C22 Evolution of farming practices in the French vineyard The use of pesticides 2006-2013

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ABSTRACT

The French surveys on viticulture 2006, 2010 and 2013 form part of a wide range of surveys on farming practices. One of their primary objective is to evaluate the use of pesticides. A good knowledge of their use is a major challenge for sustainable development because of their relationship with environmental and health risks.The first part of this study identifies the main indicators on the use of phytosanitary products and focuses on the treatment frequency index (TFI). Based on the Danish experience, this indicator is built with the normalized doses of pesticides actually applied by the wine producers. It can be easily expressed on a regional scale or on pesticides subdivision. In France, this indicator varies from 9.2 in Pyrénées-Orientales to 21.4 in Champagne in 2013. The second part raises the question of the climate effect on the TFI variations 2013/2010. The weather with its stimulus role in the parasite development can cause an augmentation of the use of pesticides. In 2013 degraded climatic conditions, the TFI has increased in all vineyards. The use of a fixed effect model leads us to estimate a significant climate effect in 7 vineyards out of 13. The weather variations between 2010 and 2013 contribute from 6% in Bourgogne to 31% in Val de Loire to the TFI increase.

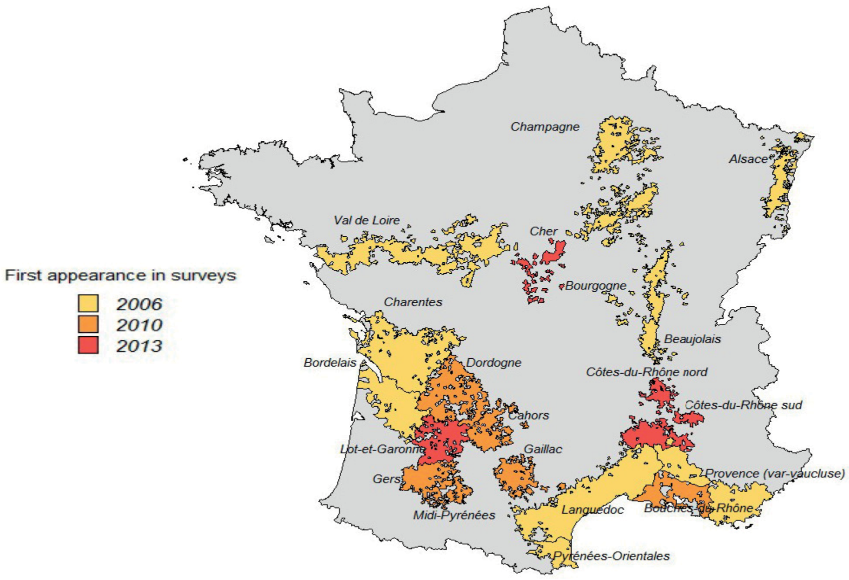
Keywords : pesticides, treatment frequency index, climate effect

PAPER

1. Introduction

Since the mid of the 2000's, the French statistical service has launched a wide range of surveys on agricultural practices. These surveys are a major tool to assess the impact of the French public policy Ecophyto[1] that was developed by the French Ministry of Agriculture in 2008 with the purpose of progressively reducing the use of pesticides while maintaining agricultural performance. The surveys cover nowadays the main crops productions: field crops, fruits, vegetables and viticulture[2]. This paper will focus on the 3 waves of the survey on viticulture implemented in 2006, 2010 and 2013.

Figure 1 - The French vineyards map Farming practices surveys in viticulture 2006, 2010 and 2013.



1 This public policy is an answer to the Article 4 of Directive 2009/128/EC. A second version of the Ecophyto plan was published in 2015. Among its main objectives is the reduction in pesticides use in two stages: -25% by 2020 and -50 % by 2025.

2 Wine grapes.

2. Measuring the use of pesticides

The relationship between pesticides and environmental and health risks is beyond doubt and is coming into sharper focus. The permanent crops like vines consume large amounts of pesticides. In 2013, the French vineyard area is about 800 000 hectares and represents a major challenge for the reduction of the use of phytosanitary treatments. To evaluate the practices, several indicators have been developed.

2.1 Number of phytosanitary treatments and sales of active ingredients

A phytosanitary treatment is defined as the use of a commercial product across a cultivated land during a cropping season. A same product applied in two passes counts for two treatments. A mixture of two products applied during a single pass also counts for two treatments. Most of pesticides can be subdivided into the fungicides (against fungi), the insecticides (against insects) and the herbicides (against plants considered to be « weeds »).

The **number of phytosanitary treatments** does not take into account the spread quantities during each pass. Some vineyards can be treated with several passes with low pesticides doses while others are often less treated but with higher doses during each pass. For example, two passes with halfdose count for two treatments whereas a single pass with full dose counts for one treatment. However, the sanitary pressure is the same in the two cases.

An other pressure indicator regularly followed in Europe is the total **quantity of active ingredients** which is sold on a given territory. The main limit of this indicator is the measure of the difference between sale and consumption of pesticides. For example, the storage variations of products from year to year can create a gap between sale and use of pesticides for a given year. Thus, this indicator can decrease even though the pressure on the environment is the same.

2.2 The treatment frequency index (TFI)

The treatment intensity index (TII) is a monitoring indicator of the use of pesticides. It has been developed in Denmark in the middle of the 80's. It is defined at the national level:

$$TII = \frac{\sum_{AI} \frac{SQ_{AI}}{ED_{AI}}}{TCA} \quad (1)$$

SQ_{AI} Sold quantity of active ingredient
ED_{AI} Effective dose of active ingredient
TCA Total cultivated area

In France, the National Institute for Agricultural Research (INRA) and the Ministry in charge of agriculture have developed in 2006 a calculation method based on the Danish experience (Champeaux, 2006 ; Pingault et al., 2009). The French version, the treatment frequency index (TFI), is not built with the active ingredients but with the phytosanitary products. It also takes into account the quantities actually applied by the wine producers instead of the sold quantities. Since 2007, it is implemented as a supporting and evaluation tool for the reduction of the use of pesticides.

For the TFI calculation, the « pesticides » item of the questionnaire allows to identify the applied products during each pass for a given vineyard parcel. For each applied treatment on the vineyard parcel[3], the TFI is the following:

$$TFI = \frac{DA}{ED} * PTA \quad (2)$$

DA Dose actually applied per hectare (from survey)
ED Effective dose for a target (diseases/pests) per hectare (from target framework)
PTA Percentage of treated area (from survey)

Specific cases:

- Some products do not have effective dose (ED). In this case, the TFI is equal to the percentage of treated area (PTA),
- If TFI<0.1 or >2, or if it is a misuse, it will be corrected by imputation (mean based on vineyard and target). Depending on the year, these corrections vary from 2% to 5% of the observations,
- TFI=1 for pheromone dispensers (mating disruption).

Until 2015, the effective dose was defined on a pair (culture, phytosanitary product). When several effective doses were available corresponding to different targets, the calculation method was based on the lowest dose. The methodology has been improved with the use of the triplet (culture, phytosanitary treatment, target) to determine the effective dose.

[3] Rodenticides, repellent products, talpicides are not included.

For the 2006 survey, the target of the used product was not collected. To calculate the TFI, the method has been as follows:

- The pairs (phytosanitary product, target) 2010 were settled.
- The 2010 target was applied to all the 2006 products still existing in 2010. For the 2006 products that disappeared in the meantime, the target has been searched in a reference viticulture basis.

Figure 2 - Examples of the TFI calculation Farming practices survey in viticulture 2013.

Date	Product	Target	Percentage of treated area	Applied dose (KG/HA)	Effective dose (KG/HA)	TFI
2013-03-01	PLEDGE	Herbicide	60	1	1,2	1/1.2*0.6=0.5
2013-05-28	VALIANT FLASH	Mildew	100	3	3	3/3*1=1

The « TFI parcel » is defined as the sum of the TFI.

2.3 Results by vineyard

In 2013, the average TFI varies largely across vineyards ranging from 9.2 in Pyrénées-Orientales to 21.4 in Champagne. The protection of grape wines against microscopic fungi is responsible for around 80% of the phytosanitary treatments. Thus the main source of regional heterogeneity is related to the dispersion of the TFI fungicide.

Between 2006 and 2013, the TFI has increased in all vineyards but in varying degrees. The highest increase has been measured in Bourgogne (+5.6), the lowest one in Alsace (+0.5).

Table 1 - TFI by pesticide subdivision and vineyard between 2006 and 2013

	TFI Herbicide			TFI Fungicide			TFI Insecticide			TFI		
	2006	2010	2013	2006	2010	2013	2006	2010	2013	2006	2010	2013
Alsace	0.6	0.3	0.3	8.8	9.3	9.8	1.1	0.8	0.7	10.4	10.4	10.9
Beaujolais	1.1	1.2	1.4	11.3	14.1	16.6	1.0	0.9	1.0	13.5	16.3	19.0
Bordelais	0.5	0.5	0.4	12.1	12.2	14.5	1.7	1.4	2.0	14.2	14.1	16.9
Bouches-du-Rhône	na	0.2	0.2	na	8.2	9.0	na	0.3	0.2	na	8.6	9.3
Bourgogne	0.8	0.7	0.9	12.7	13.9	17.4	0.7	0.4	1.6	14.2	15.0	19.8
Champagne	1.3	1.2	1.4	17.6	15.7	19.2	0.8	0.7	0.8	19.7	17.6	21.4
Charentes	0.5	0.5	0.7	10.9	12.5	14.7	1.8	2.2	2.8	13.3	15.2	18.2
Dordogne	na	0.3	0.3	na	10.5	12.6	na	1.7	2.2	na	12.5	15.1
Gers	na	0.4	0.5	na	14.5	16.2	na	1.8	2.6	na	16.7	19.3
Languedoc	0.4	0.4	0.5	8.2	9.4	10.5	1.9	1.8	2.2	10.5	11.5	13.2
Provence	0.2	0.2	0.3	6.3	8.3	8.9	0.4	0.5	0.4	6.8	8.9	9.6
Pyrénées-Orientales	0.6	0.4	0.5	5.8	6.4	6.5	2.1	2.1	2.2	8.5	8.8	9.2
Val de Loire	0.6	0.9	1.0	7.2	9.3	11.5	0.6	1.1	1.1	8.4	11.3	13.6

na: not available.
Farming practices surveys in viticulture 2006, 2010 and 2013.

3. Parasite pressure, climate and TFI

Several factors can explain the phytosanitary treatments level: the parasite pressure of the year which is partly related to climatic factors; the farming practices of the wine producers who use more or less pesticides,... The main aim of this paper is to isolate the impact of the parasite pressure on the level and the evolution of pesticides use as measured by the TFI index. The analysis will focus only on the years 2010 and 2013 to use a panel approach and also because some climatic factors, used as a proxy for parasite pressure, are not available for the year 2006. It will be based on 13 vineyards.

3.1 Measuring the parasite pressure

Mildew and oïdium are the major diseases of vine. They develop better with a hot and humid weather. Mildew affects the photosynthesis and causes a lagging maturity and a decrease in the alcoholic degree. Oïdium can cause a decrease in the grape wine quality by reducing the content in phenols and sugar. Repeated attacks of these diseases on leaves and grapes can destroy an entire crop. To evaluate the parasite pressure, two sources are available. The first one relies on quantitative indicators built by a network of regional observers. The pressure level is determined for each vineyard and covers most of the parasites. The second source is based on the farming practices surveys that also collect some qualitative indicators on the parasite pressure (strong/ average/ weak pressure). To answer this question, wine producers rely on their experience about the cultural parcel.

According to the quantitative approach, both « mildew » and « oïdium » pressures have increased between

2010 and 2013 in 2 regions (Charentes and Val de Loire) and both have decreased in one region (Provence). In the other regions, the evolution of parasite pressure is not the same for mildew and oïdium.

Table 2 - Level of parasite pressure 2013/2010

	Parasite pressure 2013/2010		
	More pressure	Equal	Less pressure
Mildew	Alsace, Bordelais*, Bourgogne, Charentes, Dordogne*, Val de Loire.	Beaujolais, Champagne.	Bouches-du-Rhône, Provence.
Oïdium	Beaujolais, Champagne, Charentes, Val de Loire.	Bouches-du-Rhône, Bourgogne.	Alsace, Bordelais*, Dordogne*, Provence.

**Regional phytosanitary results do not distinguish Bordelais and Dordogne.*
Regional phytosanitary results are not available in 2010 in the following vineyards : Gers, Languedoc and Pyrénées-Orientales. In 2013, "mildew" pressure was described as "average" in Languedoc and "weak" in Pyrénées-Orientales. At the same time, "oïdium" pressure was described as "average" in both vineyards.
Regional phytosanitary results in viticulture 2010 and 2013.

The qualitative approach provides divergent conclusions. Except for Pyrénées-Orientales, the "mildew" is perceived as a growing pressure on average for all vineyards. The "oïdium" pressure also increases except in Alsace, Bouches-du-Rhône, Gers and Pyrénées-Orientales where it is stable. Whatever the level of pressure, the TFI average in 2013 exceeds the one in 2010. Whatever the year, the highest TFI average is obtained when the parasite pressure is felt strong for mildew and weak for oïdium.

Given the difficulty to obtain objective indicators at the parcel level to quantify the parasite pressure effect, we finally opt for an indirect measure: the impact of climatic factors on the TFI. If climatic conditions are not the only determinant for parasite pressure and phytosanitary treatments, they are important parameters in the use of pesticides. In 2013, 44% of wine producers said that weather forecasts and rainfall were the main reasons for the use of pesticides.

3.2 Climatic factors and TFI

The spatialised data base of Meteo-France provides for each parcel the information collected by the nearest grid point (about ten kilometers grid). From April to August, the following monthly parameters can be observed: rainfall (RR), sunshines (INST), average and range temperatures (TMOY, AMPT), wind speeds (FFM) and humidity (HUMOY).

In April and May 2013, the rainfall has increased with respect to 2010 in all vineyards in particular in Bourgogne, Beaujolais and Champagne. During these two months, the average temperatures were significantly lower with important gaps in May (-3°C). In April, the wind was strong in particular in Dordogne and Gers. In May, except in these two vineyards and in Bordelais, it is a reverse trend. In June 2013, the rainfall has decreased and the average temperatures were significantly higher especially in Beaujolais, Bouches-du-Rhône and Provence. In July and August 2013, the weather was very sunny in particular in Alsace, Bourgogne, Champagne and Charentes.

A principal component analysis (PCA) is performed to study the correlation between climatic factors and TFI. The main results are the following:

- Overall, a stronger correlation between climatic factors and TFI for the year 2013,
- A positive correlation between TFI and rainfall and humidity variables,
- A negative correlation between TFI and sunshines, wind speeds and temperatures variables.

Using an ascending hierarchical classification (AHC), we can isolate three large geographical areas in France:

– Mediterranean area: Bouches-du-Rhône, Languedoc, Provence and Pyrénées-Orientales. This area is characterized by abundant sunshine and frequent high winds (in particular in Pyrénées-Orientales). This area has the lowest TFI level and TFI increase between 2010 and 2013 (from 10.7 to 11.9),

– Continental area: Alsace, Beaujolais, Bourgogne and Champagne. This area is characterized by wide temperature variations and abundant rainfall. This area has the highest TFI level and TFI increase between 2010 and 2013 (from 15.4 to 18.7),

– Atlantic area: Bordelais, Charentes, Dordogne, Gers and Val de Loire[4]. This area is characterized by mild temperatures and high humidity. The TFI in this area is a bit lower than in the continental area and its increase between 2010 and 2013 is more moderate (from 14.1 to 16.7).

[4] Val de Loire is classified in the "Atlantic area" but this vineyard is very close to the characteristics of the "Continental area".

4. Measuring the climate effect

The aim of this section is to focus on the impact of climatic conditions on TFI variations in order to obtain a 2010-2013 TFI evolution with controlled climatic factors.

To explain the TFI evolution, the model selects only climatic factors as independent variables. This choice is justified by the fact that farming practices, although important to explain TFI level, do not vary much over time for vineyards. Firstly, the vine is a permanent crop and has fixed characteristics like grape variety, density, no rotation.... Secondly, the main farming practices that can be observed in the surveys like weed control, fertilization, shoot and bud removing, leaf pulling, irrigation vary scarcely over time. Thus, between two years, their impact on TFI variation is rather neutral. Therefore, if the exclusion of farming practices as independent variables could in theory create a bias on the estimated coefficients (omitted-variables bias), their exclusion in the model may be justified for the vineyards.

4.1 Data modeling

The panel is composed of 4 838 parcels. Some atypical data were withdrawn (14 parcels). Several classic functional forms were tested: log-linear, semi-log and linear. Finally, the linear form was chosen.

Multicolinearity and variable selection were treated simultaneously with LASSO (Least Absolute Shrinkage and Selection Operator). Without going into details (Tibshirani, 1996), this method rewords the least squares problem but with an additional coefficient requirement. The coefficients of the most correlated variables are 0. All the average temperatures variables are excluded because of their correlation with the range temperatures variables.

17 variables and 6 cross effects are selected (04=April, 05=May, 06=June, 07=July, 08=August): RR04, RR05, RR07, RR08, AMPT04, AMPT06, AMPT08, FFM04, FFM05, FFM07, FFM08, HUMOY04, HUMOY05, HUMOY07, HUMOY08, INST05, INST07; RR07*INST07, AMPT06*HUMOY06, INST05*FFM05, INST05*HUMOY05, INST07*HUMOY07, FFM04*HUMOY04.

In a first model, we assume that the climatic variables effect is not the same across the vineyards. According to this hypothesis, the model writes:

$$TFI \;=\; \sum_{k=1}^{13} \beta_k X \, I_{(Vineyard=k)} \;+\; \beta_{0k} I_{(Vineyard=k)} \;+\; \delta_k I_{(Vineyard=k)} I_{(Year=2013)} \;+\; \varepsilon \quad (3)$$

$I_{(Vineyard=k)}$ Dummy variable for vineyard k
X Climatic factors
$I_{(Year=2013)}$ Dummy variable for year 2013
ε Residual

The number of available observations is however too limited to allow this model to be estimated. In a second model, we relax the constraint of the heterogeneity of the climatic variables effect and we assume that the climatic variables have the same effect whatever the vineyard. Only a vineyard fixed effect remains in the model to take into account specific unobserved variables that affect the TFI.

The second model with fixed effect has the following form:

$$TFI \;=\; \beta X \;+\; \sum_{k=1}^{13} \beta_{0k} I_{(Vineyard=k)} \;+\; \delta_k I_{(Vineyard=k)} I_{(Year=2013)} \;+\; \varepsilon \quad (4)$$

$I_{(Vineyard=k)}$ Dummy variable for vineyard k
X Climatic factors
$I_{(Year=2013)}$ Dummy variable for year 2013
ε Residual

The dummy coefficient of vineyard*year gives the TFI difference 2013/2010 corrected by climatic factors.

4.2 Results by vineyard

The estimated model identifies a significant climate effect on the TFI difference in 7 vineyards out of 13: Beaujolais, Bordelais, Bourgogne, Champagne, Charentes, Languedoc and Val de Loire. The weather explains from 6% in Bourgogne to 31% in Val de Loire of the difference between the TFI in 2010 and the one in 2013. For other vineyards, the change in weather conditions between 2010 and 2013 does not seem to have a significant impact on the TFI increase.

Table 3 - Climate effect 2013/2010 by vineyard

	TFI 2010	TFI 2013	TFI difference 2013/2010	Explained part (%) by the weather 2013/2010	Signif. Codes
Alsace	10.4	10.9	0.5	0	***
Beaujolais	16.3	19.1	2.8	30	**
Bordelais	14.2	17.0	2.8	13	***
Bouches-du-Rhône	8.9	9.3	0.4	0	
Bourgogne	15.1	19.8	4.7	6	***
Champagne	17.8	21.4	3.6	13	***
Charentes	15.3	18.2	2.9	27	***
Dordogne	12.6	15.1	2.5	0	***
Gers	17.0	19.4	2.4	0	***
Languedoc	11.7	13.2	1.5	10	***
Provence	9.0	9.6	0.6	0	**
Pyrénées-Orientales	9.0	9.2	0.2	0	.
Val de Loire	11.2	13.6	2.4	31	***

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

The TFI vineyards are recalculated with the panel data and are different from that observed in table 1.
Farming practices surveys in viticulture and Météo-France data 2010 and 2013.

5. Conclusion

The measure and the understanding of the use of phytosanitary products is a major challenge. In France, the main indicator is the TFI that is built with the quantities actually applied by the wine producers. With a survey every three years, the TFI evolution cannot be easily interpreted: it may be linked to changes in farming practices but also mainly to interannual climate variability. In order to go further in the understanding of TFI variations, this paper focuses on the impact of climatic factors relying on a rich spatialised meteorological data base. We thus introduce in a model several variables describing the climatic conditions encountered by the sampled parcels with a fine grid point.

A fixed effect model leads us to estimate a measure of the "climate-TFI" relationship, excluding the "farming practices-TFI" link. This approach seems admissible for the vineyards because the farming practices do not vary much over time. Otherwise, it would be necessary to add in the model all the farming practices with significant evolutions and check the linear model assumptions. As a consequence, the corrected evolutions between the two years would take into account both climatic factors and farming practices. In that case, an indicator decomposition method would be necessary to estimate an "only climate effect".

In this article, although significant in half of the vineyards, the climate effect appears somehow moderate and leaves unexplained most of the TFI variations. This may be partly explained by the fact that weather conditions are only a proxy of parasite pressure that may depend of many other unobserved factors. Collecting more data on parasite pressure may be useful to go further in the understanding of the use of pesticides.

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