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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 covers 323,905 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 a significant growth due to 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.

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.

1 Introduction
Organic viticulture covers 323,905 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 a significant growth due to 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.

<table>
<thead>
<tr>
<th>TMR Name</th>
<th>Rou68</th>
<th>Cre84</th>
<th>Hil49</th>
<th>Sav49</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grape variety</td>
<td>Riesling</td>
<td>Grenache Noir</td>
<td>Chenin Blanc</td>
<td>Chenin Blanc</td>
</tr>
<tr>
<td>PDO/Region</td>
<td>Alsace/Alsace</td>
<td>Ventoux/Provence-Alpes d'Azur</td>
<td>Saumur/Loire Valley</td>
<td>Savennières/Loire Valley</td>
</tr>
<tr>
<td>Soil type</td>
<td>Sandy-clay-silty</td>
<td>Sandy Silty -côte</td>
<td>-Silty</td>
<td>Sandy-Clay</td>
</tr>
<tr>
<td>Climate</td>
<td>Continental</td>
<td>Mediterranean</td>
<td>Temperate-oceanic</td>
<td>Temperate-oceanic</td>
</tr>
<tr>
<td>% of soil covered by grass</td>
<td>100</td>
<td>40</td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>Main Inventory elements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of years</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Quantity of copper applied in the year (g.ha⁻¹)</td>
<td>2832</td>
<td>5660</td>
<td>2880</td>
<td>2160</td>
</tr>
<tr>
<td>Quantity of sulfur applied in the year (g.ha⁻¹)</td>
<td>24500</td>
<td>69320</td>
<td>84850</td>
<td>83100</td>
</tr>
<tr>
<td>Number of mechanical operations</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of soil management operations</td>
<td>9</td>
<td>9</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Total hours of tractor</td>
<td>39</td>
<td>39</td>
<td>19,6</td>
<td>258</td>
</tr>
<tr>
<td>Total hours of manual labour</td>
<td>77,2</td>
<td>76,7</td>
<td>258</td>
<td>290</td>
</tr>
<tr>
<td>Yield (kg.ha⁻¹)</td>
<td>11250</td>
<td>11250</td>
<td>3075</td>
<td>8377</td>
</tr>
</tbody>
</table>

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).

<table>
<thead>
<tr>
<th>Main contributors</th>
<th>Climate Change</th>
<th>Terrestrial Acidification</th>
<th>Freswater ecotoxicity</th>
<th>Terrestrial ecotoxicity</th>
<th>Water depletion</th>
<th>Fossil depletion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First</strong></td>
<td>Diesel combustion (soil, canopy and diseases management)</td>
<td>Sulfur production (diseases management by sulfur)</td>
<td>Emissions grape production (not related to a specific operation)</td>
<td>Diesel combustion (soil, canopy and diseases management)</td>
<td>Diesel combustion (soil, canopy and diseases management)</td>
<td>Tractor manufacturing (soil, canopy and diseases management)</td>
</tr>
<tr>
<td><strong>Second</strong></td>
<td>Background emissions in the field (not related to any operation)</td>
<td>Diesel combustion (soil, canopy and diseases management)</td>
<td>Diesel combustion (soil, canopy and diseases management)</td>
<td>Tractor manufacturing (soil, canopy and diseases management)</td>
<td>Tractor manufacturing (soil, canopy and diseases management)</td>
<td>Tractor manufacturing (soil, canopy and diseases management)</td>
</tr>
<tr>
<td><strong>Third</strong></td>
<td>Tractor manufacturing (soil, canopy and diseases management)</td>
<td>Emissions from Fertilisation</td>
<td>Emissions plant protection (diseases management)</td>
<td>Treatments (diseases management)</td>
<td>Fertiliser manufacturing</td>
<td></td>
</tr>
</tbody>
</table>

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.

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

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References


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