Environmental impact and energy demand comparison of vineyards by the life cycle assessment methodology

Priya Devasirvatham [a,b]*, Carles M. Gasol [a,b], José Dorado [c], César Férnandez-Quintanilla [c]

[a] Inèdit Innovació SL, Research Park of the Universitat Autònoma de Barcelona, Campus UAB, 08193, Bellaterra, Catalonia, Spain.
[b] SosteniPrA (ICTA-IRTA-Inèdit), Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), Campus UAB, 08193 Bellaterra, Barcelona, Catalonia, Spain.
[c] Institute of Agricultural Sciences (ICA), CSIC, Serrano 115b, 28006, Madrid, Spain.
*Corresponding author: Priya Devasirvatham (pdevasirvatham@email.wm.edu).

Introduction

Spain is home to 18.3% of the world's vineyards and has the highest concentration of land dedicated to growing grapes for wine than any other country, approximately 10,000 km2 or 2% of its land mass[1]. Major enemies of the vines apart from the increase of temperatures due to climate change are pests, plagues and invasive weeds. This study seeks to quantify, using Life Cycle Analysis (LCA) the varying environmental impacts caused by different weed management methods utilized in viticulture.

Goals & Scenarios

Functional Units (FU): One hectare of land.

Goal:

a) To assess and compare the environmental impacts of different weed management methods in viticulture, ranging from organic to conventional.

b) Identify hotspots within the system.

Scenarios

CI (Chemically Intensive): rows and inter-vine areas are tilled. Three chemicals, 5 mechanical activities and mineral fertilizer applied

LO (Low input): spontaneous, natural plant cover grows. Herbicide and two fungicides

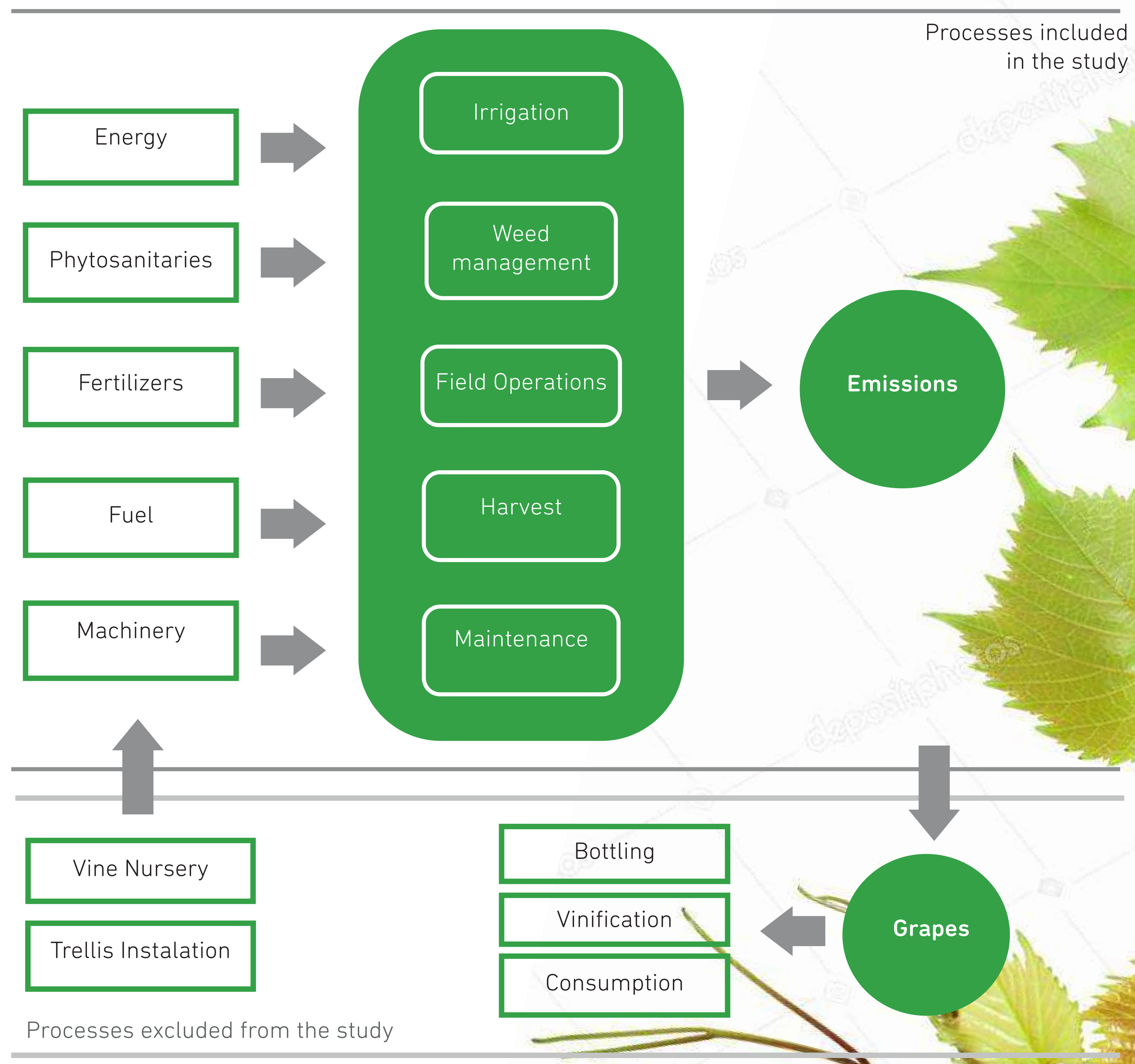
MI (Mechanically intensive): the rows alternate between natural plant cover and tilling. Every three years the rows are rotated. 9 mechanical activities, two fungicides and a mineral fertilizer are applied.

O1 (Organic 1): the rows and inter-vine areas are tilled. Composted poutry manure fertilizer is applied.

O2 (Organic 2): the rows have a natural plant cover and the inter-vine are is tilled.

Database: Ecoinvent [2]/ Software: Simapro 8.2 / Methods: Recipe H Midpoint; USETox 2.01; CEDA

FIGURE 1: System Boundary:



Inventory

TABLE 1: Inventoty for all vineyard pest and weed management scenarios for years 2015 and 2016. Values are per hectare.

Scenario	CI		LO		MI		O1		O2	
Year	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
INPUTS										
Products										
Glyphosate 36% [kg] HERBOLEX	13.6	13.6	6.8	6.8	-	-	-	-	-	-
Tebuconazole 25% [kg] EW FOLICUR	1.875	0.625	1.875		1.875	0.625	-	-	-	-
Trifloxystrobin 50% [kg] WG FLINT	-	0.15	-	0.15	-	0.15	-	-	-	-
Micronized Sulfur 98% [kg]	-	-	-	-	-	-	120	120	120	120
28)_ [kg]	-	600	-	-	-	600	-	-	-	-
Poultry Manure 4 - 3 - 3) [kg]										
FERM O FEED	-	-	-	-	-	-	-	1200	-	-
Diesel [kg]	98.28	110.8	29.4	32.76	79.8	84.84	62.16	74.24	28.56	28.56
Mechanical Activities										
Pre-Prune	x1	x1	-	-	x1	x1	x1	x1	-	-
Till	x3	x3	-	-	x3	x3	x3	x3	-	-
Mow Plant Cover	-	-	x1	x2	x2	x2	-	-	x2	x2
Intervine Cultivation	-	-	-	-	x2	x2	-	-	x1	x1
Harvest	x1	x1	-	-	x1	x1	-	-	-	-
Irrigation										
Hours	49	63	49	63	49	63	49	63	49	63
Elecricity Consumed [kWh]	450.8	579.6	450.8	579.6	450.8	579.6	450.8	579.6	450.8	579.6
OUTPUTS										
Grapes [kg]	12,726	14,740	7,726	12,188	8,100	13,475	10,353	18,942	7.050	8,338

CI=Chemically Intensive, LO=Low Input; MI=Mechanically Intensive; O1=Organic 1; O2=Organic 2

Impact Assessment

TABLE 2: Absolute values for impact/ha. All vineyard management scenarios are represented. The Values are the sum of impact from year 2015 and 2016.

Impact category	Unit	CI	LO	MI	O1	O2
Climate Change	kg CO2 eq	2134,41	786,52	1851,17	1217,55	762,73
Ozono depletion	Kg CFC - 11	0,00031	0,00013	0,00025	0,00026	0,00018
Terrestrial acidification	kg SO2 EQ	25,85	5,39	23,90	21,07	5,32
Freshwater eutrophication	kg P eq	0,63	0,24	0,46	0,21	0,16
Marine eutrophication	kg N eq	1,48	0,25	1,35	1,09	0,22
Water depletion	m3	26,27	5,50	22,54	6,80	4,28
Human toxicity, cancer	CTUh	4,1E-07	1,4E-07	1,9E-07	3,1E-08	2,2E-08
Human toxicity, non-cancer	CTUh	3,7E-07	2,1E-08	3,5E-07	3,2E-09	2,4E-09
Freshwater ecotoxicity	CTUe	2132,33	1203,80	1135,33	46,00	21,42
Energy Demand	MJ	35095,12	16013,16	30190,23	29218,93	21317,86

Values range from darker (the highest values) to lighter (the lowest values).
CI=Chemically Intensive, LO=Low Input; MI=Mechanically Intensive; O1=Organic 1; O2=Organic 2

FIGURE 2: Climate Change (CC) Impact per Scenario

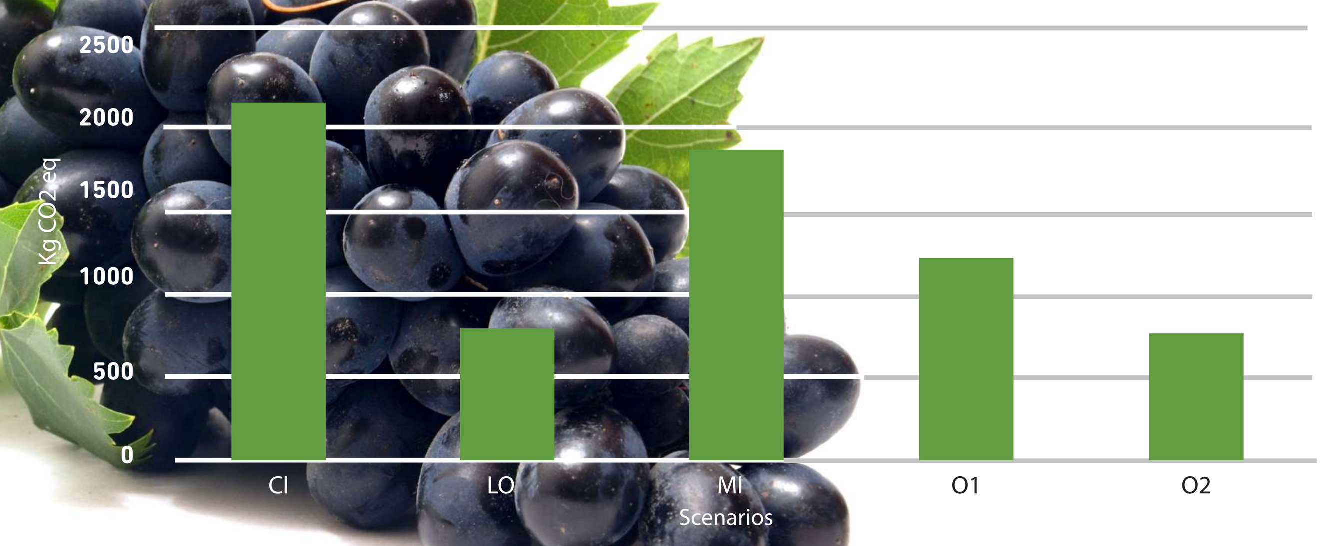
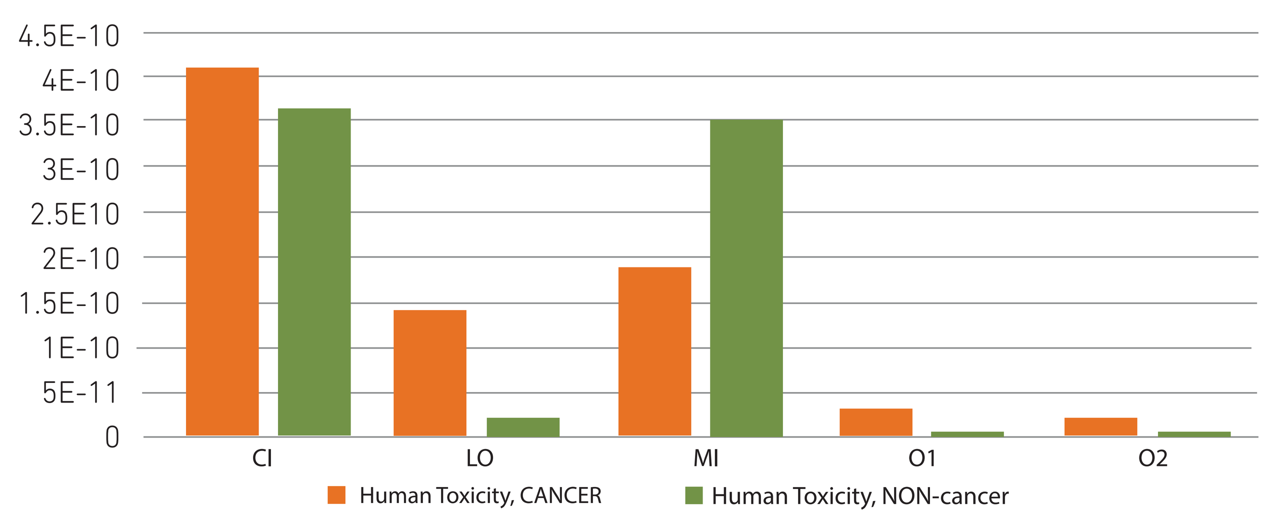


FIGURE 3: Human Toxicity (HT) Impact per Scenario



Identification of Hot Spots

- Mineral Fertilizer: The production and application of a mineral based NPK fertilizer has a higher impact than any other process across every impact category except Freshwater Ecotoxicity. Emissions include the release of the greenhouse gases N2O, NH3 and NOx to the air.
- Weed Management: The fungicide tebuconazole and the herbicide glyphosate were flagged for high impact. They primarily effect the impact categories Human Toxicity-Cancer, Human Toxicity Non-Cancer and Freshwater Ecotoxicity.
- Irrigation: The impact from irrigation derives from the use of electricity to power a pump which extracts water from an aquifer in the region. Spain´s electricity mix uses primarily nuclear, followed by coal and wind power (23, 20 and 19% respectively)[3], of which only wind is renewable. Irrigation affects every impact category, in scenarios where neither mineral fertilizers nor the aforementioned chemicals are used it is the most impacting input.

Conclusions

A comparative study of five different weed management scenarios in viticulture was successfully completed using LCA methodology.
Chemical and mineral inputs generated high environmental impact while the process of pumping water for irrigation consumed a large amount of energy in the form of unrenewable resources.
The chemically and mechanically intensive scenarios had the greatest impact. The second organic scenario had the lowest impact but also produced the lowest yield.

References

[1] INE, (2011). Spanish Statistics Institute Available at: http://www.ine.es (Last accessed 18.04.17) (in Spanish).

[2] Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B., 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230. Available at: <http://link.springer.com/10.1007/s11367-016-1087-8> [Accessed 07.02.2017].

[3] REE, El sistema eléctrico español (2012). Available at: http://www.ree.es/sites/default/files/downloadable/inf_sis_elec_ree_2012_v2.pdf Last accessed (03.05.17).

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