An innovative methodology combining Life Cycle Assessment of a product with the assessment of its Quality; case of the French vineyards

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ABSTRACT

In the wine sector, professionals want to reduce the environmental impact of their production but without taking the risk of reducing the quality of the grapes produced and the yield. The present study consists in combining environmental and quality assessment in order to take decisions about the vineyard management strategy. A multi-criteria assessment method will be used to combine those both aspects. But first, the LCA methodology must still be improved in viticulture, in particular for taking into account the carbon cycle (with carbon storage). As LCA results are potential impacts, the quality assessment needs to show also potential results instead of measured data as it is done today. A predictive model for quality evaluation, based on the vineyard management and the natural environment is, hence, being developed in this project.

Keywords: Life Cycle Assessment, multi-criteria analysis, quality, viticulture, practices, grape

1. Introduction

French government has developed a policy on sustainable development that includes a 50% reduction on the use of pesticides between 2008 and 2018. Viticulture sector is concerned about this policy because even if it represents only 3.7% of the French UAA (Utilized Agriculture Area) it uses 20% of pesticide (in kg) consumed in the country (Aubertot et al. 2005). The use of pesticide isn't the only concern of winegrowers. They also wish to reduce on a global way, the impact of their practices on the environment.

The vineyard technical management route (TMR)[1] implemented by the grower, soil and climate factors are the main determinants of quality and environmental impacts of the grapes. These factors have complex and sometimes opposite effects on environmental impacts and quality of grapes.

First of all, LCA methodology for viticulture (Renaud-Gentié et al. 2012) needs to be completed in particular by taking into account the carbon cycle (with carbon storage). Results of LCA that are presented through impact categories will be selected, combined or weighted for inclusion in a multi-criteria analysis to be compared with the quality assessment.

Secondly, the methodology of grape quality assessment has also to be adjusted for insuring comparison with LCA and for joining them together. As LCA permits predictive scenario analysis through potential impacts calculation, the quality assessment needs to give also potential results for predictive analysis besides the measured data that are available today. A predictive model for quality assessment, based on the vineyard management in one hand and soil and climate in the other hand is, hence, being developed in this project.

Finally, results of LCA that are composed by midpoint impact categories and results from the quality evaluation of grapes (which also gives many different variables) will be assessed jointly through the construction of a decision tree.

Methodologies are applied for a white grape variety on five vineyards plots, which represent the diversity of practices of the Middle Loire Valley (France) dry wine vineyards plots in Protected Designation of Origin (PDO) (Renaud-Gentié et al. 2014).

2. Methodological issues

The present study considers all activities at the field from the plantation to the uprooting of vines and by taking into account one year of full production. The period considered for the production year is from the end of the last harvest until the end of the harvest of the year considered. Environmental impacts of phases of planting and

[1] Technical Management Routes (TMRs): logical successions of technical options designed by the farmers (Renaud-Gentié et al. 2014)

uprooting of vines are amortized on the life of the vine. What happens after the harvested grapes have left the field is not considered in this study. As a consequence, winemaking process isn't considered, just as wine storage, bottle production and distribution are described in (Renaud et al. 2011).

The system boundaries include the equipment, energy, and water consumed during the viticulture period. The transportation of workers from the headquarters to the plot is considered and also the transport of all inputs.

The joint assessment method for combining Quality Assessment with LCA is being developed by Christian Bockstaller and is named CONTRA (Transparent Construction of Decision Trees) (Kaueffer 2013). It is an aggregation method based on knowledge and preferences that integrates fuzzy logic (Bockstaller et al. 2013).

LCA analysis is performed using SimaPro software (SimaPro 8). The inventories of practices come mainly from the analysis of the winemaker's practices. They are completed by data from the industry, climate data of the region studied, soils characterizations, the Ecoinvent database (version 3) and national database.

The Quality of grapes is evaluated from the incorporation of data about the practices, soil and climate of the year considered into a Quality assessment model that is being developed in this research program. This model is based on Partial Least Square (PLS) Regression 2 (Sang and Lee 2009) (Reinikainen and Höskuldsson 2007) applied on a data set of plots studied for four years in the region of the present researches. The resulting model will be validated after comparison with actual measurements of quality study plots. The approach used for developing the joint evaluation is explained through a scheme shown in Figure 1.

The experimental network concerns the Chenin Blanc grape variety, which is one of the major cultivars of the Middle Loire Valley for white wine production. Five plots representing the diversity of vineyard management strategies of the central Loire Valley PDO vineyards compose the network (Renaud-Gentié et al. 2014).

Two functional units are considered for this study; first the surface of 1 ha of a producing vineyard. This functional unit will enable us to compare the systems from the land occupation point of view. The second functional unit is the kg of grapes produced.

3. Discussion

A part of this study is to continue the adaptation of LCA on viticulture from the research lead off by Christel Renaud-Gentié (Renaud et al. 2012). Most of these adaptations consist in taking into account the carbon cycle in the assessment including carbon sequestration (Rabl et al. 2007; Helin et al. 2013).

First, the vine leaves falling on the soil each year are biodegraded by the soil fauna and provides a part of minerals and nutriments that will allow the plant to continue growing. The balance is not null but there is compensation between the material consumed by the plant for the production of leaves and the carbon released by the plant when the leaves fall.

Secondly wood is produced during one year of production by the development of the vine cane. The main part of this wood is cut every year after harvest. The wood can be mowed, left on the soil and directly biodegraded by the soil fauna, but it can also be burnt as energy source or be collected and processed by a waste treatment plant.

The quantity of wood produced yearly represents a small quantity compared to the quantity of wood available at the end of the vineyard life while the vine plants of a plot are grubbed up. At its end of life, this wood is mostly burnt through house warming or collected and processed by a waste treatment plant. In this case represents a much bigger quantity of carbon potentially released and suddenly a more significant environmental impact depending on the end of life destination of the wood. In addition, while plot are grubbed up, there is a release of carbon associated with the destruction of the cover crop, if present, at the time of pulling.

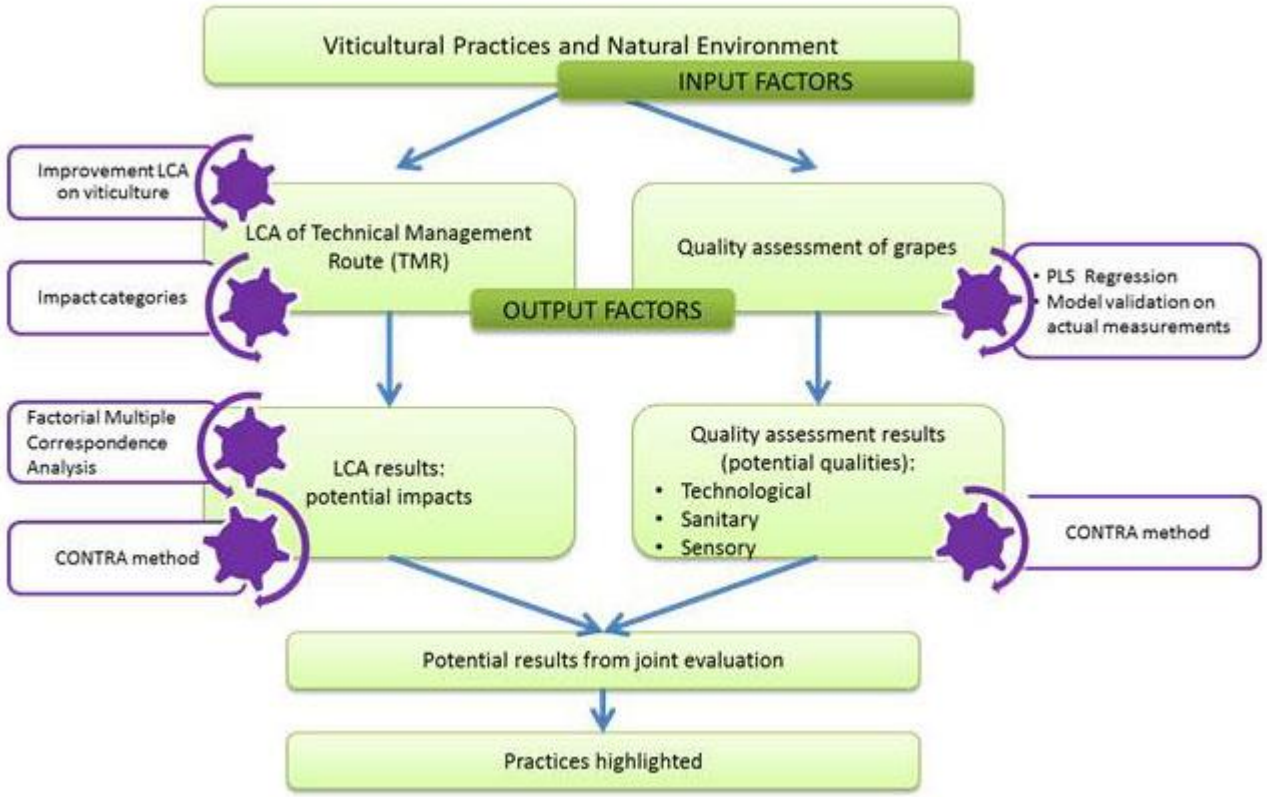

Figure 1. Overall scheme of the joint assessment process.

Concerning the environmental assessment, it should also be noted that some environmental indicators may not tie into the problems of the viticulture sector. That's why indicators used for assessment will be those, which represent an issue for the professional sector like Global Warming potential, acidification potential, toxicity indicators or even land use.

For ensuring the combination of LCA with Quality assessment a predictive model of the grape Quality based on practices and environmental factors (soil, climate…) is being developed. Most factors that influence the quality of grapes are taken into account. The notion of Quality can be defined in many different ways. In this study, the goal is to define a Quality assessment that would help the winegrower to transform its grapes into the best wine he could expect to have. To do so, Quality is assessed through the technological, sanitary and sensory evaluations of grapes. The sanitary assessment is the visual estimate of the decay rate of grapes. Technological qualities are evaluated by the sugar level, phenolic compounds by spectrophotometry (SO 280 and DO 420), pH and acidity of a representative grapes berries sample. Sensory assessment considers aromas, sugar, acidity, the grape berries texture and other properties of a representative grapes berries sample. The panel who evaluates the grapes berries is composed of industry professionals who taste the berries up to a maximum of 48 hours after collection.

For each of those components of the Quality, several parameters have been defined and are measured.

Most of those parameters have been registered in past years on different plots of Chenin Blanc in the Loire Valley, and kept in databases.

From those data previously mentioned, a mathematical relation is being built between the inputs (practices, climate and soil) and the outputs (sensory, sanitary and technological Qualities). It's important to notice that there also are interactions between input data and it's the same for output data.

Partial Least Square Regression 2 (Reinikainen and Höskuldsson 2007) is able to find relations between input and output data while there is interaction between factors. The results of the PLS Regression 2 (Reinikainen and Høskuldsson 2007) will be evaluated by a group of experts that will adjust its structure according to their expertise. They will define priorities between each input: practices, climate and soil and its degree of influence on each component of the quality (Table 1).

Indicators	Components	Type of assessment
Global Warming Potential		Results of Life Cycle Assessment
Ozone formation		
Acidification		
Eutrophication		
Human Toxicity	Human Toxicity	
Terrestrial Ecotoxicity	Ecotoxicity	
Aquatic Ecotoxicity		
Resources consumed	consumption of natural resources	
Total water use (blue water)		
Non renewable, fossil		
Yields grapes	Yields	Results of Quality Assessment
Yields musts		
Sugar	Technological analyzes	
Total acidity		
Malic acid		
Tartaric acid		
Assimilable nitrogen		
Optical density at 420 nm		
Optical density at 280 nm		
pH		
$d^{13}C$		
Decay rate	Sanitary analyze	
Hue bay	Sensory analyzes of berries and juice	
Firmness bay		
Amount of flesh on the pedicel		
Juiciness bay		
Aroma pulp		
Shredding of the film of bay		
Agressiveness of the film		
Color of the seeds		
Juice aroma		
Hue juice		
Sugar juice		
Juice acidity		

Table 1. Presentation of the decision tree for joint evaluation

Developing a predictive empirical model of quality may be not accurately reflecting the real phenomenon that occurs. The objective in this study isn't to reflect the exact reality but to get as close as possible from it for being able to model the consequences of a change in practice, taking into account environment factors. There are many interactions between the input factors of the model and those factors have numerous interactions that influence model outputs. Similarly, introducing the sensory evaluation of grapes quality is a challenging innovation as sensory analyzes must be adapted for each grape cultivar. Finally, there might be too many quality indicators to get the joint assessment; that's why they will have to be selected.

Thanks to the predictive method for the grape quality it should become possible to estimate the quality of grapes from the practices on the field, its soil and climate. It's important to notice that the model for evaluating the Quality of grapes from practices, climate and soil can be used only for the cultivar Chenin under the Loire Valley climate conditions. Indeed the Quality assessment is based only on this cultivar for the region considered.

At the end of the LCA and Quality assessments there are multi-results for each assessment. CONTRA can help joining both assessments but in this case there are too many results. For LCA results, a Factorial Multiple Correspondence Analysis (FMCA) will be applied on impact categories to keep only the main components of environmental impacts; avoid duplication of information and therefore reduce the number of impact categories.

The methodology CONTRA helps defining, with the user decision rules aggregation based on results from LCA and Quality assessment model.

4. Conclusion

The combination of LCA and grape quality assessments will allow understanding how to improve practices and select the ones, which prove to be the best trade-offs between quality and environmental performances.

It will be possible to analyze the input data that are responsible for the impact on the environment through one or more impact categories. And in the meantime we'll know their importance on grape quality. According to their importance on the combined assessments, advices will be given to the winegrower to point out the impact of his practices.

By working on five plots which are managed in completely different way, it will be interesting to identify practices that are able to improve both aspects of the assessment (environmental and quality) or that are able to decrease the environmental impact of the process without reducing the quality of the product. The positioning of each TMR evaluated will give a list of the vineyard management techniques responsible for results obtained. Thanks to that, advices would be given to the winegrower for adapting some of his practices for decreasing the environmental impact of his grape production without reducing or even with increasing the quality of his grapes.

The research on grapes led us to believe that those methods could also be applied on other agricultural productions; perennial products first but also annual products. It would also be interesting to even include this multi-criteria assessment in or combine it with Sustainable Life Cycle Assessment.

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