WHICH RISK ASSESSMENT OF WATER QUALITY IN PDO VINEYARDS IN BURGUNDY (FRANCE)?

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Abstract (ID A103)

To meet the demand of assessment tool of water managers we adapted to the vine production the INDIGO® method to developed initially for arable farming at the field scale. This article aims to assess the quality of water in Burgundy areas where viticulture is pointed out to downgrade quality of surface water and groundwater. Knowing production practices at field scale allow locating where changes of production practices could upgrade surface water and groundwater quality.
INDIGO® I-phy indicator of sustainability were built based on different aggregation methods of winegrowers practices and field characteristics with a mark between 0 (risk maximum) and 10 (no risk) and 7 is the acceptable limit for environment. Water modules of I-Phy were tested in three PDO vineyards in Burgundy, in two climate conditions (2011 and 2012). Calculations have been done for I-phy indicator and groundwater (ESO) and surface water (ESU) modules on 32 fields, equally distributed in very high quality and regular quality PDO areas and in integrated or organic/biodynamic systems.
The results lead us to assess water pollution risk in different vineyard conditions. Global risk for environment is low: a very few fields under 7: 6 in 2011 and 7 in 2012 which one field under 3. Most of the global risky fields are in PDO-Rully area.
ESO risk is higher than ESU risk for almost all the fields in the 3 PDO areas. There are 4 reasons explaining the results: (i) active ingredients in used pesticides, even for organic. Active ingredient are classed R50/53. (ii) rate of the active ingredient. (iii) vine growing period of application. (iv) at least, the slope of the fields, the length of the rows, the proximity of a river and the rate of clay in the soil are also important risk factors for ESO risk. Winegrowers in Burgundy are aware of ESO risk and already manage to reduce rate of pesticides and chose the right moment to treat the vine according to the field characteristics.

Keywords: Practices, PDO vineyards, groundwater quality, surface water quality, environmental assessment, INDIGO®

1 INTRODUCTION (SECTION, CAPITAL TIMES NEW ROMAN, BOLD 12PT, LEFT ALIGNED)

The environmental impact of viticulture is a key argument particularly in the context of international competition on global wine markets (Warner, 2007). Sustainable wine growing practices not only matter for water quality protection but also happen to be relevant when it comes to evaluating the quality of wine. Water protection around vineyards 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. for ground water, surface water, air, soil and beneficial (Thiollet-Scholtus and Bockstaller, 2015) at field scale, one can find it very important to manage larger areas like PDO areas. In 2000, INRA searchers 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. During many years, RDE agents used INDIGO® method at field scale. And now, water agencies use INDIGO® indicators at larger scales, i.e. Protected Designation of Origin (PDO) areas.
This article aims to present the calculation of Water modules (groundwater and surface water) of I-Phy indicator for different vintages, vineyards conditions and winegrowers practices in three different PDO vineyards in Burgundy, France.

2 MATERIALS AND METHODS

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". I-Phy (i.e. pesticide-indicator) elaborated according to the INDIGO® method by the research team "Agronomie-Environnement" (UMR ENSAIA-INRA, Colmar, France) is expected to offer several benefits

(Girardin et al., 1999): I-Phy indicator is scientifically relevant, user friendly and its results easy to understand. For all these reasons, each water module of I-Phy indicator is also 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, water modules of I-Phy indicator are named: ESO for groundwater and ESU for surface water. ESO and ESU are both expressed on a scale of 0 (high risk) to 10 (no risk) with a reference value of 7 (minimal acceptable impact) and can be aggregated to others modules to get a global value of I-Phy indicator (not presented in this paper). Water modules of I-Phy indicator are calculated at the field level and are highly representative of each PDO areas.

Fuzzy expert systems

Expert system is used aggregate variables for water modules of I-Phy indicator. 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". In order to calculate ESO and ESU, the system is used to aggregate all the input variables in each module.

French vineyards

We calculated ESO and ESU modules of I-Phy indicator for two years, using data on winegrowers' practices from 32 vineyards in Burgundy (Tables 1 and 2): 12 in Beaune, 8 in Rully and 12 in Vosne-Romanée, equally distributed in very high quality and regular quality PDO and in integrated or organic/biodynamic systems. Surveys have been conducted in sets of selected vineyard in order to build a sample of most types of vineyard existing in Burgundy with regards to size, method of harvest (harvested grapes transformed on site or in a cooperative) and vineyard protection strategies (integrated, organic and biodynamic). Surveys are based on direct closed-ended interviews with a questionnaire, which were carried out with all winegrowers about their practices. Thirty-two winegrowers were interviewed between in 2013.

3 RESULTS AND DISCUSSION

The results leads us to that these INDIGO® I-phy indicator allow us to assess water pollution risk in all different vineyard areas in Burgundy (Figure 1).

Global risk for environment calculated with I-Phy indicator is low: a very few fields under 7: 6 in 2011 and 7 in 2012 which one field under 3.

I-Phy risk is low for both studied years: respectively 6 fields have a risk under 7 in 2011 and 8 fields have a risk under 7 in 2012.

I-Phy risk for environment minimum value is 3.0: for the field B12_1, from Beaune area in 2012. B12_1 field is Premier Cru PDO. B12_1 practices are integrated.

Thirteen fields have an I-Phy value up to 9.5 in 2011: six Beaune fields, one Rully field and six Vosne-Romanée fields. Twels fields have an I-Phy value up to 9.5 in 2012, but not exactly the same fields as il 2011: three Beaune fields, one Rully field and eight Vosne-Romanée fields.

Some pest pressure on the vine may explain these differences. Indeed 2011 was a climate vintage drier and hotter than 2012. As a result, in 2012, winegrowers might have managed pest pressure easier in 2011 than in 2012. That could explain the difference in the lowest I-Phy values, respectively 6.2 and 3.0.

Most of the global risky fields are in Rully area. The reasons explaining these differences are:

The building of I-Phy indicator, made in the 2000's is dealing with references (0, 7 and 10) available at this moment and corresponding to what winegrowers usually manage as practices in the fields. The environmental references in the 2010's have move forward from the 2000's.

This is illustrated by comparing I-Phy results in the same wine production area, Burgundy, between 2000 and 20016. In these high quality PDO areas, winegrowers have practices more and more environment friendly (Thiollet-Scholtus et al., 2010).

ESO risk is higher than surface water risk for almost all the fields and the PDO areas (Figure 2).

ESO risk is high for both studied years: respectively 22 fields have a risk under 7 in 2011 and 27 fields have a risk under 7 in 2012.

ESO risk for environment minimum value is 2.2: for the field V21_1, from Vosne-Romanée area in 2012. V21_1 is in Village PDO. V21_1 practices are integrated.

ESO risk for environment maximal value is 7.8: for the field V22_2, from Vosne-Romanée area in 2012. V22_2 is in Village PDO. V21_1 practices are biodynamic.

In 2011, ESO risk varies between 4.88 and 7.27.

There are four reasons explaining the results: (i) the active ingredients of the pesticide used in the fields, even for organic. Active ingredient are classed R50/53. (ii) the rate of the active ingredient is the second reason of risk of groundwater pollution. (iii) the vine growing period of application is the third risky factor for groundwater pollution. (iv) at least, the slope of the fields, the length of the rows, the proximity of a river and the rate of clay in the soil are also important risk factors for groundwater pollution.

ESU risk is lower than groundwater risk for almost all the fields and the PDO areas (Figure 3).
ESU risk is very low for both studied years: respectively 2 fields have a risk under 7 in 2011 and 3 fields have a risk under 7 in 2012.
ESU risk for environment minimum value is 4.0: for the field B12_1, from Beaune area in 2012. B12_1 field is Premier Cru PDO. B12_1 practices are integrated.
ESU risk for environment maximal value is 9.6: for the field V4_2, from Vosne-Romanée area in 2012. V4_2 is ESU Premier Cru PDO. V4_1 practices are biodynamic.
In 2011 and in 2012, ESU risk sensitively varies in the same interval, respectively, from 5.6 to 9.6 and 4.0 to 9.4.
ESU risk is low because most of the vineyard fields are far enough from rivers and surface water. As a consequence, pesticide active ingredients have time to be deleted by inorganic (i.e. photo-oxidation) or organic (i.e. oxidation of reduction) pathways before having a risk to infect the nearest surface water of the field.

4 CONCLUSION

Winegrowers in Burgundy are aware of groundwater risk and already manage to reduce rate of used pesticides and chose the right moment to treat the vine according to the field characteristics. Water modules if I-Phy indicator from INDIGO® method is a very useful decision tool to manage vineyard territories according to more and more environmental friendliness.

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Table 1: PDO distribution of fields in the three studied areas in Burgundy.

	Grand Cru	Premier Cru	Village
BEAUNE		**10**	**2**
RULLY		**5**	**3**
VOSNE-ROMANEE	**2**	**4**	**6**
Total	**2**	**19**	**11**

Table 2: Production system distribution of fields in the three studied areas in Burgundy.

	Integrated	Organic	Biodynamic
BEAUNE	**8**	**3**	**1**
RULLY	**7**	**1**	
VOSNE-ROMANEE	**6**	**1**	**5**
Total	**21**	**5**	**6**

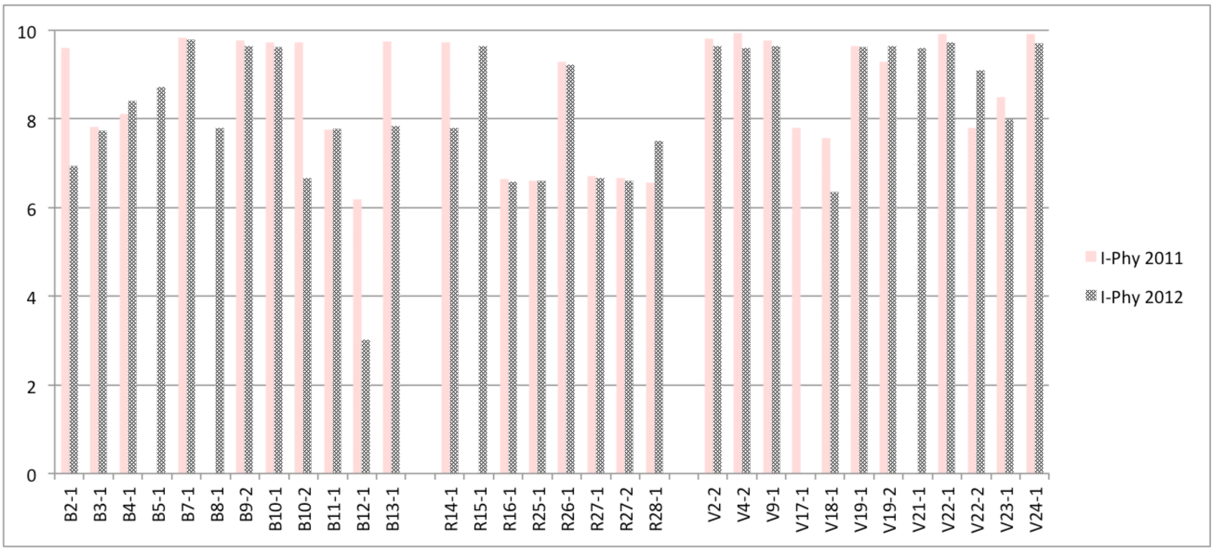

Figure 1: I-Phy results in PDO Beaune, Rully, Vosne-Romanée, for vintages 2011 and 2012.

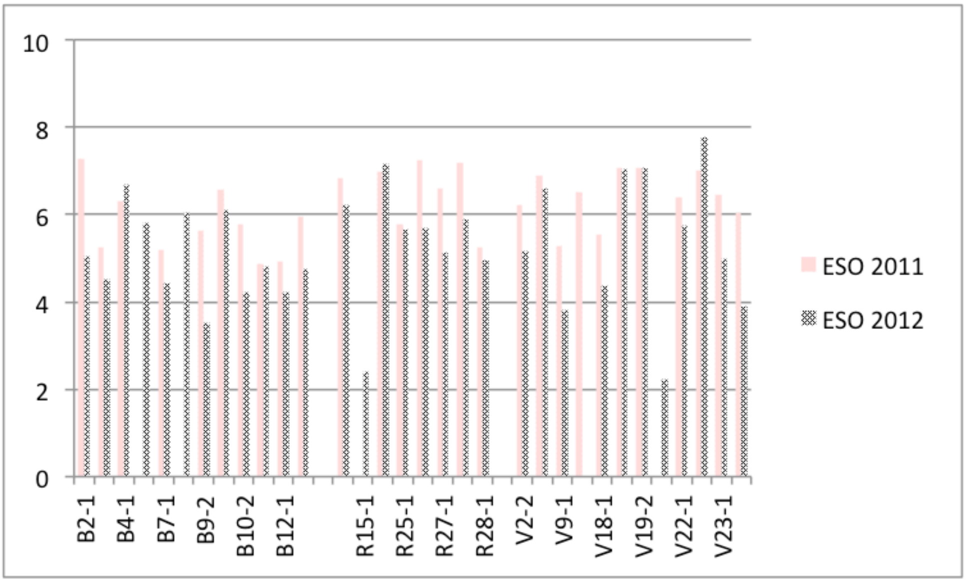

Figure 2: ESO results in PDO Beaune, Rully, Vosne-Romanée, for vintages 2011 and 2012.

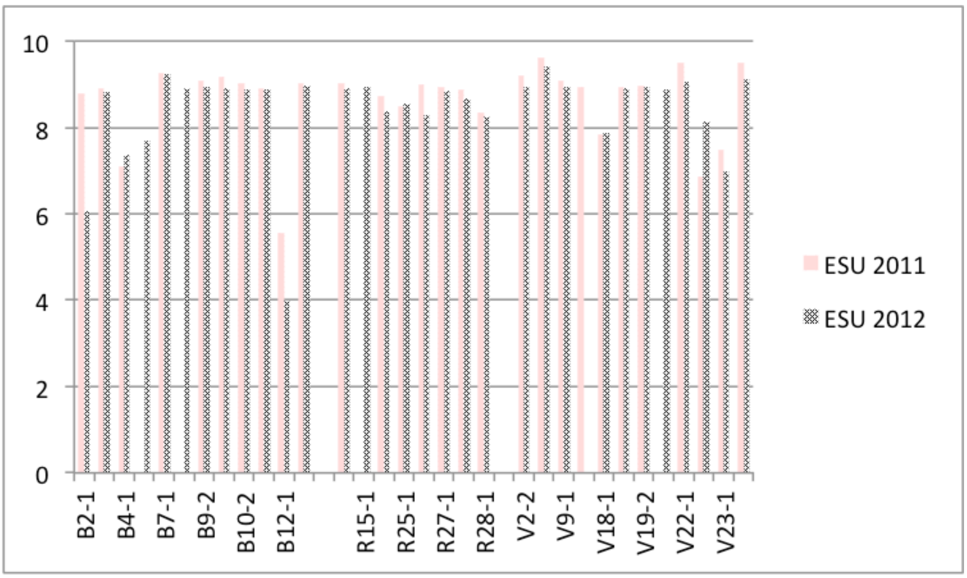

Figure 3: ESU results in PDO Beaune, Rully, Vosne-Romanée, for vintages 2011 and 2012.