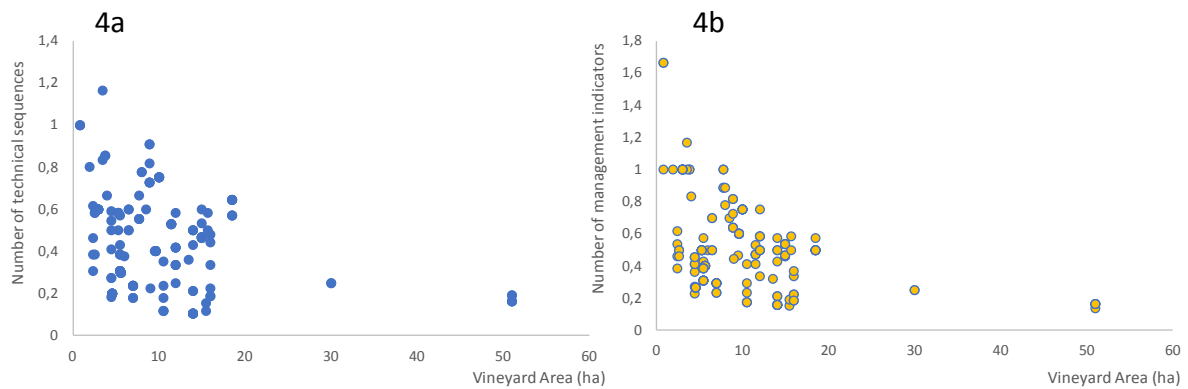


Figure 3: Evolution of two complexity indicators according to vineyard area 4a) The number of technical management sequences normalized by the number of plots in the farm and 4b) the number of management indicators normalized by the number of plots in the farm. Data for the vineyard area superior to 60ha are not shown (5 situations, a situation is the combination of a vineyard and a year)

Findings on the interactions between complexity indicators: When analysing the link between the three indicators studied, we showed that the number of technical management sequences decreased with the increase of the vineyard area (Figure 3a). The evolution of the number of management indicators in the vineyard system followed the same trend as the number of technical management sequences. When the vineyard area increased, the number of management indicators decreased.

Complexity evolution in vineyard systems in transition to low pesticide used: The analysis of the three indicators showed that the complexity evolved with pesticide reduction. The number of technical management sequences and the number of management indicators increased significantly with pesticide reduction (respectively $p=0.09$, $p=0.08$; Figure 4) whereas the vineyard area decreased with the pesticide reduction ($p=0.06$; Results not shown). Our results showed that pesticide reduction is associated to an increase in functional complexity that could be compensated by a reduction in the structural complexity, and reversely.

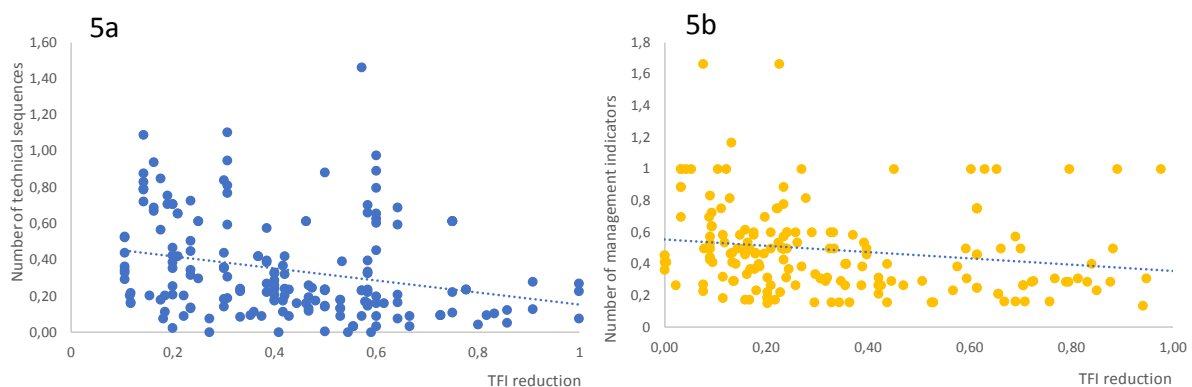


Figure 4 : Evolution of the number of the technical management sequences (5a) and the number of management indicators (5b) in function of the pesticide reduction.

Practical Implications

These results are a step forward in the understanding of the conditions for progressing in the transition towards low pesticide systems. In fact, among the vineyards analysed, some are more advanced than others in pesticide reduction. Our results showed that managing the increase in complexity seemed to be essential to ensure the progression in the transition towards low pesticide systems.

Theoretical Implications

This study contributes to research on the lock-ins and conditions for change implementations from plot to farm scale. Further analyses have to be performed to better understand these results and identify potential compensations and ruptures in the transition. This work must also be completed by the analysis of the other indicators of complexity proposed by Merot and Wery (2017). Anyway, we showed that the transition can be understood as an evolution in the trade-off between the functional complexification and the structural complexity during transition. Farmers have to manage this trade-off during transition adjusting continuously production factors and logic of action when they implement changes.

References

- Bates, D., et al. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 61, 1–48.
- Cadenasso ML., et al. (2006). Dimensions of ecosystem complexity: heterogeneity, connectivity, and history. *Ecol complex.* 3: 1 – 12.
- Darnhofer, I., et al. (2005). Converting or not converting to organic farming in Austria: Farmer types and their rationale. *Agric Human Values.* 22 (1): 39-52.
- Duru M, et al. (2015). How to implement biodiversity-based agriculture to enhance ecosystem services: a review. *Agron Sustain Dev.* 35(4): 1259-1281.
- Flood, RL., Carson, ER. (1993). *Dealing With Complexity: An Introduction to the Theory and Application of Systems Science.* Plenum Press, New York.
- Fouillet, E., et al. (2023). Pesticide use trajectories during agroecological transitions in vineyards: The case of the French DEPHY network. *Agricultural Systems.* 210, 14.
- Fouillet, E., et al. (2022). Reducing pesticide use in vineyards. Evidence from the analysis of the French DEPHY network European. *Journal of Agronomy.* 2022, 136, 126503.
- Guichard, L., et al. (2017). Le plan Ecophyto de réduction d’usage des pesticides en France : décryptage d’un échec et raisons d’espérer. *Cahiers d’agriculture.* 26, 14002. IPBES (2016). Assessment report on pollinators, pollination and food production. Intergovernmental Science-Policy Platform on Bio-diversity and Ecosystem Services, Bonn, Germany.
- Lamanda, et al. (2012). A protocol for the conceptualisation of an agro-ecosystem to guide data acquisition and analysis and expert knowledge integration. *Eur J Agron.* 34: 104-116.
- Merot, A., et al. (2019). Implementing organic farming in vineyards. *Agroecology and Sustainable Food Systems.* pp.1-24.
- Merot, A., Belhouchette, H. (2019). Hierarchical Patch Dynamics Perspective in Farming System Design. *Agronomy,* 9 (10), pp.1-17.
- Merot, A., Wery, J. (2017). Converting to organic viticulture increases cropping system structure and management complexity. *Agronomy for Sustainable Development.* 37 (3).
- R Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.