ASSESSMENT OF ENVIRONMENTAL SUSTAINABILITY OF WINE GROWING ACTIVITY IN FRANCE

[1] [1] [2]
M. Thiollet -Scholtus , G. Barbeau [1]
A. Tonus , , C. Bockstaller
[1]INRA, UE 1117, UMT Vinitera, F-49070 Beaucouzé, France
[2]INRA, UMR 1121 Nancy-Colmar Agronomie-Environnement, F-68021 Colmar, France
marie.scholtus@angers.inra.fr

ABSTRACT

To meet the demand of assessment tool of vine growers and their advisers we adapted to the vine production the INDIGO® method to developed initially for arable farming. This article aims to assess the feasibility and the robustness of the INDIGO® Indicators multi-criteria method of environmental assessment.

INDIGO® indicators of sustainability were built based on different aggregation methods of winegrowers practices and field characteristics. Indicators were tested in Alsace, Champagne, Burgundy, Jura vineyards for northern climate and four vintages (2000, 2001, 2002 and 2003) and Loire Valley vineyards for oceanic climate for 2008 vintage. Four viti-ecological indicators - I-pesticide, I-energy, I-nitrogen and I-organic-matter – were adapted from arable farming. And two viti-ecological indicators - I-soil-cover and I-frost– were created for vineyards. The six indicators were tested in Northern French vineyards and three of them -I-pesticide, I-energy and I-soil-cover- were adapted to oceanic conditions of vineyard production and calculated with 2008 data. INDIGO® viti-ecological indicators were successfully tested in several French vineyards illustrated the large variations between vineyards in rain intensity, fungi attack and winegrowers practices. The results leads us to that these INDIGO® viti-ecological indicators are robust and can be used in all vineyards.

KEY-WORDS

Practices, vineyard, environment, assessment, decision aid tool.

INTRODUCTION

The environmental impacts of viticulture has become a key argument particularly in the context of international competition on global wine markets (Warner, 2007). Sustainable wine growing practices not only matter for environment protection but also happen to be relevant when it comes to evaluating the quality of wine. Far from being a sheer marketing argument for environment-friendly consumers, the "green" label has been proved to affect consumers' wine-purchasing behavior because it is considered as a token of the quality of the product. Sustainability has also become a public concern in France, raising governmental interest for "sustainably made" wine production and sustainable viticulture practices. However, given the significant environmental impact of viticulture practices like fertilization, pesticides, soil cover management in slopes etc. (Girardin et al., 1999), one can find it hard to understand the relative paucity of research on the sustainability of winegrowers' techniques and practices in relation to wine's quality. In 2000, the authors were asked by the Research Development and Extension (RDE) administration to create and develop innovative integrated farming systems and to engineer appropriate viti-ecological tools to evaluate them. INDIGO® indicators, developed initially for arable farming, were designed and tested to answer the need of viticulture industry. The first part of the project was developed in North Eastern France.

This article aims to present the adaptation of four indicators from arable farming, the original building of the two viti-ecological indicators and the calculations of viti-ecological indicators for different vintages, vineyards conditions and winegrowers practices.

MATERIALS AND METHODS

INDIGO® method

According to (Mitchell et al., 1995), indicators are "alternative measures [...] They enable use to gain an understanding of a complex system [...] so that effective management decisions can be taken that lead towards initial objectives". All indicators elaborated according to the INDIGO® method by the research team "Agronomie-Environnement" (UMR ENSAIA-INRA, Colmar, France) are expected to offer several benefits (Girardin et al., 1999): they should be scientifically relevant, user friendly and their results easy to understand. For all these reasons, indicators are calculated with the data available on the vineyard (cultivation practices, soil analyses, permanent characteristics such as field size, slope) . In order to ensure a simple presentation, indicators are expressed on a scale of 0 (high risk) to 10 (no risk) with a reference value of 7 (minimal acceptable impact). Most INDIGO® indicators are calculated at the field level and then weighted by the field size to obtain a mean farm value. The seven step method introduced by (Bockstaller and Girardin, 1999) is used to elaborate and test each indicator (Thiollet, 2003) . Some INDIGO® indicators are bases on continuous variables aggregated in operational models or on qualitative variables aggregated in fuzzy expert systems (Bockstaller et al., 2008).

Fuzzy expert systems

Expert system is used aggregate variables for some of INDIGO®indicators. Expert systems correspond to mathematical reasoning based on a set of rules and decisions made up of premises (IF...) inter-connected by "AND", followed by a conclusion (THEN...) and meet an increasing interest in environmental sciences (Silvert, 2000) . This method allows the aggregation of quite different variables like variables expressed in different units or qualitative variables. The fuzzy expert system is based on a conventional superset (Boolean) logic system with three classes: a "completely true" class, a "completely false" class and a fuzzy class in which values are between "completely true" and "completely false". For example, in order to calculate I-Phy, the system can be used to aggregate both the input variables for each complex module (ESO, ESU and AIR) and the five modules overall (ESO, ESU, AIR, RATE and BEN).

French vineyards

We tested INDIGO® viti-ecological indicators for three years, using data on winegrowers' practices from 51 vineyards in North-eastern France (13 in Alsace, 18 in Burgundy, 10 in Champagne and 10 in Jura) and for 15 vineyards with an oceanic climate in Loire Valley. Surveys have been conducted in sets of selected vineyard in order to build a sample of most types of vineyard existing in France with regards to size, method of harvest (harvested grapes transformed on site or in a cooperative) and vineyard protection strategies (conventional, integrated and organic). Surveys are based on direct closed-ended interviews with a questionnaire, which were carried out with all winegrowers about their practices. 66 winegrowers were interviewed between 2000 and 2009 and follow ups interviews were made after 2 months.

RESULTS AND DISCUSSION

1) I-Phy: adapted indicator from arable farming / fuzzy expert system / pesticides

From I-Phy arable farming evaluation, we kept the global structure of the indicator and of the groundwater quality (ESO), surface water quality (ESU), air quality (AIR) and RATE modules (Thiollet, 2003; van der Werf et al., 1998). Those comportments are based on continuo us and categorical variables, which are aggregated with a fuzzy expert system. The variables belong to three variables groups: the active compounds of the pesticide used, the field characteristics and the winegrowerÕs practices (Tab. 1). Several adaptations to vineyard systems were achieved:

- We developed a new module assessing the effect of pesticides on beneficial organisms (BEN). The calculation integrates (i) the toxicity of the active ingredient on two beneficials *Typhlodromuspyri* and *Kampimodromus aberrans*, which are very important for the vine, (ii) the pesticide formulation, (iii) the number of pesticide applications and (iv) the pesticide rate.
- We considered that sulfur, a fungicide used at high rates spread to protect vines against mildew, is not a significant problem for environment because sulfur can be integrated into the life cycles of animals, plants and microorganisms. The decision rule of the expert system is that the value for the sulfur RATE module is always favorable.
- The module AIR was enhanced by adding a variable assessing the impact of the type of pesticide spraying on drift.
- Soil cover under vineyard rows and between vineyard rows were also taken into account in soil-cover calculation in ESU module.

We changed the structure of the new version of I-Phy for vineyard by aggregating the ESO, ESU, AIR and RATE into an environment module (ENVI), which is then, aggregated with the BEN module (Fig. 1).

Tab. 1: The I-Phy indicator modules RATE, ESO,

Input variables	RATE	ESO	ESU	AIR	BEN
Active compound properties					
ESU, AIR and BEN and their input variables.					
Field half-life (DT50)			*	*	
GUSTAVSON index		*			
Volatility (KH)				*	
Human toxicity (DJA)		*		*	
Aquatic toxicity			*		
Beneficial organisms toxicity					*
Site-specific conditions					
Sensitivity to leaching		*			
Sensitivity to runoff			*		
Drift risk			*		
Application factors					
Rate of application	*				
Position of application	*		*	*	
Type of application				*	

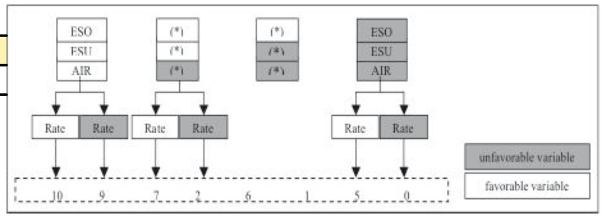

Fig. 1A: Decisions rules for the aggregation of ESO, ESU, AIR and RATE.

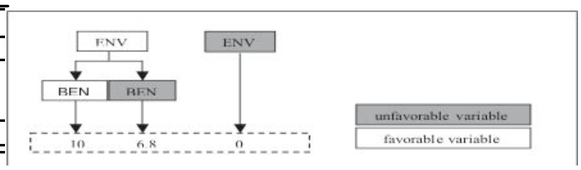

Fig. 1B: Decisions rules for modules aggregation. ENVI: aggregation of ESO, ESU, AIR, RATE and BEN modules.

2) I-frost; new indicator / fuzzy expert system / Erosion and unsustainable energy

RDE administration was interested in having data on environmental assessment of frost protection in vineyards so we built a new indicator. In this context, 3 variables are aggregated with a fuzzy expert system. Three variables, which compose the indicator are: (i) the type of frost protection, (ii) the percentage of the area of the field in which the frost-protection system is implemented and (iii) the number of days per year when the frost protection is switched on to protect the vineyard. To establish a typology of the different frost systems, we aggregated experts' evaluation according to SIMOS method (Maystre et al., 1994; Thiollet, 2003).

3) I-soil-cover: new indicator / equation of a model / Soil erosion

One of the key issues of integrated viticulture is keeping the fertility of soil and controlling soil erosion. This aspect is taken into account in I-soil-cover, which purpose is environmental evaluation of soil erosion. Continuous variables are aggregated with a model adapted from the soil loss universal equation (Schwertmann et al., 1987; Thiollet et al., 2002; Wischmeier, 1975). I-soil-cover indicator represents factors variable influencing significantly the losses of soil in vineyards: percentage and length of slope, coverage of the ground and climate period of erosion risk, field cover includes winegrowers' soil management practices surveyed in French Northern vineyards. We built soils cover tables of the vineyard during the year and according to winegrower's practices to manage soil cover on and between rows (Battany et al., 2000; Louw et al., 1991; Thiollet & Girardin, 2002; Zuzel et al., 1993). We built climate period of erosion risk for Northern and Oceanic vineyards.

4) I-energy: adapted indicator from arable farming / equation of a model / energy use

I-energy indicator purpose is environmental evaluation of energy use, adapted from arable farming. Continuous variables are aggregated with a model adapted from energy used equation (Pervanchon et al., 2002; Pervanchon et al., 2004). I-energy is based on the energetic uses (in MJ/ha) of four types of energy: two for indirect energy (pesticides and fertilizers) and two for direct energy (machinery and frost protection systems for vineyard instead of irrigation for arable farming).

Several adaptations to vineyard systems had been done:

- The remove of irrigation consumption because.
- The addition of frost protection systems consumption.
- The estimation of the machinery fuel consumption on a farm is difficult to obtain directly with the information given by winegrowers but we found and used an equation (Donaldson et al., 1994), which needs only data that are available on farm and we built a database of absorbed power of the machine carried by the tractor (kW) for vineyard.
- We adapted the pesticide and fertilizers databases of indirect energy to vineyard systems.

5) I-nitrogen and I-organic-matter: adapted indicator from arable farming / equation of a model / Leaching and soil fertility

a) The nitrogen indicator IN included in the INDIGO® method. It is based on an operational model simulating nitrate leaching and nitrogen gaseous emissions, NH3 and N2O, in a quantitative way. The model outputs are transformed into scores. Concept of operational model refers here to the choice of input variable based on the availability of data. Several complex inputs such as the wind speed which is are levant variable for NH3 volatilisation are not included into the nitrogen indicator IN (Bockstaller et al., 2008; Pervanchon et al., 2005).

b) The organic matter indicator, I-OM evaluates the effect of winegrowers' practices on the evolution of soil organic matter (SOM) in order to help winegrowers adapt their cultural practices to maintain the SOM at a satisfactory level. The calculation of the indicator is given in an equation based on the comparison of the organic matter (OM) inputs by manure, crop residues and type of soil cover between vine rows with recommended levels of inputs obtained by running Hénin-Dupuis model for several classes of clay and limestone contents in the soil (Bockstaller et al., 1997; Thiollet, 2003).

For both of these indicators, we adapted the databases of organic and mineral fertilizers and soil cover residues especially used in vineyard.

6) Calculation and robustness of indicators

The calculations of the INDIGO® viti-ecological indicators yielded results varying between 0 to 10 (Fig. 2A, 2B, 2C) excepted for I-frost, which showed results between 5 to 9 (Fig. 2D).

For I-Phy, the best values (>7) are always for winegrowers who reduce quantity of pesticide application like (i) using sexual confusion instead of insecticides to struggle to grape-worm (farms A2, A5, A11, B4, B11, B12, C3, C7, C11); (ii) organic farming vineyards (farms A2, B4, L3, L12, L15); or (iii) selling the grapes to a cooperative which uses an integrated farming management (farms L5 and L6), (Fig. 2A). I-soil-cover results allow appreciating (i) soil cover evolution in French vineyards in 2001, vineyard average went from 2.7 to 4.7 whereas, in 2008, vineyard average is 7.2; and (ii) erosion taken into account by winegrowers the same year, in 2001: Alsace average is almost 2 points more than all others vineyards, Burgundy (2.9), Champagne (3.1) and Jura (2.7) averages (Fig. 2B). I-energy results show differences between Jura (average, 7.8) and Loire Valley (average, 5.8) vineyards: according to mechanic grinding of vine shoots pruned in winter, which use a lot of energy (Fig. 2C). I-frost results varied according to the number of days for frost protection and the type of protection used. Strategies based on the used of heating conductors are the most environmental friendly (Fig. 2D). These results showed that viti-ecological indicators can be very useful for agronomists, stakeholders and environmentalists to help vineyard systems to be more and more sustainable, to compare vineyard sustainability at field, farm and region scale. Validations of vineyard INDIGO® indicators deal with "design", "output" and "end-use" validations which are about to be done (Bockstaller et al., 2003).

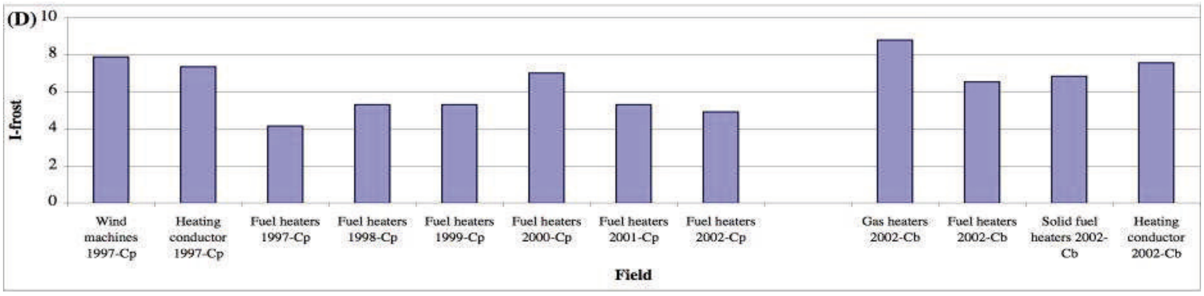

Fig. 2: Results of calculation of INDIGO® viti-ecological indicators at farm scale exept for I-frost. (A) I-Phy: Alsace (2001, Ax), Burgundy (2001, Bx), Champagne (2001, Cx), Jura (2002, Jx) and Loire Valley (2008, Lx); (B) I-soil-cover: Alsace (2001, Ax), Burgundy (2001, Bx), Champagne (2001, Cx), Jura (2001, Jx) and Loire Valley (2008, Lx); (C) I-energy: Jura (2002, Jx) and Loire Valley (2008, Lx); (D) I-frost: Champagne (Cp) and Chablis (Cb) fields different vintage.

CONCLUSIONS

We adapted the INDIGO® method by improving to vineyard by enhancing the structure of some indicators (I-phy, I-energy), creating new ones (I-frost, I-soil-cover) and re-parametrizating others (I-N, I-OM). The INDIGO® viti-ecological adapted and new indicators proved to be robust across time and space, and under different climatic conditions. The INDIGO® viti-ecological indicators are already used in several vineyards at field and farm scales by agronomists, stakeholders and environmentalists even if validation of those indicators need to be finished. Others indicators like social and economic indicators could be calculated with this environmental assessment to have a complete sustainable assessment. And enological environment assessment should be great to help winegrowers in getting more and more eco-friendly practices.

BIBLIOGRAPHY

Battany, M. C., & Grismer, M. E. (2000).. *Hydrological processes, 14*, 1289 -1304.
Bockstaller, C., & Girardin, P. (2003). *Agricultural Systems, 76*, 639-653.
Bockstaller, C., Girardin, P., & Van Der Werf, H. M. G. (1997). *European Journal ofAgronomy, 7*, 261-271.
Bockstaller, C., Guichard, L., Makowski, D., Aveline, A., et al. (2008). *Agronomy for Sustainable Development, 28* , 139-149.
Donaldson, J. V. G., Hutcheon, J. A., & Jordan, V. W. L. (1994). *Aspects of applied biology, 40*, 87-91.
Girardin, P., Bockstaller, C., & Van der Werf, H. M. G. (1999). *Journal of Sustainable Agriculture, 13*(4), 5-21.
Louw, P. J. E., & Bennie, A. T. P. (1991). *Wind and water erosion* , 25-26.
Maystre, L.-Y., Pictet, J., & Simos, J. (1994). *Méthodes multicritères ELECTRE*. Lausanne.
Mitchell, G., May, A., & McDonald, A. (1995). *Int. J. sustain. dev. world ecol., 2*, 104-123.
Pervanchon, F., Bockstaller, C., Amiaud, B., Peingé, J., et al. (2005). *Agriculture, Ecosystems and Environment, 105*, 1-16.
Pervanchon, F., Bockstaller, C., & Girardin, P. (2002). *Agricultural Systems, 72*, 149-172.
Pervanchon, F., & Thiollet, M. (2004). *Travaux & Innovations, 115*, 35-37.
Schwertmann, U., Vogt, W., & Kainz, M. (1987). *Bodenerosion durch Wasser*. Stuttgart: Egen UlmermbH & Co.
Silvert, W. (2000). *Ecological modelling, 130*, 111-119.
Thiollet, M. (2003). Construction des indicateurs viti-environnementaux de la méthode INDIGO. In. Colmar: INRA.
Thiollet, M., & Girardin, P. (2002). *Proc. XIV Intern. Kolloquium " BegrŸnung im Weinbau "*. Geisenheim (Germany).
Van der Werf, H. M. G., & Zimmer, C. (1998). *Chemosphere, 36* (10), 2225 -2249.
Warner, K. D. (2007). *Journal of Rural Studies, 23*(2), 142-155.
Wischmeier, W. H. (1975). *Agriculture research service, USDA, ARS-S-40*, 118-124.
Zuzel, J. F., & Pikul, J. L. j. (1993). *Soil Science, 156*(2), 111-117.