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Life-cycle assessment of grape cultivation in Piedmont, Italy

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Abstract

The main objective of this paper is to present a comprehensive life-cycle assessment (LCA) of grape cultivation for wine, in Piedmont, Italy. A cradle-to-gate approach was followed for grape cultivation (functional unit: 1 kg of grapes), based on data collected for the Barbera and Moscato varieties. Life cycle environmental impacts were analysed for the following categories: fossil depletion (FD), global warming (GW), terrestrial acidification (TA), freshwater eutrophication (FEUT) and freshwater ecotoxicity (FWecot). The calculation of impacts included fertilization (nitrogen and urea field emissions), application of plant protection products (PPPs), diesel combustion in agricultural operations, and production of agricultural inputs. FWecot impacts of pesticide application were assessed by combining a framework developed for the inventory of pesticide emissions to different compartments (off-field natural soil, agricultural soil, and air) with characterization factors from USETox.
Results show that energy use in agricultural activities (diesel) was the largest contributor to GW and FD (more than 70 %). For TA, the largest contributors were PPP and diesel (44 % and 40 %, respectively). Fertilizers and PPPs represented 57 % and 34 % of FEUT impacts, respectively. PPP field emissions alone represented 93 % of FWecot impacts. The equipment used in agriculture activities represented less than 8 % of the total impacts. Overall, impacts due to pesticide application (including diesel use) represented 27 to 56 % of impacts, except FWET where it represented nearly 100 % of impacts. This paper shows the importance of LCA to identify improvement opportunities to reduce environmental burdens related with grape cultivation, namely adopting strategies to decrease the amount of fertilizer and pesticide applied (and associated energy use). Furthermore, it highlights the importance of assessing the application of PPP in current agriculture practices in a comprehensive way, especially when assessing toxicity categories (where PPPs dominate impacts).

Keywords: *Grapes, life cycle assessment, toxicity impacts, plant protection products, fertilizers*

Introduction

Grape cultivation for wine is an important economic activity in Italy – the world-leading producer in 2018 with 54.8 million hectolitres. The main objective of this paper is to present a life-cycle assessment (LCA) of grape cultivation for wine in a vineyard located in Nizza Monferrato, Piedmont region, Italy, addressing comprehensively the application of plant protection products (PPPs) and fertilization (nitrogen and urea field emissions), in contrast to most studies that neglected the assessment of PPP application or performed outdated inventory modelling that restricted and overestimated the assessment of PPPs impacts (Margni et al. (2002) and Nemecek et al. (2007)) (e.g. studies ignoring several factors that affect PPP fate in the environment, such as PPP characteristics, application method, wind drift and plant growth stage). For freshwater ecotoxicity (FWecot) impacts of PPP application, we combined a framework developed for the inventory of PPP emissions to different compartments (off-field natural soil, agricultural soil, and air) with characterization factors from USETox. This study is part of the project OPTIMA – "Optimised Pest Integrated Management to precisely detect and control plant diseases in perennial crops and open-field vegetables", funded by the European Union's Horizon 2020 Research and Innovation Programme.

Material and methods

The agriculture operations considered for grape production were PPP application, fertilization, and other field operations (e.g., pruning, trimming, harvest). The vineyard is assumed to be at full production; therefore, only grape production was considered and vineyard planting and end-of-life were excluded from the assessment as these stages represent minor impacts due to the long (and uncertain) lifespan of the vineyard. The functional unit is one kg of grapes. Table 1 shows the primary data related to agricultural operations for 2018. Fifteen different active ingredients (AIs) of PPPs were applied.

Table 1. Inventory data for vineyard per kg of grapes (2018)

Inputs	Amount	Units
Fertilizers		
N	19.9	
P	9.3	g
K	7.9	
PPPs (active ingredients)		
metiram	0.078	
cymoxanil	0.011	
meptyldinocap	0.016	
isopropylamine salt	0.108	
dimethomorph	0.039	
folpet	0.100	
pure sulphur	4.477	
mancozeb	0.489	
carfentrazone-ethyl	0.007	g
metalaxyl-m	0.022	
penconazol	0.007	
metalic copper	0.760	
potassium phosphonate	0.336	
chlorpyrifos methyl	0.038	
thiamethoxam	0.006	
Energy		
Diesel	55.22	g
Outputs		
Grapes	1	kg

Life cycle environmental impacts were analysed for the following categories: fossil depletion (FD) (Huijbregts et al. 2017), global warming (GW) (IPCC 2013), terrestrial acidification (TA) (Huijbregts et al. 2017), freshwater eutrophication (FEUT) (Huijbregts et al. 2017) and freshwater ecotoxicity (FWecot) (Rosenbaum et al. 2008). Direct and indirect N_2O emissions and CO_2 emissions from urea application were calculated following Nemecek et al. (2015). For FWecot impacts, results are present for recommended (rec.) and indicative (ind.) USEtox characterization factors. Recommended factors correspond to substances for which the USEtox model is considered appropriate and the underlying substance data are of sufficient quality to support a recommendation based on scientific consensus, in line with Hauschild et al. (2008). In cases where relatively high uncertainty in addressing fate, exposure and/or effects of a substance is expected, the related characterization factors are labelled as indicative (Fantke et al. 2015).

Results and Discussion

The environmental life cycle impacts per kg of grapes are presented in Table 2. Overall, results show that energy (associated with diesel consumption) used in the various agricultural activities had the largest environmental impacts in GW and FD. The largest contribution to FEUT was fertilization. PPP production and field emissions presented the largest contribution to FWecot and TA. The main contributor for TA was the application of pure sulphur. For FWecot, considering only recommended characterization factors, the main contributors were folpet and chlorpyrifos methyl; for indicative characterization factors, the main contributor was metalic copper. It should be noted that, for FWecot calculated with USEtox recommended characterization factors, 10 out of 15 AIs are covered (i.e. assessed), while, for indicative characterization factors, the coverage is 14 out of 15 AIs.

Table 2. – Life cycle impacts in all agricultural activities per kg of grapes produced in a vineyard farm in Nizza Monferrato (Piedmont, Italy).

Indicator	Unit per kg of grapes	Equipment	Energy (diesel)	Fertilizer (production + field emission)	PPP (production + field emission)	Total
GW	kg CO_2 eq.	2.00E-02	1.76E-01	3.59E-02	1.23E-02	2.45E-01
FD	kg oil eq.	6.33E-03	6.01E-02	7,64E-03	6.88E-03	8.09E-02
TA	kg SO_2 eq.	9.77E-05	1.43E-03	4.71E-04	1.60E-03	3.60E-03
FEUT	kg PO_3^{4-}eq.	1.11E-05	2.81E-06	8.92E-05	5.42E-05	1.57E-04
FWecot-rec	CTUe	4.02E-04	2.95E-04	1.69E-05	1.67E-01	1.68E-01
FWecot-in	CTUe	4.83E-01	7.68E-02	1.14E-03	2.31E+03	2.31E+03
←Lower impacts					Higher impacts →	

Conclusions

We assessed environmental life cycle impacts of grape production in a vineyard in Piedmont region addressing comprehensively PPP application and fertilization. Results showed the significant contribution of pest management to FWecot impacts, mainly due to PPP field emissions. Results also showed a high contribution of energy use in agriculture operations for global warming and fossil depletion. This paper shows the importance of LCA to identify improvement opportunities to reduce environmental burdens related with grape cultivation, namely adopting strategies to decrease the amount of fertilizer and PPP applied (and associated energy use). Furthermore, it highlights the importance of assessing the application of PPP in current agriculture practices in a comprehensive way, especially when assessing ecotoxicity categories (where PPPs dominate impacts).

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