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Addressing organic viticulture environmental burdens by better understanding causes of inter-annual impacts variations

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Abstract
Organic viticulture is developing rapidly due to consumers demand and state incentives in some EU countries. Nevertheless, it has shown higher inter-annual variability in its environmental impacts than conventional viticulture. Therefore, the organic winegrowers would benefit from a better understanding of this variability in order to better address their environmental impacts. A study was conducted in four contrasted pedoclimatic conditions and two contrasted years in terms of climate and of pest and disease pressure. LCAs of organic wine grape was calculated based on detailed inventories of data from the eight real vineyard situations.

Main contributor to impacts was diesel combustion. The inter-annual variation was different between the plots. The impacts that varied the most were the freshwater and soil eco-toxicities, marine eutrophication, freshwater eutrophication and metal depletion. The main agricultural operations contributing to impact variations were disease management due to disease pressure related to climatic conditions variations.

Keywords: *sustainable agriculture; Cradle-to-farm gate LCA; variability; climate, diesel, copper.*

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1 Introduction

Organic viticulture covers 332,905 ha in the world, of which 88% is in Europe (Agence-Bio, 2017), and in some countries, such as Spain and Italy, there has been two-digit growth due to an increasing demand for organic wines and the support of public subsidies. However, organic viticulture may be more subject to inter-annual variations of intervention frequency than conventional one (Beauchet et al., accepted with minor corrections), especially due to fungal pressure and organic fungicides washability by rain leading to important variability in environmental impacts. This sector will benefit from maintaining its very good image in consumers' minds (Jourjon and Symoneaux, 2014) by addressing its environmental impacts, through a better understanding of the inter-annual and site-related variations of impacts and their causes.

This paper deals with quantification and causes identification of the environmental performance of four different organic technical management routes (TMRs), their causes, and variability in order to propose improvement drivers. After presenting the cases studied and methods, we identify and discuss the main hotspots and their variation causes.

2 Material and methods

Four real vineyard plots were studied for two years with contrasting climate or diseases pressure in three French wine regions: One in Alsace, one in Provence Alpes Côte d'Azur and two in the Loire Valley, (Table 1). In each region, the cases where chosen so as to be representative of one or two different types of organic TMRs by applying Renaud-Gentié *et al.* (2014) method.

Life Cycle Assessment (LCA) was conducted using Recipe and USETox™ as characterization methods. Soil erosion [$T.ha^{-1}$] for heavy metals and phosphorus emission calculations was calculated thanks to Rusle2, then emission models were the same as Rouault *et al.* (2016). Inventory included all operations performed in the vineyard during the year studied and the related inputs.

Table 1: Main characteristics of the contrasted plots (*in italic*) and vineyard operations of the TMRs.

TMR Name	**Rou68**		**Cre84**		**Hil49**		**Sav49**	
Grape variety	*Riesling*		*Grenache Noir*		*Chenin Blanc*		*Chenin Blanc*	
PDO/Region	*Alsace/Alsace*		*Ventoux/ Provence-Alpes -côte d'Azur*		*Saumur Blanc/ Loire Valley*		*Savennières/ Loire Valley*	
Soil type	*Sandy-clay-silty*		*Sandy Silty*		*-Silty*		*Sandy-Clay*	
Climate	*Continental*		*Mediterranean*		*Temperate-oceanic*		*Temperate-oceanic*	
% of soil covered by grass	*100*		*40*		*30*		*80*	
Main Inventory elements								
Year	2013	2015	2013	2015	2010	2012	2010	2012
Number pesticide spraying	6	6	9	8	9	12	10	11
Quantity of copper applied in the year ($g.ha^{-1}$)	2832	5660	2880	2160	2648	5811	3480	4683
Quantity of sulfur applied in the year ($g.ha^{-1}$))	24500	69320	84850	83100	40000	51200	36480	50680
Number mechanical operations (except soil and pesticide)	6	6	4	4	6	4	3	2
Nb soil management operations	9	9	7	6	11	9	6	5
Total hours of tractor	39	39	19,6	17,63	51	45,33	11,75	33,41
Total hours manual labour	77,2	76,7	258	290	249	236	296	340
Yield ($kg.ha^{-1}$))	11250	11250	3075	8377	3600	5250	2250	2250

On the basis of LCA results, for each of the four studied situations, the percentage of inter-annual variation was calculated for each impact category and for each type of operation, in order to identify the main contributors to the total impact variation. Due to limited room, a selection of results is presented here.

3 Results and discussion

Considering the LCA results of the four cases for the two years, the main causes of the environmental impacts were identified (Table 2). Diesel was found as one of the major contributors in all the impacts, followed by the emissions from plant protection (copper) or not directly related to operations (N, P, heavy metals from the soil reserve). Fertilisation being not applied on all the plots did not appear as a major contributor.

We observed a variation of impacts between the contrasted years from 0 to 235% according to the plot and to the impact category for a cumulated variation of all impacts of 182% up to 564% (Figure1). The two plots situated in the Loire Valley showed the highest variability.

The impacts that varied the most (Figure 2) were relating to ecotoxicity (terrestrial, freshwater and marine) as well as freshwater eutrophication and metal depletion.
Amongst the seven groups of vineyard operations and two types of emissions non-related to operations, the main contributors to inter-annual variation are summarized in the table 3.

The annual climate, influenced:

- fungal pressure and thus the number (implying each time a mechanical operation) and dose of fungicide treatments required
- weed growth and thus the number of mechanical soil management operations
- vine growth and thus the number of mechanical operations
- erosion and lixiviation and as a consequence nitrogen and phosphorous emissions from fertilisers or from soil reserve

Table 2: Main causes of the impacts in the eight LCA results, causes are classified according to their number of occurrence as first contributor (in brackets, the related vineyard operations).

Main contributors	**Climate Change**	**Terrestrial Acidification**	**Freswater ecotoxicity**	**Terrestrial ecotoxicity**	**Water depletion**	**Fossil depletion**
First	Diesel combustion (soil, canopy and diseases management)	Sulfur production (diseases management by sulfur)	Emissions of grape production (not related to a specific operation)	Emissions from plant protection (diseases management by copper)	Diesel combustion (soil, canopy and diseases management)	Diesel combustion (soil, canopy and diseases management)
Second	Background emissions in the field (not related to any operation)	Diesel combustion (soil, canopy and diseases management)	Diesel combustion (soil, canopy and diseases management)		Tractor manufacturing (soil, canopy and diseases management)	Tractor manufacturing (soil, canopy and diseases management)
Third	Tractor manufacturing (soil, canopy and diseases management)	Emissions from Fertilisation	Emissions plant protection (diseases management)		Treatments (diseases management)	Fertiliser manufacturing

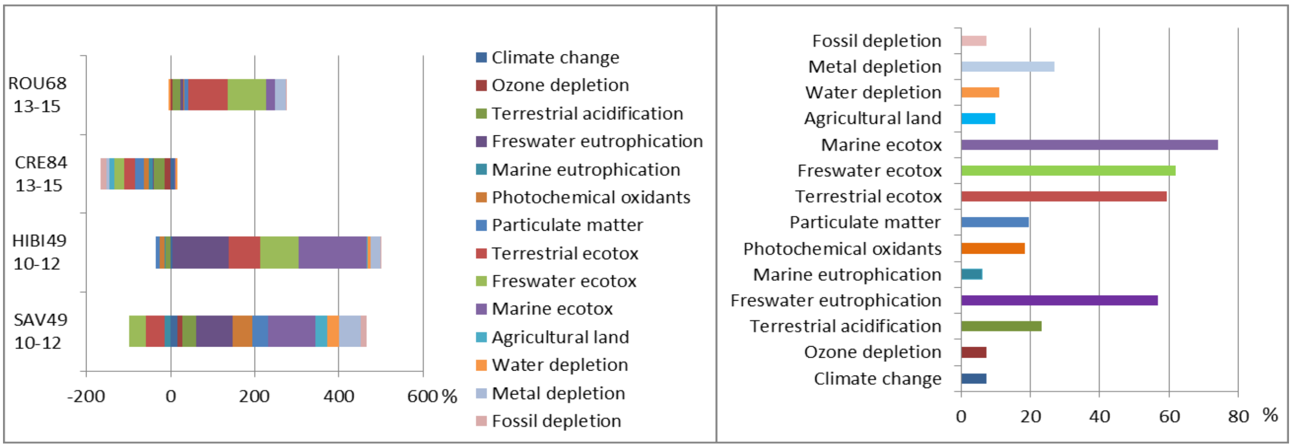

Figure 1 (left): Cumulated percentage of variation of all impact categories between two contrasted years for four organic vineyard TMRs; Figure 2 (right): Average percentage of variation per impact category for four organic vineyard TMRs.

The winegrower's technical choices regarding type of organic fertiliser, or different forms of copper (used as fungicide), and tractor speed also influenced the inter-annual variation.

The main pathways for environmental performance improvements are i) reducing fuel consumption by either limiting the number of operations or/and using more fuel-efficient machines or different energy sources; adjusting the tractor speed; ii) reducing the dose and emission of copper products by the use of tunnel sprayers, and iii) limiting nitrogen emissions through the choice of fertiliser type and management, limiting the use of fertilisers using manganese coming from manganese extraction industry; iv) design the vineyard plot in order to limit erosion (rows perpendicular to slope, use of grass cover) .

4 Conclusions

This study provides an overview of the hotspots, causes and variability of the environmental impacts of organic viticulture in contrasting climates and sites, as well as improvement paths.

Table 3: Main contributors and drivers to inter-annual variation of impacts for four organic vineyard TMRs.

Impact categories	**Operations or non-related to operations emissions**	**Drivers**
All impact categories	Soil management operations duration (mainly plot SAV (150% variation) but also the others to a lesser extent (up to 50%))	Weed growth due to climate of the spring, and change in the tractor speed (strategy of the winegrower)
	Occasional operations (replacement of dead plants) (plot HIL)	Strategy of the vinegrower (impact to be amortised on more years)
Water depletion metal depletion	Dose of manganese sulfate foliar fertiliser (plot CRE),	Strategy of the vinegrower
	Duration of soil management operations (plot SAV)	Weed growth due to climate of the spring, and change in the tractor speed (strategy of the winegrower)
Soil ecotoxicity, soil acidification, marine ecotoxicity, freshwater and marine eutrophication	Number of pesticide application and the nature of copper used (all the plots)	Fungal pressure due to climate of the spring and summer
Photochemical oxidation, climate change soil acidification	Background emissions (N and P) (plots HIL and CRE)	Effect of climate on emissions
Marine Eutrophication photochemical oxidation soil acidification	Mechanical operation (plots HIL and SAV)	Canopy growth and fungal pressure, due to the climate of the spring

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