DOUBLE SUCCESS OF COMBINING TECHNICAL MANAGEMENT WITH LOW PESTICIDE INPUTS IN THE VINEYARD TO OBTAIN PDO WINES IN FRANCE

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Abstract:

Context and purpose of the study – Viticulture is a major contributor to the antagonism of positive reputation and negative environmental impacts of agriculture. Vine contrinbute to structure landscape in the world, resulting, for example, in the delimitation of protected designations of origin (PDO). PDO vine is currently subject to the double challenge of sustainability and climate change adaptation. As vine is very sensitive to diseases and pests, vine requires a high use of pesticides to achieve its quality and yield goals. This high need for pesticides is the most important negative impact of environmental components. This is why there is a challenge to reduce pesticide use without defacing quality and quantity of harvest. For that, new agroecological vine system can be designed with the Efficiency-Substitution-Redesign framework (Hill & Mac Rae, 1995). Consequently, it is necessary to assess existing and future vine systems to validate jointly sustainability and quality. One efficient way is to design or adapt methods developed for other agricultural systems. The purpose of the presentation is to present examples of assessment methods and their implementation on vine, grape and wine.

Material and methods - The results are based on experimentation, survey, qualitative and quantitative analysis of datasets. Material was fields in research institute and in private wineries located in French PDO vineyards.

Results – First, we proposed examples methods assessing sustainability of vine management. The first example is INDIGO®-vine method which assess environemental impact of vine management. INDIGO® was adapted from arable crops. INDIGO® assesses the risk for soil, water, air and human health to vine system (Thiollet-Scholtus & Bockstaller, 2015). The method also implies the design of 2 new indicators dealing with soil cover management and frost protection management. INDIGO®-vine offers a compromise between feasibility and predictive quality. The second example is IDEA method (Zahm *et al.*, 2008), which assesses environmental, social and economic dimensions of sustainability. Finaly, Life Cycle Analysis (LCA) was adapted to vine (Renaud-Gentié *et al.*, 2015, 2020). LCA-vine assesses the environmental components (Nemecek *et al.*, 2022). The adaptation deals with emission and toxicity modelling of pesticides and emission modelling of nitrates (Kadouno *et al.,* 2022). The three methods have been implemented and validated on conventional, integrated, organic and biodynamic vine system.

Secondly, it was necessary to join the assessment of the quality of products of vine, in particular in PDO areas. Lemoigne et al. (2008) built an original multicriteria method to assess ripening of grape. The method makes more efficient to choose the level of grape ripening to the targeted wine to be produced, according to climatic conditions and PDO area. The second example is a predictive assessment model of global quality of grape (Beauchet *et al.*, 2020). Both methods were implemented in real field conditions under several contrasted climatic vintages. At the same time, society is increasingly demanding a more sustainable vine with maintaining grape quality for PDO wine production. To answer this demand, we need to join assessment of sustainability and quality and we need to design and adapt assessment methods to future agroecological vine system.

Thirdly, the first example of an joint method is the aggregation of LCA assessment and the predictive assessment model of grape quality (Beauchet *et al*., submitted). The join method was applied on integrated and organic vine systems. The second example joins INDIGO® indicators, a new socio-economical indicator, named SOECO, biochemical analysis of berry and sensory assessment of wine (Thiollet-Scholtus *et al.,* 2021). The method was implemented on 11 new agroecological vine systems, dealing, for example, with no pesticides and resistant varieties. To conclude, multi-criteria methods to assess future viticulture are a strategic tool for maintaining PDO vineyards both for their sustainability and their ability to adapt to climate change.

Keywords: vine, pesticide reduction, quality, wine, agroecology, system analysis, survey, experimentation

1. Introduction

Maintaining vineyard to produce Protected Designation of Origin (PDO) wines in the world will be a major challenge in a context of climate change (Ollat et al. 2016). PDO vineyard gives a major contributor to a positive reputation of quality of agriculture. But viticulture is also a major contributor to the negative environmental impact implied in climate change. As vine is very sensitive to diseases and pests, vine requires a high use of pesticides to achieve its quality and yield goals. This high need for pesticides is the most important negative impact of environmental components. This is why there is a challenge to reduce pesticide use without defacing quality and quantity of harvest following the Efficiency-Substitution-Redesign framework (Hill and Mac Rae, 1995), already improved for vine system (Merot and Wery, 2017). Increasing agroecological vineyard cropping system in PDO areas will help to reduce impact of vineyard on climate change. Assessment of coupled agroecological practices and required PDO performances of vineyard cropping system is one answer for maintaining production of PDO vines. Several multicriteria methods exist to assess sustainability of agricultural systems (Bockstaller et al., 2008, 2009). Some methods exist to assess sustainability of vineyard cropping system (Angevin et al., 2017). Consequently, it is necessary to assess existing diversity of vineyard cropping system to validate jointly sustainability and quantity and quality of grape. Efficient ways are to use or adapt existing assessment method developed for other agricultural systems and to join these methods together. The present study aims to present examples of assessment methods and their implementation on vine in order to give realistic results of performances of vine both in sustainability assessment and in quantity and quality of grape destinated to produce PDO wines in the world.

2. Material and methods

Experimentation, survey and analysis

The results are based on experimentation, survey, qualitative and quantitative analysis of datasets. Material was fields on-station and on-farm wineries located in French PDO vineyard. Almost all the methods existing in vine experimentation are used combined to get the datasets needed for multicriteria assessment of vine system. The methods used in the results are available in cited references.

3. Results and discussion

3.1 ***Assessment of sustainability*** *of vineyard cropping system*

First, we proposed - results about examples of **implementations of multicriteria methods to assess sustainability** of vineyard system in a context of reducing vineyard impact on climate change. **Assessing is possible by scoring. IDEA** method (Zahm *et al.*, 2019) assesses with scoring environmental, social and economic dimensions of sustainability of cropping system. IDEA is a simple method based on scores linked to practices. IDEA assesses sustainability according to the 3 agroecological, socio-territorial, and economic dimensions. This assessment process is based on a scoring system without any compensation between the scores of the three dimensions. More precisely, the vine-IDEA assesses the level of sustainability based on 5 properties of sustainable viticultural system (autonomy, robustness, ability to produce and reproduce goods and services, territorial embeddedness and overall responsibility). The vine-IDEA is divided into 15 constituent branches of the 5 properties. The 53 indicators are aggregated with a qualitative and hierarchical approach, using the DEXi tool which include modelling (Metral et al. 2015). **Including models** in assessment allows to take into account complexity of vine system. Secondly, we propose **INDIGO®-vine** method example. INDIGO®-vine is a predictive method based on an operational model to assess environmental impact of vine management. INDIGO®-vine method use expert system associated to fuzzy logic, adapted from arable systems four existing indicators addressing issues relevant in viticulture and designing two new indicators, specified for soil cover management and frost protection of the vine. The four indicators were modified to different extent. The structure of the pesticide and energy indicators were changed by adding or removing sub-indicators. For nitrogen and organic matter, the parameter tables were adapted to viticulture and the spatial heterogeneity of vineyard (row and interrow) was introduced in the calculation. The results of vine assessment diverse pedoclimatic contexts and certification (integrated, organic, biodynamic) highlighted some potentialities of using the INDIGO®-vine method. Such assessment can be carried out at field or at farm level with the weighted average values by field size. The spider diagram points (Fig. 1) out strong and weak points of each vine system but does not permit to compare or to rank them. In this case, a composite aggregated indicator would be needed. To achieve this, Fragoulis et al. (2009) used the approach of fuzzy decision tree to aggregate the indicators of the EIOVI approach. Another approach is the MASC model developed for arable cropping systems by Sadok et al. (2009) and using the DEXi software based on qualitative "if then" rules (Thiollet-Scholtus & Bockstaller, 2015). At least**, taking into account the whole life of the product** is another option with Life Cycle Analysis **(LCA)** which was adapted to vine (Renaud-Gentié et al., 2015, 2020). The PestLCI 2.0 inventory model, due to its rather flexible framework, has here been adapted for viticulture without compromising the model framework. The widespread use of PestLCI 2.0 in viticulture reveals the need for models capable of quantifying inorganic Pesticide Active Ingredients emissions. As a second step, Kadouno et al. (2022) selected a nitrate emission calculation model by comparing three of them found in the literature. INDIGO® model has the best suited for the need of risk of nitrates emissions from vineyard and should be integrated in LCAvine® in the future. The three methods, IDEA, INDIGO® and LCA have been implemented and validated on conventional, integrated, organic and biodynamic vineyard copping system.

3.2 ***Assessment of quality*** *of vineyard cropping system for production PDO wine*

As for sustainability, several methods can assess quality of grape, in a context of maintaining production of PDO wine. We propose examples of multicriteria methods to assess quality of grape for PDO wine, implemented in field PDO area and in real field conditions under contrasted climate vintages. Le Moigne et al. (2008) built an original multicriteria method to assess ripening of grape. The method linked sensory analysis with compression parameters measured by spectrometry to predict a consistent description of ripening and plot effect in PDO areas of Loire valley. The results give the possibility to predict sensory attributes of the harvested grapes by spectroscopy and compression. The authors' method makes more efficient to choose the level of grape ripening to the targeted wine to be produced, according to climatic conditions and PDO area. To go further in prediction of quality of grapes, Beauchet et al. (2020) designed a predictive model for assessing the potential quality of a vineyard plot. The model analyzed by partial least squares (PLS) regressions grape quality criteria, viticultural practices, pedological data and climatic data (Fig. 2). The authors identified and quantified the soil, climate and viticultural practice variables that strongly influence grape quality at harvest. At the same time, society is increasingly demanding a more sustainable vine with maintaining grape quality for PDO wine production. To answer this demand, some authors worked on joining assessment of sustainability and quality for PDO by combining designed or adapted assessment methods to future PDO agroecological vineyard cropping system.

3.3 *we need to* ***couple assessment methods*** *to get resilient quality vineyard cropping system in the future*

As previously, scoring, models, and expert system associated to fuzzy logic were used to join method assessment of environmental performances with product quality of vine system. Beauchet et al. (submitted) aggregated LCA assessment for environmental value and a predictive assessment model of grape quality with CONTRA software (Fig. 3). The second example is the coupled INDIGO®-vine environmental method to a new designed **socio-economic indicator, named SOECO** (Thiollet-Scholtus et al., 2021). These additional sustainable indicators were designed to assess socio-economic sustainability of a diversity of agroecological vine system. To discriminate among agroecological vineyard systems, socio-economic indicators have been improved (Fig. 4). We then, defined their thresholds, references, and limits, which are parameters that greatly influence their sensitivity (Bockstaller et al., 2017). For example, from a cost perspective, the high variability in economic performance suggests that not all of the 11 studied agroecological vineyard systems are sustainable. This instability could hinder adoption of agroecological vineyard systems by winegrowers. However, an economic assessment may be insufficient to assess the economic viability of agroecological vine systems. Future economic assessments could benefit from additional detail and a wider range of factors, such as investment and depreciation rates at the farm scale.

4. Conclusions

To conclude, design of method to assess future viticulture is a strategic tool for continuing producing sustainable PDO wine and their ability to reduce impact on environment and on climate. And as a perspective, consequence of transitioning agroecological vine should include assessment method for all vine performances (Fig. 5).

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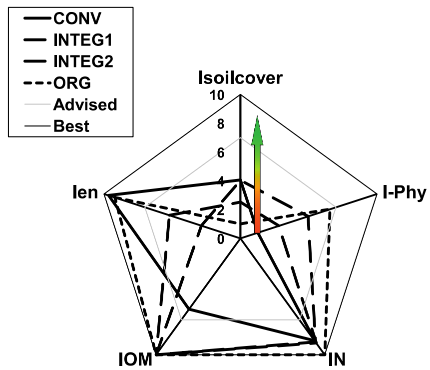

Figure1. INDIGO®-vine multicriteria methods to assess sustainability of vine system, (Thiollet-Scholtus and Bockstaller, 2015).

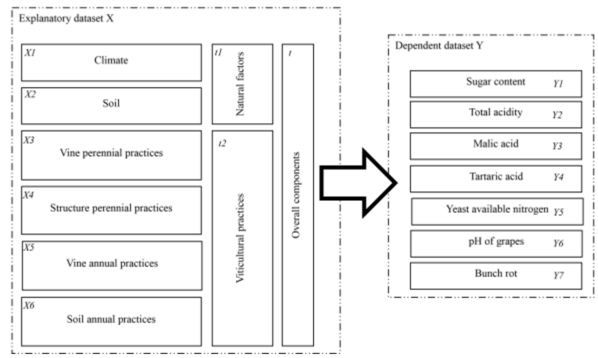

Figure2. Multicriteria method created to assess quality of vine product for PDO area: blocks and group datasets showing the relationships between the blocks of variables used in PLS model of grape quality for wine (Beauchet et al. 2020).

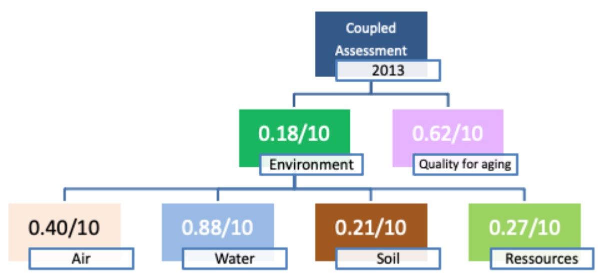

Figure3. Multicriteria method to assess LCA and quality of vine product in PDO area (Beauchet et al. 2017).

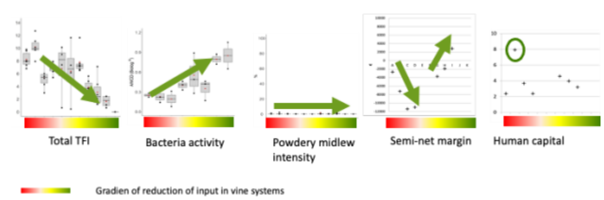

Figure4. Environmental (total TFI, bacteria activity), quality (powdery mildew intensity), economic (semi-gross margin) and social (human capital) indicators results to assess agroecological vine production systems. (Thiollet-Scholtus et al. 2021).

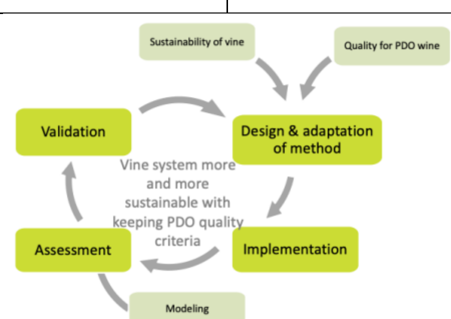

Figure 5. Multicriteria iteration to get more and more performance vine system according to coupling sustainable and quality assessment

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