Life project ADVICLIM
Action B2

Greenhouse gases emissions assessment of viticulture technical itineraries: method and results

With the contribution of European Union financial instrument LIFE

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Table of contents

Introduction

The aim of Adviclim action B2 is to assess the carbon footprints of technical itineraries for the five project pilot sites. The objectives of doing this assessment were to :

1. identify the main processes responsible for greenhouse gases (GHG) emissions and to characterize some interventions frequently producing high GHG emissions for each pilot site ;
2. identify the proportion of indirect emissions against the proportion of direct emissions from the plot, on which the vine-growers can make modifications ;
3. compare GHG emissions of observed practices against the practices modelled in scenarios with SEVE model (action B1) ;
4. ultimately integrate new constraints in the multi-agents model for systematically reducing GHG emissions when the model proposes new scenarios of adaptation of practices to global warming;
5. extrapolate, if possible, the emissions produced by sampled plots to the pilot site scale according to plots representativity.

The application of the assessment method described in a previous methodological report (Demarez et al, 2016) on twenty-seven sampled plots over the five Adviclim pilot sites led to the results presented in the report. They give answers to the two first objectives noted above. The third objective of assessing adaptation scenarios has not been tackled in this report, as the scenarios were not mature enough at the end of the project or were not relevant regarding GHG emissions assessment. But the methodology for assessing them would have been exactly the same.

1.Methodology synthesis

This first part is the summary of the previous previous methodological report (Demarez et al, 2016) which was very detailed.

1.1. Outlines of the study

1.1.1. Approach, perimeter and functional unit

The approach to calculate the carbon footprint of a viticultural activity is a life cycle approach. It takes into account all the life cycle steps of a product in the GHG flows inventory, from resources extraction and energy production for inputs manufacturing to their end of life (cf Figure 1). This approach implies to define the studied object, system, perimeter and the functional unit of the study, in accordance with its objectives.

Studied object: a plot planted with vine.

Studied system: The studied system gathers all the elements involved in the activities of the studied object (tools, inputs, equipments, staff).

Boundaries of the study: The boundaries of the study include all the ***direct emissions*** produced by the activities linked to the technical itinerary (use of tools, functioning of equipments, transport between the farm and the plot), and all the ***indirect emissions*** produced by manufacturing, transporting and dealing with the end of life of the elements of the studied system. Those two types of emissions are drawn on the Figure 1.The boundaries include only the production of grape and its transport back to the farm. The transformation into wine, the conditioning and distribution of wine are out of the scope of this study.

Functional unit: GHG emissions are calculated for 1 ha of planted vine and 1 year.

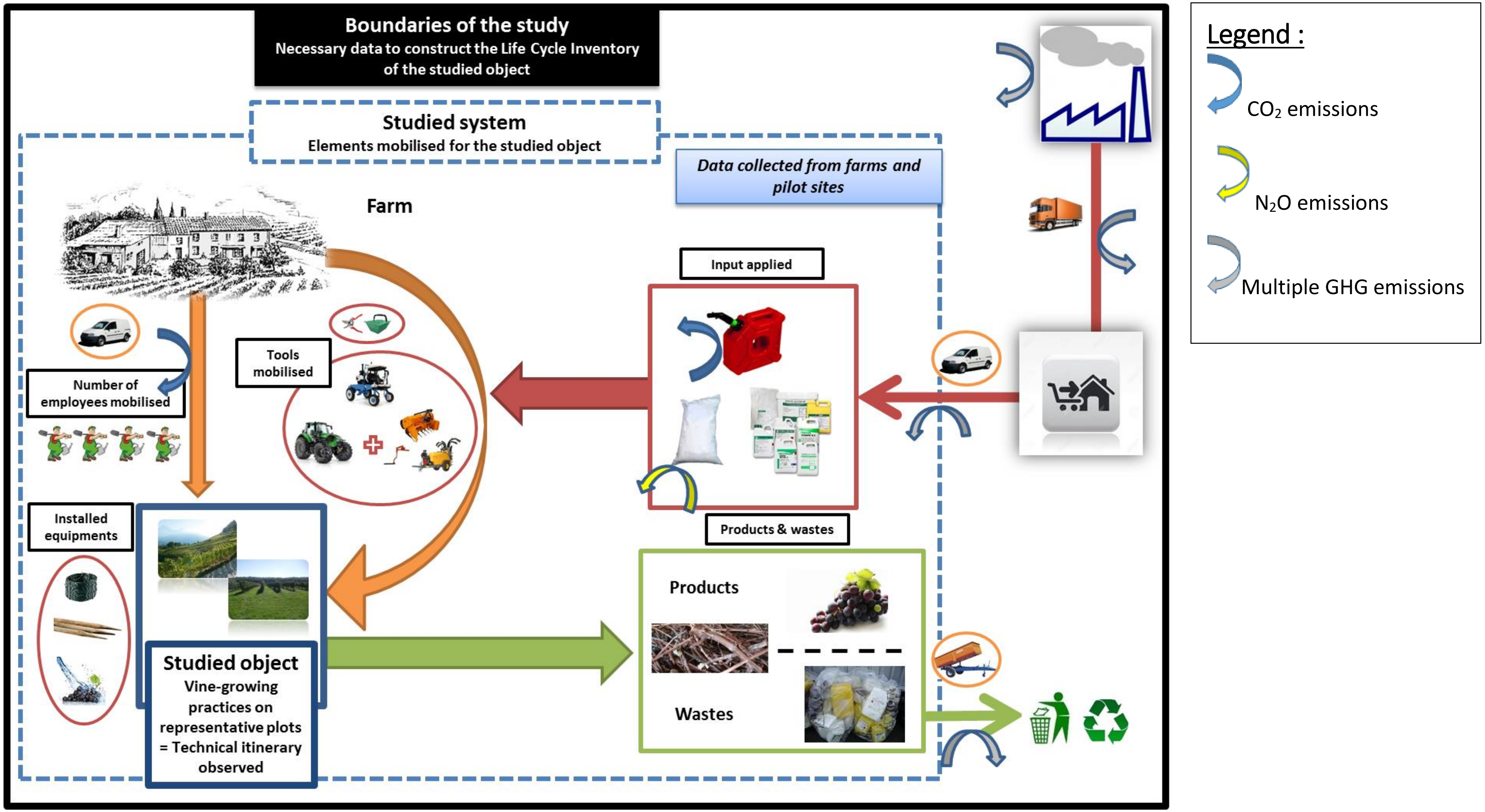

Figure 1 : Life cycle of the cultivation of a plot planted with vine (Demarez et al, 2016)

1.1.2. RESULTS SCALE

The scale for presenting GHG emissions budgets was set at an intermediate level of detail. The budgets for each sub-operation are indeed grouped by vineyard operations, 10 in total (cf Table 1). This way of aggregation helps to meet the first aim of the study (cf Introduction).

Tools and inputs are used and spread during interventions. Tools and diesel can be used for all vineyard operations. Other inputs (pesticides, fertilizers) are only linked to the three vineyard operations "Application of fertilizers and manures", "Pest and disease management" and "Soil maintenance".

Equipments are permanently installed. They can be linked to four vineyard operations:

- Pest and disease management (Sexual confusion diffusers),
- Plot management and maintenance (Drainage),
- Treillis management and maintenance (Trellising),
- Vine maintenance (Irrigation).

The transport of tools and employees between the farm and the plot, as well as transport of tools, inputs and equipments from the manufacturer to the farm are linked to the vineyard operation "Transport".

Then, for each vineyard operation, the distinction is made between:

→ The direct emissions: this includes CO_2 emissions (all operations) and N_2O emissions (« Application of fertilizers and manures » only), respectively linked to carbon and nitrogen cycles and directly emitted on the plot.

→ The indirect emissions: this includes the GHG emissions produced during the extraction of raw materials, the manufacturing of system elements (tools, inputs, equipments) and the transport of system elements from the manufacturer to the farm.

This distinction helps to meet the second aim of the study (cf Introduction).

Vineyard operation	Vineyard sub-operation	Category of sub-operation
1 - Application of fertilizers and manures	Fertilizers application	Intervention
	Foliar fertilization	Intervention
2 - Canopy management	Debudding	Intervention
	Chemical thinning out	Intervention
	Non chemical thinning out	Intervention
	Non thermal leaf removal	Intervention
	Thermal leaf removal	Intervention
	Chemical berries removal	Intervention
	Non chemical berries removal	Intervention
	Chemical vine shooting	Intervention
	Non chemical vine shooting	Intervention
	Trimming	Intervention
	Regulation of growth treatment	Intervention
3 - Harvest	Harvest	Intervention
4 - Pest and disease management	Sexual confusion diffusers	Equipment
	Soil desinfection - Vines devitalization	Intervention
	Observation of pests	Intervention
	Fungicide treatment	Intervention
	Insecticide treatment	Intervention
	Defense stimulators treatment	Intervention
5 - Plot management and maintenance	Stones grinding	Intervention
	Drainage	Equipment
	Equipement - other	Equipment
	Edge management - Sowing	Intervention
	Edge management - Mowing	Intervention
	Intervention - other	Intervention
6 - Soil maintenance	Inter-row soil management - Deep loosening	Intervention
	Inter-row soil management - Chemical weeding	Intervention
	Inter-row soil management - Mechanical weeding	Intervention
	Inter-row soil management - Thermal weeding	Intervention
	Inter-row soil management - Mowing	Intervention
	Inter-row soil management - Mulching	Intervention
	Inter-row soil management - Sowing	Intervention
	Intervine soil management - Hilling	Intervention
	Intervine soil management - Ridges ploughing	Intervention
	Intervine soil management - Chemical weeding	Intervention
	Intervine soil management - Mechanical weeding	Intervention
	Intervine soil management - Thermal weeding	Intervention
	Intervine soil management - Mowing	Intervention
7 - Trellis management and maintenance	Trellising management	Intervention
	Trellising	Equipment
	Lifting	Intervention
8 - Vine maintenance	Watering	Intervention
	Vines replacement	Intervention
	Irrigation	Equipment
	Antifrost system	Equipment
9 - Winter pruning	Canes and vine shoots shredding	Intervention
	Canes and vine shoots burning	Intervention
	Canes and vine shoots export	Intervention
	Pre-pruning	Intervention
	Pruning	Intervention
	Canes pulling	Intervention
10 - Transport	Transport between the farm and plot	Transport
	Transport of tools and inputs	Transport

Table 1 : Description of the 10 vineyard operations

1.2. Life cycle inventories

1.2.1. General methodology of a life cycle inventory

A life cycle inventory (LCI) is an inventory of all the flows coming from natural resources (water, atmospheric gas, mining resources,…), and emitted to natural compartments (water, air, soil), when making a product or providing a service. Considering the amount of data needed to estimate these elementary flows according to a life cycle approach, a LCI consists in using ***existing data sets***, which are elementary life cycle inventory for many inputs, tools, equipments or energy, available in dedicated databases such as Ecoinvent or Agribalyse®. They are used for indirect emissions assessment.

It can happen that some datasets are not available. The building of a ***proxy*** is then needed *(intermediate LCI between existing data sets and the product or service LCI)*, by aggregation of data sets of the constituents of an input, a tool, an equipment or by aggregation of sources of energy included in an energy mix.

Here are the steps to carry out a LCI :

→ Case n°1 : if the data set of the system element exist (*ex : vineyard tractor*) :

a. **Identify the closest data set from the inventoried element**
Ex : the data set « Tractor, LT 7'500h, production/ U » from the database Agribalyse®, corresponding to the emissions linked to the manufacturing of a tractor of which the lifetime is under 7500 h, is the most appropriate data set for a vineyard tractor.

b. Calculate the weighting factor of the data set to adapt the studied element and the functional unit
Ex : the data set « Tractor, LT 7'500h, production/ U » gives the emissions for the manufacturing of 1 kg of 7500 h lifetime tractor. So this data set needs to be multiplied by the mass of the studied vineyard tractor, and to be weighted by the use time during one year and one hectare to fit the functional unit of this study.

→ Case n°2 : if the data set of the studied element does not exist (ex : pesticide commercial product):

a. **Identify the closest data set from the constituents of the inventoried element.**
Ex : « Cyclic N-compound {GLO}| market for | Alloc Rec, S » (in kg) for the active ingredient Tetraconazole of the commercial product Greman.

b. Calculate the weighting factor of the data set of each constituent of the inventoried element.
Ex : 0,1 kg of « Cyclic N-compound {GLO}| market for | Alloc Rec, S » for 1 L of Greman.

c. Create a proxy of the inventoried element and collect the weighting factor corresponding to the functional unit of this proxy
Ex : 0,23 L of Greman spread on the plot for the growing year 2015-2016.

For the study presented in this report, the creation of proxy has been carried out only for pesticide commercial products and for the trellising equipment.

After this sequence of data sets search and proxys creation, all the inventoried data sets and the weighting factors relating to them are entered in the SimaPro© tool, which aggregates those data at the defined assessment scale.

For the study presented in this report, the thinnest assessment scale is the vineyard operation and the split between direct and indirect emissions for each vineyard operation (cf Table 1).

1.2.2. GHG FLOWS TAKEN INTO ACCOUNT IN THIS STUDY

The methodological report on the estimation of GHG emissions (Demarez et al, 2016), inventories all the theoretical system elements producing direct and indirect emissions. This exhaustive inventory is presented in the Table 2.

The methodology initially designed has been partially applied for the plots of Saint-Emilion, due to the lack of LCI in LCA data sets. Hence the color code of the column "Direct emissions" and "Indirect emissions" of Table 2 :

- Darker orange : emissions taken into account in the study
- Lighter orange: emissions linked to some elements of the studied plots, but not taken into account. Two reasons for that: either data sets don't exist for those elements and are difficult to model, either the collected data to weight the data sets were not complete at the moment of calculating the results.
- Green: emissions not taken into account because no elements producing those emissions inventoried for the studied plots.

The emissions taken into account are only fossil carbon emissions: the biogenic carbon budget is excluded (carbon sequestration in grapes, leaves, vine shoots and vine roots, and possible carbon releasing).

In the following paragraphs (1.2.2.1 and 1.2.2.2), the formulas for calculating data sets weights are written with a color code:

- Green: reference value
- Orange: data collected for the studied plot.

	Elements and processes to take into account for estimating GHG emissions in a viticultural system			Direct emissions	Indirect emissions	Corresponding vineyard operation(s) (cf Table 1)
linked to equipments	Simple equipments	Antifrost equipments consuming energy (electricity, oil or gas)	Manufacturing of the equipment		X	8 – Vine maintenance
			Equipment functioning	Oil or gas combustion (CO_2 emissions)	Energy extraction/production	
		Antifrost equipments by water spraying	Manufacturing of the equipment		X	
			Equipment functioning		Sprayed water production	
		Simple equipments– others (sexual confusion diffusers, leftover spray management system, drainage,…)	Manufacturing of the equipment		X	4 – Pest and disease management **or** 5 – Plot management and maintenance
	Compound equipments	Trellising	Manufacturing of the equipment		X	7 – Treillis management and maintenance
		Irrigation	Manufacturing of the equipment		X	8 – Vine maintenance
			Equipment functioning		Irrigation water production	
linked to tools	Motorized pulling tools and towed tools		Tool manufacturing		X	All vineyard operations **except** 10 – Transports
			Tool functioning	Diesel combustion (CO_2 emissions)	Diesel extraction/production	
	Motorized non pulling tools		Tool manufacturing		X	
			Tool functioning	Diesel combustion (CO_2 emissions)	Diesel extraction/production	
	Tools		Tool manufacturing		X	
linked to inputs	Pesticide		Input manufacturing		X	4 – Pest and disease management
			Input diluting		Dilution water production	
	Fertilizers and enrichments		Input manufacturing		X	1 – Application of fertilizers and manures
			Input spreading	N_2O emissions at the field		
linked to transport	Transport from the farm to the plot	of motorized pulling tools and towed tools	Tool manufacturing		X	10 - Transport
			Transport of tools on roads	Diesel combustion (CO_2 emissions)	Diesel extraction/production	
		of spraying tool for tank refilling during a treatment	Tool manufacturing		X	
			Transport of tools on roads	Diesel combustion (CO_2 emissions)	Diesel extraction/production	
		of employees	Transport of employees by vehicule	Diesel combustion (CO_2 emissions)	Vehicule manufacturing and diesel extraction/production	
	Transport from the manufacturer to the retailer	of tools/inputs/equipments			X	
	Transport from the retailer to the farm				X	
	Transport from the farm to the sorting centre				X	

Table 2 : Processes taken into account for the preliminary results (bolded boxes), and correspondance between system elements and vineyard operations

(Legend for « direct emissions » and « indirect emissions » columns :

- *bolded darker orange boxes = emissions taken into account ;*
- *lighter orange = emissions from system elements but not taaken into account ;*
- *green = emissions not taken into account because elements not in the case study system)*

1.2.2.1. Direct emissions

a. Direct emissions linked to tools uses

Available data sets

Direct emissions	Data set	Unit
Tool diesel combustion	« Diesel combustion, in tractor/ U »	kg

Calculation method

Direct emissions	Calculation method
Tool diesel combustion	$Consumption\ for\ each\ intervention\ (kg) = Diesel\ motor\ specific\ consumption\ (kg/hp/h^1) \times motor\ rated\ power\ (hp) \times\ loading\ rate\ (\%) \times intervention\ duration\ (h)$

The reference values in green are:

- → Diesel motor specific consumption : 0.1865 kg/hp/h
- → Loading rate: see Appendix 1.

If two tools are towed during a single intervention, the loading rate used in the formula is the average of the loading rate of the two tools. Half of this intervention fuel consumption is allocated to the vineyard operation linked to each tool.

[1] kg/hp/h = kg per horsepower per hour.

Example of datasets and quantities for the plotSaint-Emilion - 9:

Application of fertilisers and manures			
	Diesel combustion, in tractor/ U	0,000	**kg**
Canopy management			
	Diesel combustion, in tractor/ U	38,408	**kg**
Harvest			
	Diesel combustion, in tractor/ U	72,680	**kg**
Pest and disease management			
	Diesel combustion, in tractor/ U	72,015	**kg**
Plot management and maintenance			
	Diesel combustion, in tractor/ U	0,000	**kg**
Soil maintenance			
	Diesel combustion, in tractor/ U	131,566	**kg**
Trellis management and maintenance			
	Diesel combustion, in tractor/ U	48,749	**kg**
Vine maintenance			
	Diesel combustion, in tractor/ U	0,000	**kg**
Winter pruning			
	Diesel combustion, in tractor/ U	0,000	**kg**

Table 3 : Inventories of direct emissions linked to tools use

b. Direct emissions linked to transport

« Direct emissions linked to transport » means emissions linked to fuel consumption from motorized tools on road and from cars transporting people on the return journeys between the farm and the plot.

Available datasets

Direct emissions	Datasets	Unit
Transport of motorized tools on road	Diesel combustion, in tractor/ U	kg
Transport of people	Transport, passenger car, petrol, fleet average/ Direct/ RER U	person.km

Calculation method

<table>
<tr><th>Direct emissions</th><th>Calculation method</th></tr>
<tr><td>Transport of motorized tools on road</td><td>Consumption for each intervention (kg) =
average tractor speed on road (km/h)
* average consumption on road (L/h)
* 2 * distance plot-farm (km)
<table><tr><td>Motorized tool category</td><td>Average speed km/h</td><td>Average consumption on road (L/h)</td></tr><tr><td>Tractor</td><td>30</td><td>10</td></tr><tr><td>Straddle tractor</td><td>20</td><td>13.5</td></tr></table></td></tr>
<tr><td>Transport of people</td><td><u>For each intervention with a motorized tool :</u>
Number of transported people.distance (person.km) = (number of people mobilised for the intervention – 1)
* 2 * distance plot-farm
* number of worked days for the intervention

<u>For each intervention without motorized tool :</u>
Number of transported people.distance (persone.km) = (number of people mobilised for the intervention)
* 2 * distance plot-farm
* number of worked days for the intervention</td></tr>
</table>

Example of datasets and quantities for the plot Saint-Emilion - 9 :

Transport

Diesel combustion, in tractor/ U	27,756	**kg**
Transport, passenger car, petrol, fleet average/ Direct/ RER U	67,33	**person.km**

Table 4 : Inventory of direct emissions linked to transport

c. Direct emissions linked to input spreading (only fertilizers)

Only 9 plots over the 15 of Saint-Emilion applied fertilizers in 2016. As the fertilizer spreading is thought at a pluriannual scale, no calculation using the emission model N_2O, NH_3, NO_3^-, NO were done in this study.

d. Direct emissions linked to equipment activity (irrigation/antifrost) (fuel consumption)

Fuel or gas combustion has not been modeled for now because the case-study does not use irrigation or antifrost systems.

1.2.2.2. Indirects emissions

a. Indirect emissions linked to the use of tools

This part takes into account indirect emissions linked to:

- Fuel consumption : extraction, refining, transportation.
- Tools production.

<u>Datasets available</u>

Indirect emissions	Datasets		Unit
Use of a tool (motorized tool towed or mounted)	Diesel, at regional storage/S		kg
	Towed tool	General machinery, with tires, LT <2'500h, production/ U	
		General machinery, with tires, LT >5'000h, production/ U	
		General machinery, with tires, LT 2'500-5'000h, production/ U	
	Mounted tool	**General machinery, without tires, LT 8000h, production/ U**	
	Harvesting machine	**Harvester/Machine with engine, LT <5'000h, production/ U**	
		Harvester/Machine with engine, LT >10'000h, production/ U	
		Harvester/Machine with engine, LT 5'000 to 10'000h, production/ U	
	Tractor	Tractor, LT 10'000h, production/ U	
		Tractor, LT 12'000h, production/ U	
		Tractor, LT 7'500h, production/ U	

Datasets in bold are the most used tools for vine-growing.

<u>Calculation method</u>

For the amount of fuel consumed, the calculation and the result are identical to those of direct emissions.

Indirect emissions	Calculation method
Use of a tool (motorized tool towed or mounted)	$\text{Tool quantity (kg/ha/an)} = \text{Tool mass (kg)} \times \left(\dfrac{\frac{\text{Duration of use (h/an)}}{\text{Lifetime (h)}}}{\text{Worked area of the plot (ha)}} \right)$

The lifetime of a tool is the accumulation of the duration of use during all the life of the tool.

While the quantity linked to each tool has been requested, the law response rate regarding tools mass and lifetime led to the use of baseline data from Agribalyse®.

Example of datasets and quantities for the plot Saint-Emilion - 9:

Canopy management

Diesel, at regional storage/S	38,408	kg
General machinery, without tires, LT 8000h, production/ U	1,722	kg
Tractor, LT 7'500h, production/ U	2,750	kg

Harvest

Diesel, at regional storage/S	72,680	kg
Harvester/Machine with engine, LT <5'000h, production/ U	5,743	kg

Pest and disease management

Diesel, at regional storage/S	72,015	kg
General machinery, without tires, LT 8000h, production/ U	3,960	kg
Tractor, LT 7'500h, production/ U	4,125	kg

Soil maintenance

Diesel, at regional storage/S	131,566	kg
General machinery, without tires, LT 8000h, production/ U	6,079	kg
Tractor, LT 7'500h, production/ U	6,876	kg

Trellis management and maintenance

Diesel, at regional storage/S	48,749	kg
Tractor, LT 7'500h, production/ U	1,650	kg

b. Indirect emissions linked to inputs

The only inputs studied here are pesticides because they are the only one inventoried for the plot.

Datasets available

Cf. Appendix 2

The data collected and that makes sense for winegrowers is the commercial product. It is necessary to build a proxy for each product from the available datasets.

The table below presents the aggregations realized to create the proxy for the plot Saint-Emilion - 9.

Product type	Name of the pesticide	Functional unit proxy	Active substance	Active substance concentration (source : ephy.anses.fr)	Unit c°	Available datasets
Fungicide	Amarok	1 L	Cymoxanil	40	g/L	[sulfonyl]urea-compounds, at regional storehouse/kg/RER
			Folpet	334	g/L	Pesticide, unspecified {GLO}| market for | Alloc Rec, S
	Atemi	1 kg	Cyproconazole	100	g/kg	Cyclic N-compound {GLO}| market for | Alloc Rec, S
	Chaoline	1 kg	Fosetyl	471	g/kg	Fosetyl-Al {GLO}| market for | Alloc Rec, S
			Metiram	289	g/kg	Pesticide, unspecified {GLO}| market for | Alloc Rec, S
	Escadril	1 L	Cymoxanil	40	g/L	[sulfonyl]urea-compound {GLO}| market for | Alloc Rec, S
			Folpet	334	g/L	folpet, at regional storage/kg/rer
	Greman	1 L	Tetraconazole	100	g/L	Cyclic N-compound {GLO}| market for | Alloc Rec, S
	Indar EW	1 L	Fenbuconazole	50	g/L	Cyclic N-compound {GLO}| market for | Alloc Rec, S
	Kocide 35 DF	1 kg	Copper hydroxide	350	g/kg	Pesticide, unspecified {GLO}| market for | Alloc Rec, S
	kumulus	1 kg	Sulphur	800	g/kg	Secondary sulphur, at refinery/kg/RER
	Nordox 75 WG	1 kg	Copper oxide	350	g/kg	Copper oxide, at plant/kg/RER
	Privest	1 kg	Ametoctradin	120	g/kg	Pesticide, unspecified {GLO}| market for | Alloc Rec, S
			Metiram	440	g/kg	Pesticide, unspecified {GLO}| market for | Alloc Rec, S
	Rhodax	1 kg	Fosetyl	440	g/kg	Fosetyl-Al {GLO}| market for | Alloc Rec, S
			Mancozeb	260	g/kg	Pesticide, unspecified {GLO}| market for | Alloc Rec, S
	Sulfojet	1 kg	Sulphur	800	g/kg	Secondary sulphur, at refinery/kg/RER

Calculation method

Indirect emissions	Calculation method
Pesticides spreading	$$\text{Product j quantity spread (kg/ha/an)} = \sum_{i}^{n} \textit{Dose spread during intervention i}$$

Proxys and quantities for the plot Saint-Emilion - 9 :

Pest and disease management		
Amarok	1,8	**L/ha**
Atemi	0,07	**kg/ha**
Chaoline	3,68	**kg/ha**
Escadril	2,3	**L/ha**
Greman	0,23	**L/ha**
Indar	0,75	**L/ha**
Kocide	2,96	**kg/ha**
kumulus	5	**kg/ha**
Nordox	0,15	**kg/ha**
Privest	2,4	**kg/ha**
Rhodax	2,69	**kg/ha**
Steward	0,13	**kg/ha**
Sulfojet	7	**kg/ha**
Soil maintenance		
Heliosol	0,2	**L/ha**
Round up	3	**L/ha**
Viaglif	3	**L/ha**

c. Indirect emissions linked to equipments

Two type of equipments are studied :

Simple equipments (ex : system for pesticide treatment) : only data regarding the equipment lifetime.

Compound equipments (ex : trellising) : data regarding the number and the mass of the « material units » that compose the equipment, and the equipment lifetime.

Available datasets

It does not exist datasets for vine-growing equipments neither for material units from compound equipments.

For simple equipments, proxys from materials and quantities that compose the equipments should be created. But these data have not been collected. Equipments are not modelised in this study.

For compound equipments, a test was realised for the equipment of trellising used on the plot Saint-Emilion - 9. Proxys for each material are created in order to be used again for other plots. Thus, the functional unit of each proxy is chosen depending on data that are non-specific from farms or regions (mass, area and lifetime of each material unit).

Material unit	Material	Datasets for production and end of life of the material unit	Dataset unit	Functional unit of the proxy « material unit »	Calculation quantity of dataset	Quantity of dataset for 1 functional unit
Pole (Ø 8 cm, H 2m)	Wood	Sawnwood, softwood, dried (u=20%), planed {RoW}| market for | Alloc Rec, S	m^3	1 pole	$\frac{Cylindrical\ volume\ (m}{Lifetime\ (year)}$	0,0005
Wire (Ø 2.5 mm)	Cast iron	Steel, low-alloyed {GLO}| market for | Alloc Rec, S	kg	1 kg of wire	$\frac{Mass\ (kg)}{Lifetime\ (year)}$	0,0333
		Wire drawing, steel {RoW}| processing | Alloc Rec, S	kg		$\frac{Mass\ (kg)}{Lifetime\ (year)}$	0,0333
		Zinc coat, coils {GLO}| market for | Alloc Rec, S	m^2		$\frac{Cylinder\ surface\ (m^2)}{Lifetime\ (year)}$	0,0066
Anchoring (Ø 3 cm, H 50 cm)	Cast iron	Steel, low-alloyed {GLO}| market for | Alloc Rec, S	kg	1 anchoring	$\frac{Mass\ (kg)}{Lifetime\ (year)}$	0,071
		Wire drawing, steel {RoW}| processing | Alloc Rec, S	kg		$\frac{Mass\ (kg)}{Lifetime\ (year)}$	0,071
		Zinc coat, coils {GLO}| market for | Alloc Rec, S	m^2		$\frac{Surface\ cylindre\ (m^2)}{Lifetime\ (year)}$	0,0012

Trellising material unit dimensions are reference data from « « Le coût des fournitures en viticulture et œnologie 2014 » (IFV/APCA). Datasets of materials and treatment process for this type of equipments are described in the annex 2 of the methodological report.

<u>Proxys and quantities for the plot Saint-Emilion - 9 :</u>

Proxys material units for classical trellisng (1.2.1)	Calculation proxy quantity	Proxy quantity	Units
Pole	$\frac{Number\ of\ pole\ on\ the\ plot}{Plot\ area\ (ha)}$	1287	pole/ha/yr
Wire	$\frac{Wire\ mass\ on\ the\ plot\ (kg)}{Plot\ area\ (ha)}$	792	kg/ha/yr
Anchoring	$\frac{Number\ of\ anchoring\ on\ the\ plot}{Plot\ area\ (ha)}$	99	anchoring/ha/yr

1.3. Impact assessment

The Global Warming Potential (GWP) is a weighting factor that aims to aggregate the effect of all the substances contributing of global warming into one value. The unit of this indicator is "CO_2 equivalent", as, by definition, the CO_2 greenhouse effect has been set up to 1, and the greenhouse effect of other gases relatively to the CO_2. The GWP 100 years calculates the radiative forcing over a time horizon of 100 years, in order to take into account the different residence times of the substances in the atmosphere.

$$\text{Conversion of gases quantities (in eq. CO2)} = \text{Gas quantity} \times \text{GWP to 100 years weighting factor of the gas to convert}$$

Different GWP values exist according to different assessment methods. The Table 3 summarizes the GWP of the main GHG emitted by viticulture (CO_2 and N_2O), for three main European and international methods.

	IMPACT	Europe RECEIPE	IPCC 2013 100 years	Unit
CO_2	1	1	1	kg CO_2 eq/kg
N_2O	156	298	265	kg CO_2 eq/kg

Table 3 : GWP values for CO2 and N2O and several assessment methods

The **IPCC 2013 GWP 100 years** has been selected for the Adviclim project, to be consistent with the French database Agribalyse®. This method, built by the Intergovernmental Panel on Climate Change (IPCC), provides characterization factors for the largest number of greenhouse gases.

2. Results and discussion

2.1. Saint-Emilion pilot site

2.1.1. Plots description

For Saint-Emilion, GHG emissions calculations were processed on fifteen plots for the cultural year 2015-2016. Some characteristics of the technical itineraries, useful to interpret the results, are presented in Table 4.

All the sampled plots are planted with Merlot, and equipped with the same classic wooden trellising. None of the plots are equipped with irrigation system or antifrost system.

However, the plots show a good variability in terms of:

- quantity of manual work,
- motor power of motorized tools,
- inter-rows plant cover surface.

The vines of a majority of plots are grown in a conventional way, two plots are under integrated viticulture, one under organic and one under biodynamic viticulture.

The numbers of intervention days for each vineyard operation are summarized in the Table 5. The two most frequent vineyard operations are the Pest and disease management, and the Soil maintenance. They show some variability also, due in some extent to the type of viticulture (conventional/integrated/organic/biodynamic) for the Pest and disease management mainly. But even among the conventional plots, the number of intervention days are quite variable for those two vineyard operations.

The work output (the time to execute an intervention on 1 ha) is roughly the same between all the plots. There are some differences for inter-rows mowing and weeding work output, due to the differences in inter-rows plant cover surface of the plots (half or all the inter-rows mowed).

Plot code	Type of viticulture practised on the vineyard	Manual harvest	Harvesting machine used for pesticide spraying	Mean motor power of motorized tools, excepting harvesting machine (hp)	Planting distance between 2 rows (m)	Planting density (stocks/ha)	Inter-rows plant cover surface	Inter-rows plant cover duration
Plot 102	Integrated	**No**	**Yes**	70-78	1,5	5800	Entire surface	Permanent
Plot 83	Integrated	Yes	No	55-90	1,5	6500	Alternative	Permanent
Plot 232	Conventionnal	Yes	No	45-70	1,3	6500	Entire surface	Permanent
Plot 242	Conventionnal	Yes	No	45-70	1,3	6500	Bare soil	-
Plot 14	Conventionnal	Yes	No	55-90	1,4	5900	Alternative	Permanent
Plot 106	Conventionnal	**No**	No	55-65	1,5	5500	Alternative	Permanent
Plot 15	Conventionnal	**No**	**Yes**	48-65	1,4	6000	Alternative	Permanent
Plot 78	Conventionnal	Yes	No	60	1,25	5700	Entire surface	Permanent
Plot 9	Conventionnal	**No**	No	55-65	1,4	6500	Entire surface	Permanent
Plot 32	Conventionnal	**No**	No	60-75	1,2	5820	Entire surface	Permanent
Plot 1	**Biodynamic**	Yes	No	65-75	1,5	5500	Bare soil	-
Plot 70	Conventionnal	Yes	No	50	1,4	6400	Alternative	Temporary (spring and summer)
Plot 90	Conventionnal	Yes	No	44-80	1,5	6000	Entire surface	Permanent
Plot 55	Conventionnal	**No**	**Yes**	60-125	1,1	6000	Alternative	Permanent
Plot 552	**Organic**	**No**	**Yes**	60-125	1,1	6000	Alternative	Permanent

Table 4 : Some agronomic characteristics of the sampled plots (Saint-Emilion)

Plot code	1 - Application of fertilizers and manures	2 – Canopy management	3 – Harvest	4 – Pest and disease management	6 – Soil maintenance	7 – Trellis management and maintenance	8 - Vine maintenance	9 – Winter pruning
Plot 102		7	1	**16**	3	1		1
Plot 83		4		**11**	**11**			
Plot 232	2	3		**12**	**12**		1	1
Plot 242	2	3		**12**	**11**		1	1
Plot 14		5		**12**	**9**			1
Plot 106		6	1	**11**	**11**			1
Plot 15	1	6	1	**11**	**10**			1
Plot 78	2	5		**10**	**8**			2
Plot 9		3	1	**9**	**6**	1		
Plot 32		4		**17**	4			1
Plot 1	**12**			**26**	**10**			1
Plot 70	2,5	4		**10,5**	**9**			
Plot 90	0,5	7		**13,5**	**8**		2	
Plot 55	2	6	1	**11**	**10**			1
Plot 552	1	5	1	**16**	**16**			1

Table 5 : Number of intervention days for each vineyard operation and each plot for the year 2015-2016 (Saint-Emilion)

2.1.2. GHG EMISSIONS RESULTS

2.1.2.1. Analysis of a case study : the plot Saint-Emilion - 9

The Figure 2 illustrates the GHG emissions assessment results for the plot Saint-Emilion - 9, regarding the observed technical itinerary of the plot for the growing year 2015-2016. Those results are presented in details in Table 6.

GHG emissions due to viticulture on this plot are mainly direct emissions (61 % of total emissions).

However, the split between direct and indirect emissions is different according to vineyard operations: the direct emissions represent 78 % of the emissions linked to harvest, while they represent only 45 % of the emissions linked to trellis management and maintenance. Some vineyard operations (for ex, n°4 and n°7) involve indeed inputs or equipments that do not produce themselves any GHG emissions directly in the field when installed or applied (for example, trellising or pesticides), but of which the manufacturing produces significant indirect emissions. Only the use of tools to manage or apply it produces direct emissions that balances the indirect ones.

The most emitting vineyard operations, excepting trellis management and maintenance, are the soil maintenance (24 % of the total emissions) and the pest and disease management (23 %). The numerous motorized pulling tools use days for those two operations explain this result (cf Table 5). The mechanical harvest, executed in only one day, represent also a significant part of the total emissions (14 %). On the contrary, the pruning doesn't show any GHG emissions, as it is manual interventions, and the employees' transportation is allocated to the vineyard operation "Transport".

To finish with, the result of indirect emissions for the trellising equipment (13 % of the total emissions) shows the importance to take into account this kind of equipment, even after having smoothed the manufacturing emissions over the quite high lifetime (between 20 and 40 years for the material units of the trellising equipment).

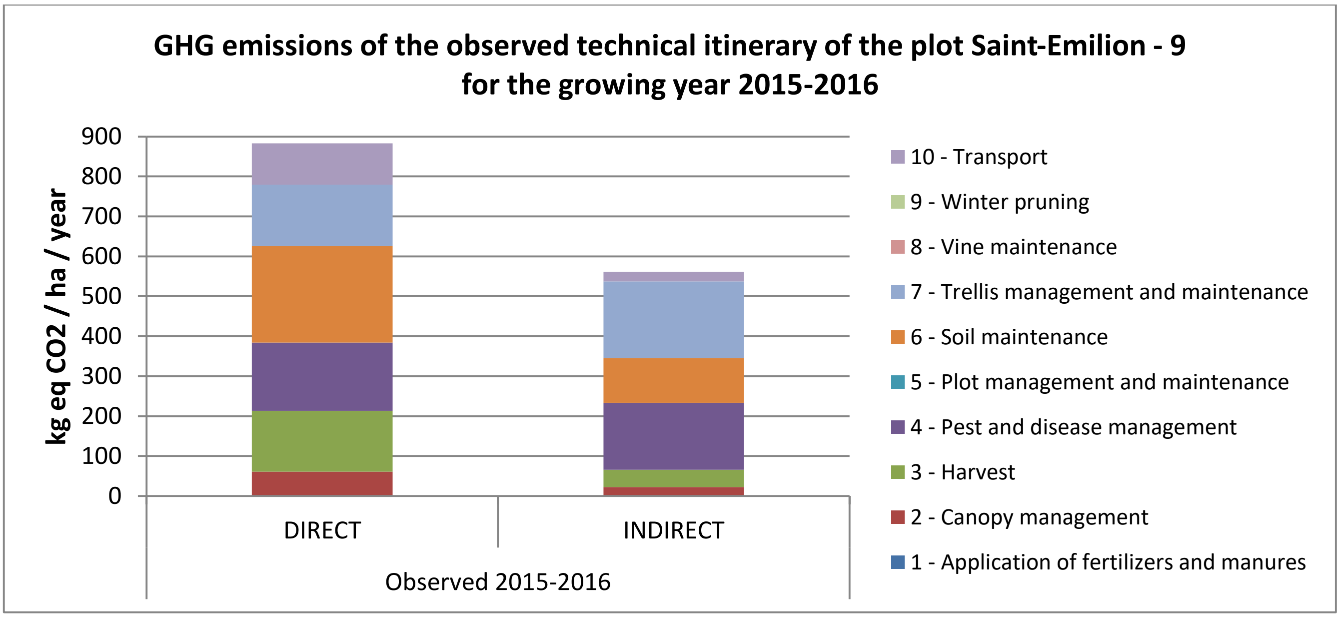

Figure 2 : Results of the GHG emissions assessment for the plot Saint-Emilion - 9

	Direct emissions		Indirect emissions		Total of emissions for the vineyard operation	
Vineyard operation	**GHG emissions (kg CO2 eq/ha)**	**% of total emissions of the vineyard operation**	**GHG emissions (kg CO2 eq/ha)**	**% of total emissions of the vineyard operation**	**GHG emissions (kg CO2 eq/ha)**	**% of total emissions at plot scale**
1 - Application of fertilizers and manures	0	0%	0	0%	0	0%
2 - Canopy management	61	73%	23	27%	83	6%
3 - Harvest	153	78%	43	22%	196	14%
4 - Pest and disease management	170	50%	168	50%	339	23%
5 - Plot management and maintenance	0	0%	0	0%	0	0%
6 - Soil maintenance	241	68%	112	32%	353	24%
7 - Trellis management and maintenance	154	45%	191	55%	345	24%
8 - Vine maintenance	0	0%	0	0%	0	0%
9 - Winter pruning	0	0%	0	0%	0	0%
10 - Transport	104	81%	24	19%	129	9%
Total of emissions at plot scale	883	61%	561	39%		

Table 6 : Results of the GHG emissions assessment for the plot Saint-Emilion- 9

2.1.2.2. Comparison between the 15 sampled plots of Saint-Emilion

The variability of technical itineraries appears also after the application of GHG emissions assessment method, on the Figure 3 for the distinction between direct and indirect emissions, and on the Figure 4 for the distinction between vineyard operations.

The total GHG balances per plot varies from single (1180 kg eq CO_2/ha/year for the plot 90) to triple (3000 kg eq CO_2/ha/year for the plot 552), with a mean of 1860 kg eq CO_2/ha/year.

The main conclusions drawn above on the case study (plot 9) are also valid for all the fifteen plots:

- GHG emissions due to viticulture are mainly direct emissions (between 57 and 77% of the total emissions of the plot) ;
- The most emitting vineyard operations are the Soil maintenance (between 23% and 53% of the total emissions of each plot) and the Pest and disease management (between 10% and 38% of the total emissions of each plot) ;
- The harvest can be a significant part of the total emissions when not manual (between 7% and 14% of the total emissions of each plot).

According to the technical itineraries, the Application of fertilizers and manures, and the Canopy management, can also constitute a significant part of the total emissions.

The variability of those results can be explained by the number of intervention days per vineyard operation, but also by the motor power of the motorized tools.

For example, the plots 55 and 552 have the same motor power for the tractor used for Pest and disease management (150 hp), but the plot 55 have less intervention days than the plot 552 for this vineyard operation (respectively 11 and 16 days), hence the difference of 400 kg eq CO_2/ha/year between the two plots.

Then the plots 55 and 106 have the same number of intervention days for Pest and disease management, but the motor power of the motorized tool used for spraying pesticides is from single to double (150 for the plot 55, 65 for the plot 106, as the harvesting machine is used on the plot 55 for this intervention), hence the difference of 600 kg eq CO2/ha/year.

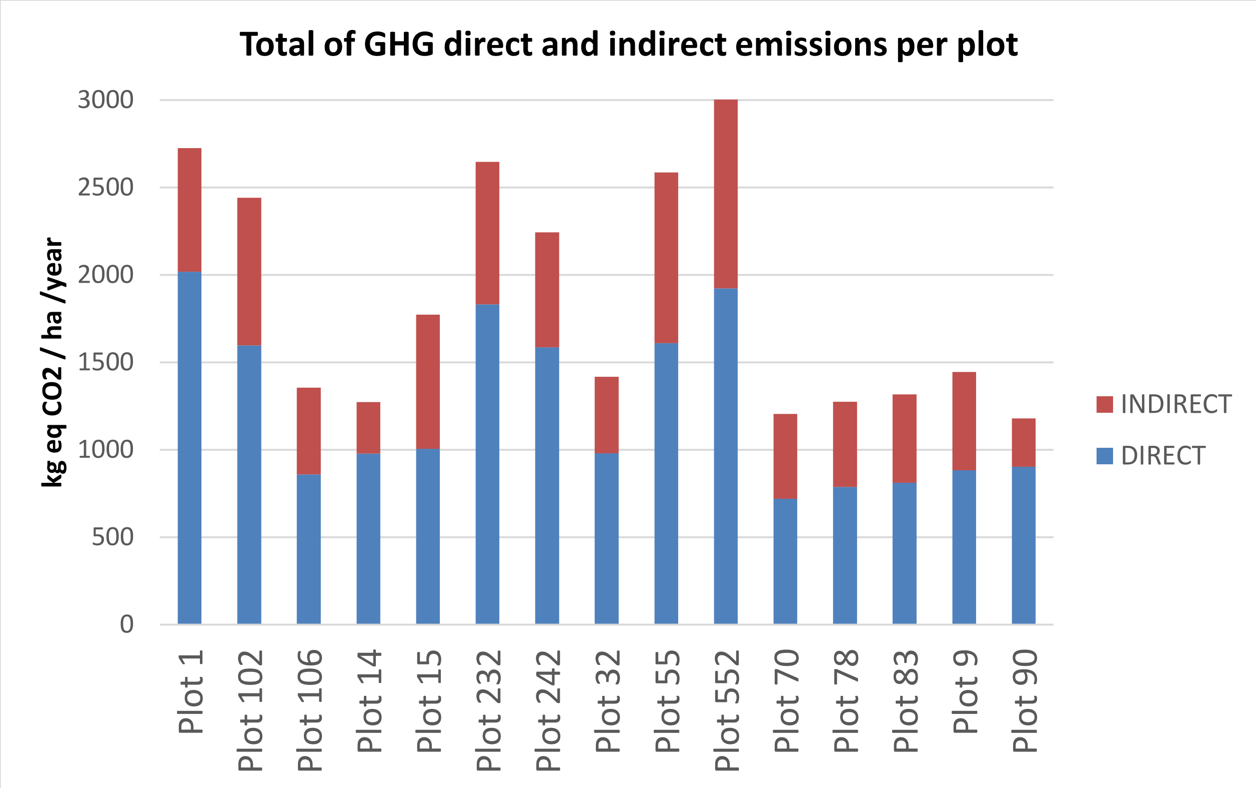

Figure 3 : Results of the GHG emissions assessment for the 15 plots of Saint-Emilion (direct and indirect emissions)

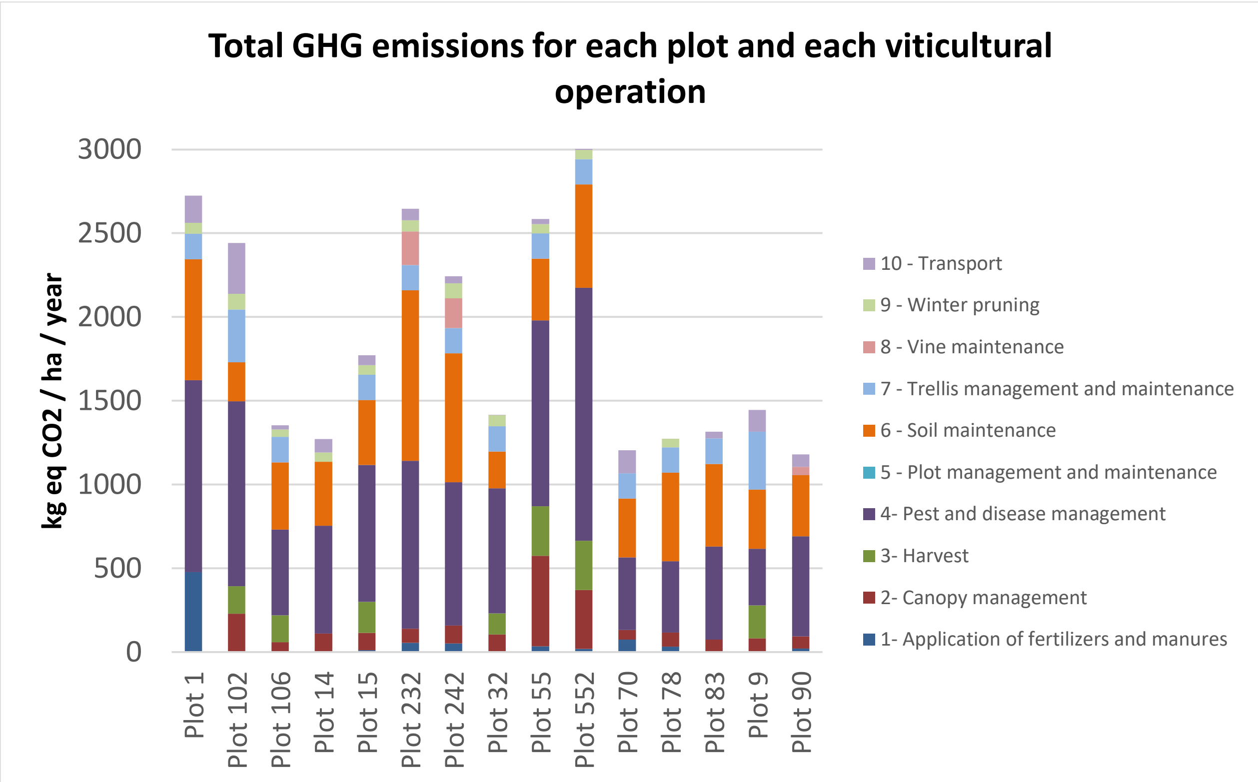

Figure 4 : Results of the GHG emissions assessment for the 15 plots of Saint-Emilion and each viticultural operation

2.2. Cotnari pilot site

2.2.1. Plots description

For Cotnari, GHG emissions assessment was processed on two groups of plots that present the same cultural itinerary, for the cultural year 2016-2017. Some characteristics of the technical itineraries, useful to interpret the results, are presented in Table 7. On the plot "B1-B2", the tractor used has a smaller motor rated power and there are slightly less interventions than on the second plot. The two plots are equipped with the same metallic trellising.

	Plot B1-B2	Plot N1-N2-T1-T2-V1-V2
9 – Winter pruning	0	0
8 – Vine maintenance	0	0
7 – Trellis management and maintenance	0	0
6 – Soil maintenance	4	7
5 – Plot management and maintenance	0	0
4 – Pest and disease management	6	7
3 - Harvest	0	0
2 – Canopy management	0	1
1 – Application of fertilizers and manure	0	0
Distance between winery and plot (km)	0-0,5	0-0,5
Motor rated power of the main tractor (hp)	45	68

Table 7 : Number of intervention days for each vineyard operation and each plot for the year 2016-2017 (Cotnari)

2.2.2. GHG emissions results

The Figure 5 first highlights an important difference of GHG emissions between the two type of plots. The emissions level of the most emitting plot (2537 kg eq CO2/ha/year) is twice more than the emissions level of the least emitting plot (1136 kg eq CO2/ha/year).
Considering the total emissions, the main emitting vineyard operation types are:

- Trellising management throught the indirect emissions of trellising equipement(about 50% of the total emissions for the plot B1-B2).
- Pest and disease management and Soil maintenance.

According to Figure 6, the indirect impact of trellising equipment is important, as it is metallic trellising. Therefore, the indirect emissions are the most important for the plot B1-B2 (71% of the total emissions), or are at the same level as the direct emissions for the second plot.

For both plots, the main direct emissions are due to Pest and disease management, and Soil maintenance (Figure 7 and Figure 8). The difference of direct emissions level between the two plots is explained by the motor rated power (30 hp of difference), and three more interventions of Soil maintenance for the plot N1-N2-T1-T2-V1-V2.

Harvest is manual in both cases, and the impact of road transport is negligable as the distance of each plot to the winery is less than 500 meters (Table 7).

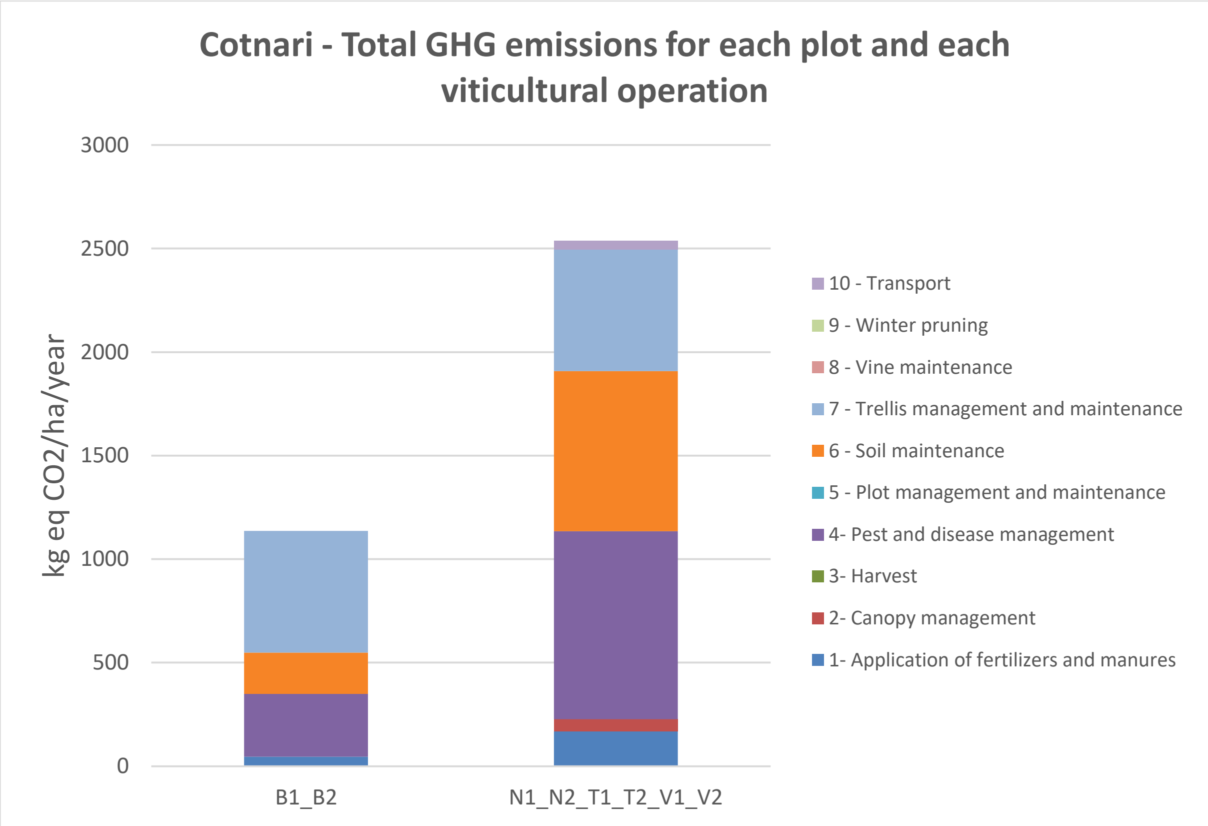

Figure 5 : Results of the GHG emissions assessment for the two plots of Cotnari and each vineyard operation

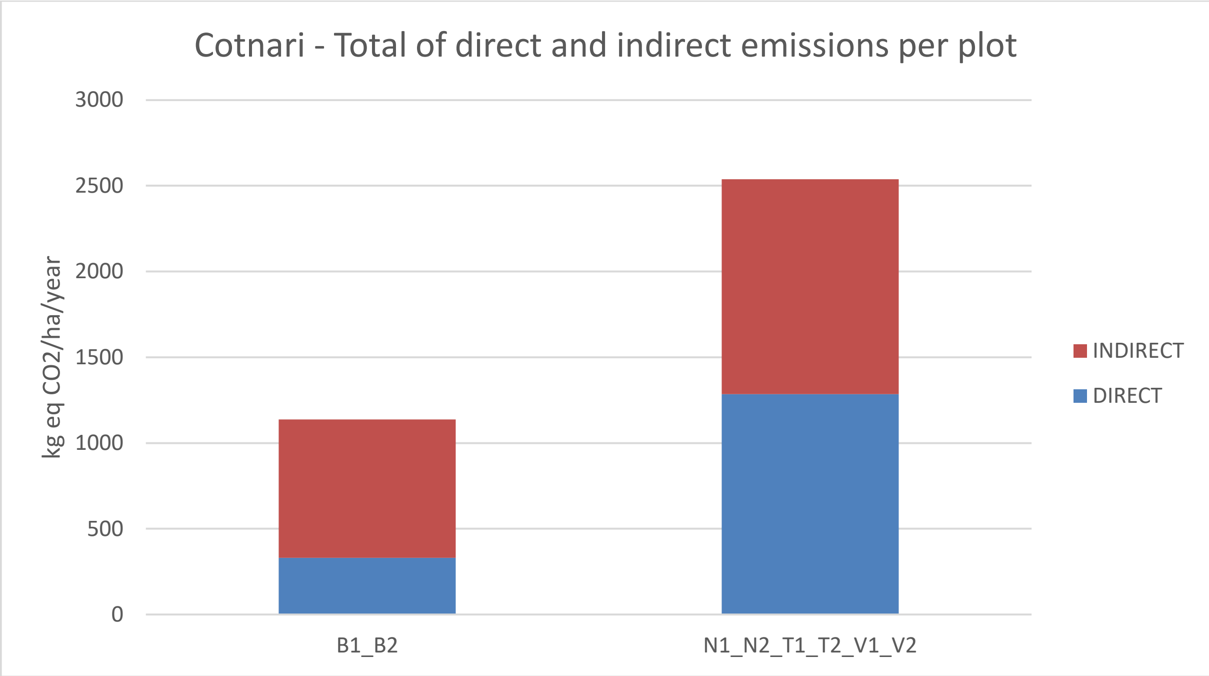

Figure 6 : Results of the GHG emissions assessment for the two plots of Cotanri (direct and indirect emissions)

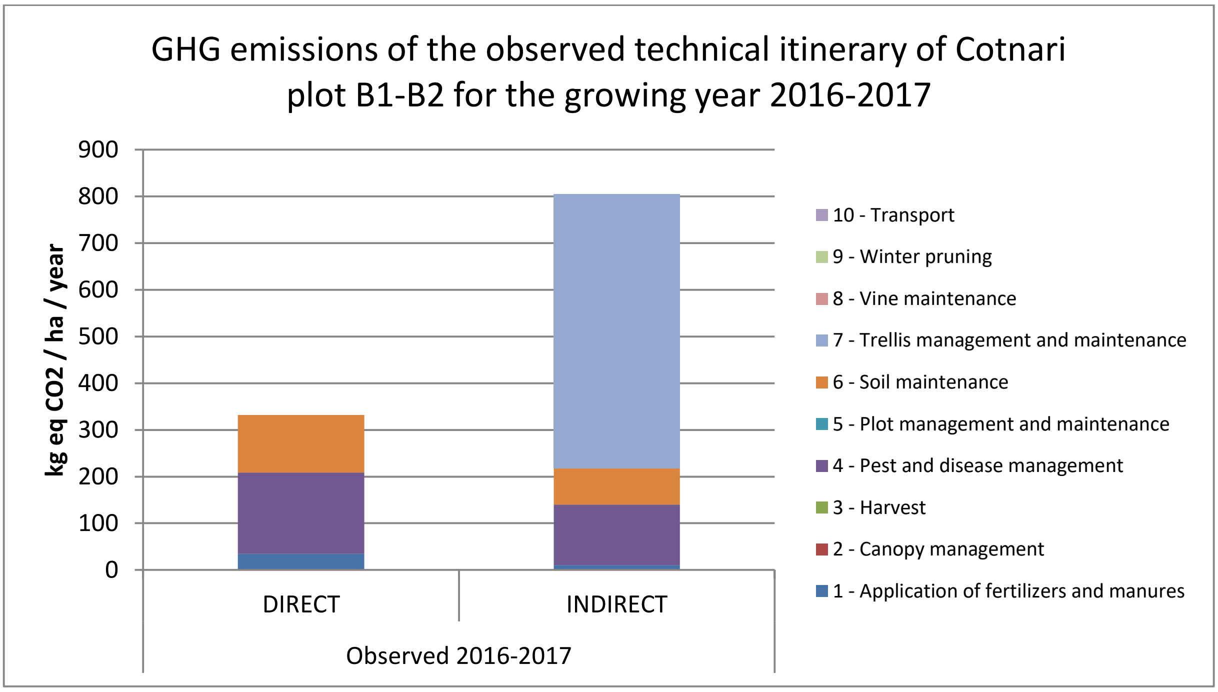

Figure 7 : Results of the GHG emissions assessment for the plot B1-B2

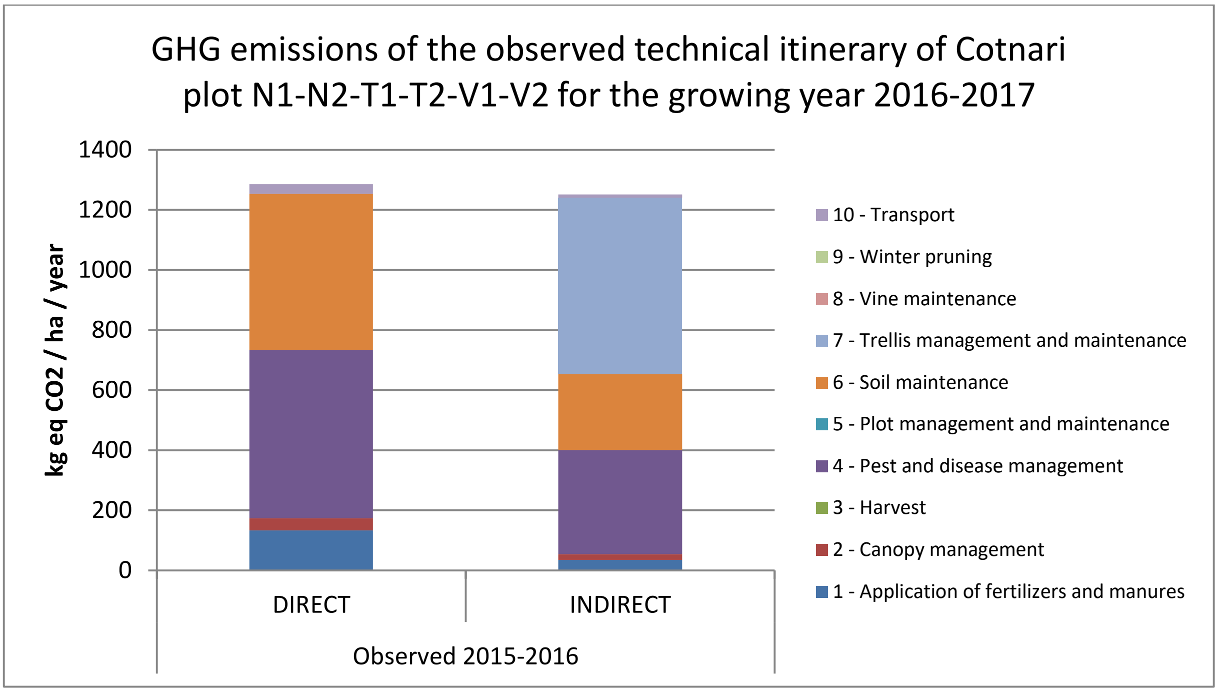

Figure 8 : Results of the GHG emissions assessment for the plot N1-N2-T1-T2-V1-V2

2.3. Val de Loire pilot site

2.3.1. Plots description

For Val de Loire, GHG emissions assessment was processed on five plots for the cultural year 2015-2016. Some characteristics of the technical itineraries, useful to interpret the results, are presented in Table 8.

A good variability of the distance between winery and plot can be observed, as well as the number of pest and disease management interventions. Only one plot is harvested mechanically.

The collected data didn't contain any information about trellising equipment. By default, the same classic wooden trellising as the one of Saint-Emilion plots has been modelled for Val de Loire plots.

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
9 – Winter pruning	2	0	2	2	2
8 – Vine maintenance	0	0	0	0	0
7 – Trellis management and maintenance	0	0	0	0	0
6 – Soil maintenance	7	6	7	9	8
5 – Plot management and maintenance	0	0	0	0	0
4 – Pest and disease management	8	9	10	6	6
3 - Harvest	0	0	0	1	0
2 – Canopy management	3	4	5	5	2
1 – Application of fertilizers and manure	0	1	1	1	0
Distance between winery and plot (km)	0-0,5	1,3	2,5	0-0,5	2,4
Motor rated power of the main tractor (hp)	69	70-80	70-80	70-80	65

Table 8 : Number of intervention days for each vineyard operation and each plot for the year 2015-2016 (Val de Loire)

2.3.2. GHG emissions results

The Figure 9 first highlights an important variability of GHG emissions between the five plots. The emission level of the most emitting plot (1853 kg eq CO2/ha/year) is 2,2 times more than the emission level of the least emitting plot (840 kg eq CO2/ha/year).
Considering the total emissions, the main emitting vineyard operation types are:

- for all the plots : Pest and disease management and Soil maintenance.
- for the plots 3 and 4, the emissions due to Harvest are significant as it is mechanical harvest.
- for the plots 2,3 and 5, the emissions due to Transport on road are also significant as the plots are at least at 1,3 km from the winery.

For all plots, the direct emissions are more important than indirect emissions, and represent from 59 to 68% of the total emissions (Figure 10). The trellising equipment, which is a Classic 1.2.1 type with wooden poles, has significant impact on indirect emissions even if not the main explicative factor of indirect emissions.

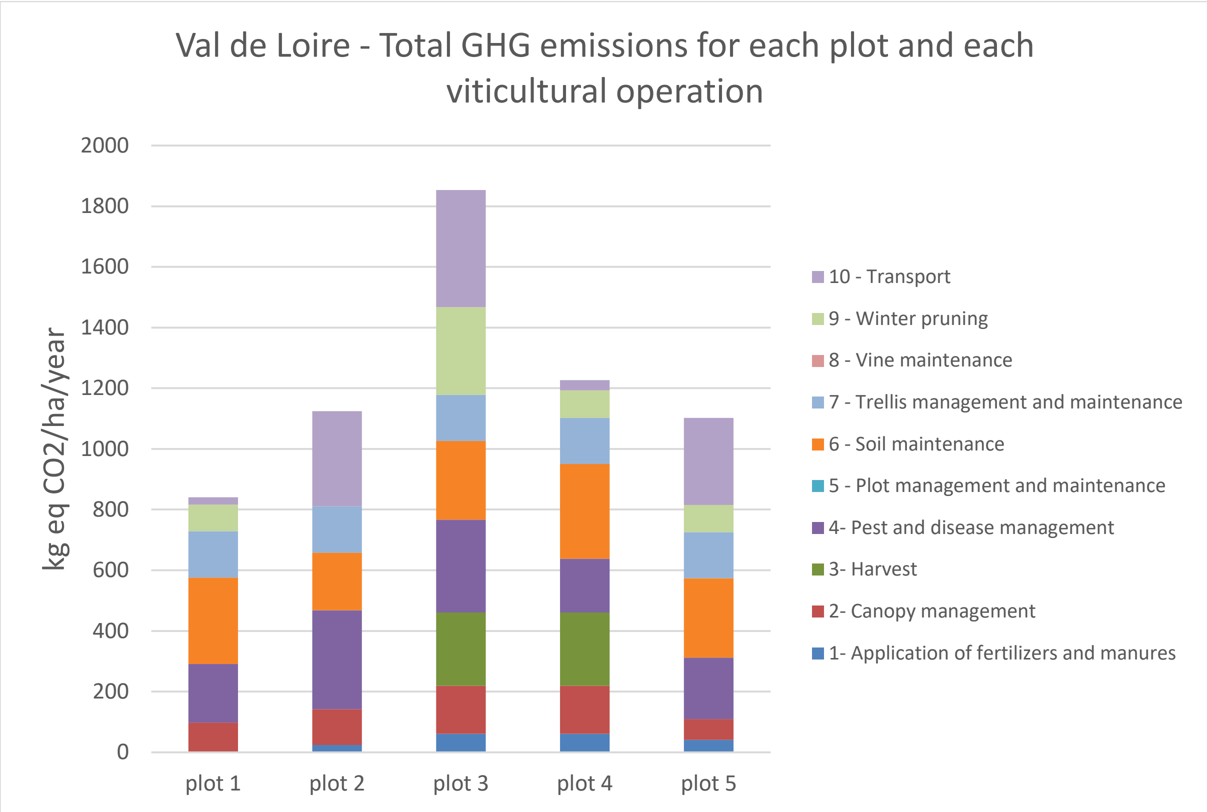

Figure 9 : Results of the GHG emissions assessment for the five Val de Loire plots and each vineyard operation

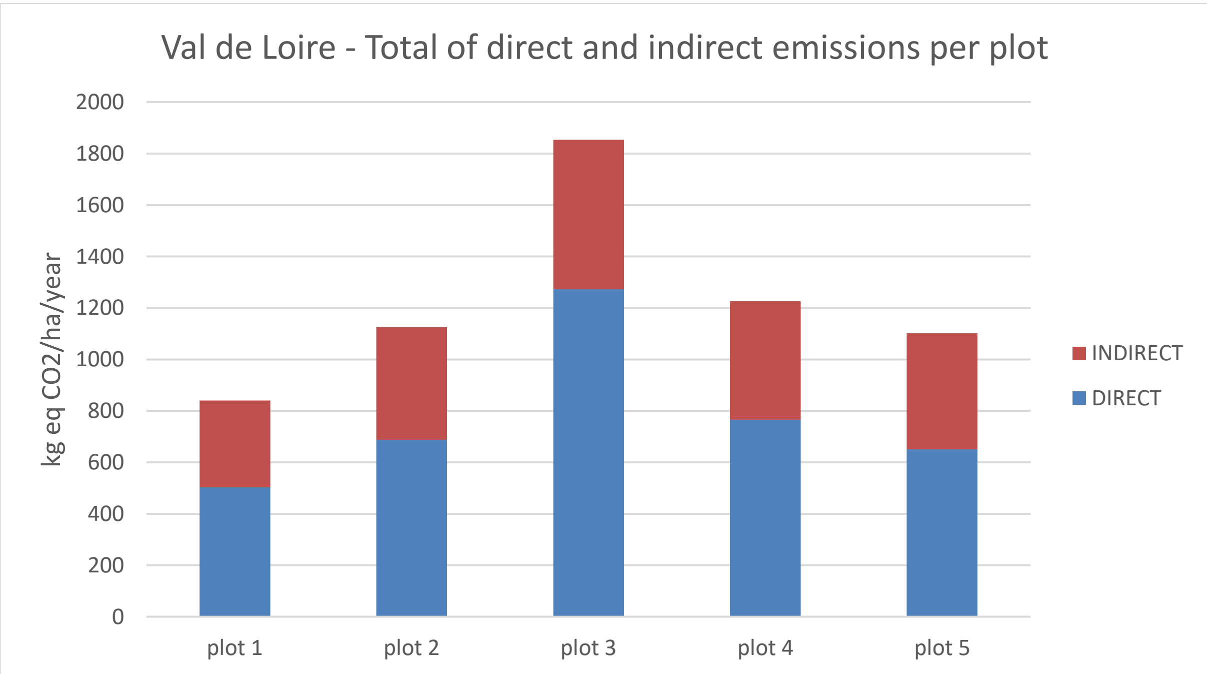

Figure 10 : Results of the GHG emissions assessment for the five Val de Loire plots (direct and indirect emissions)

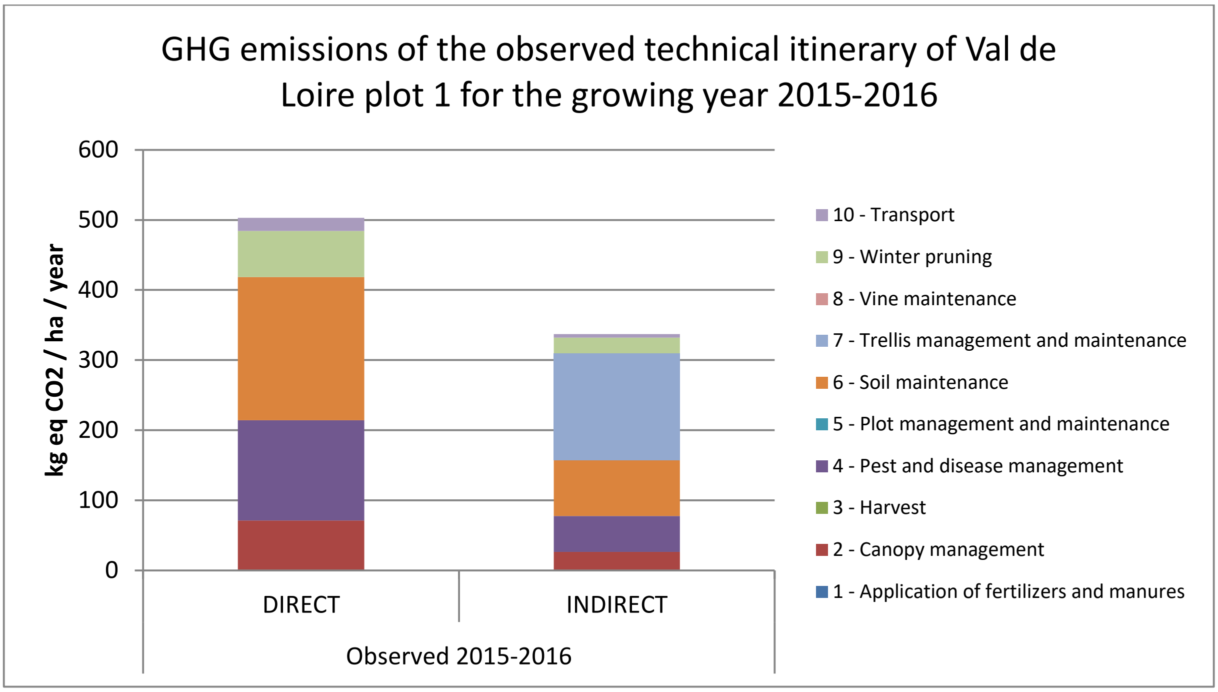

Figure 11 : Results of the GHG emissions assessment for the plot Val de Loire 1

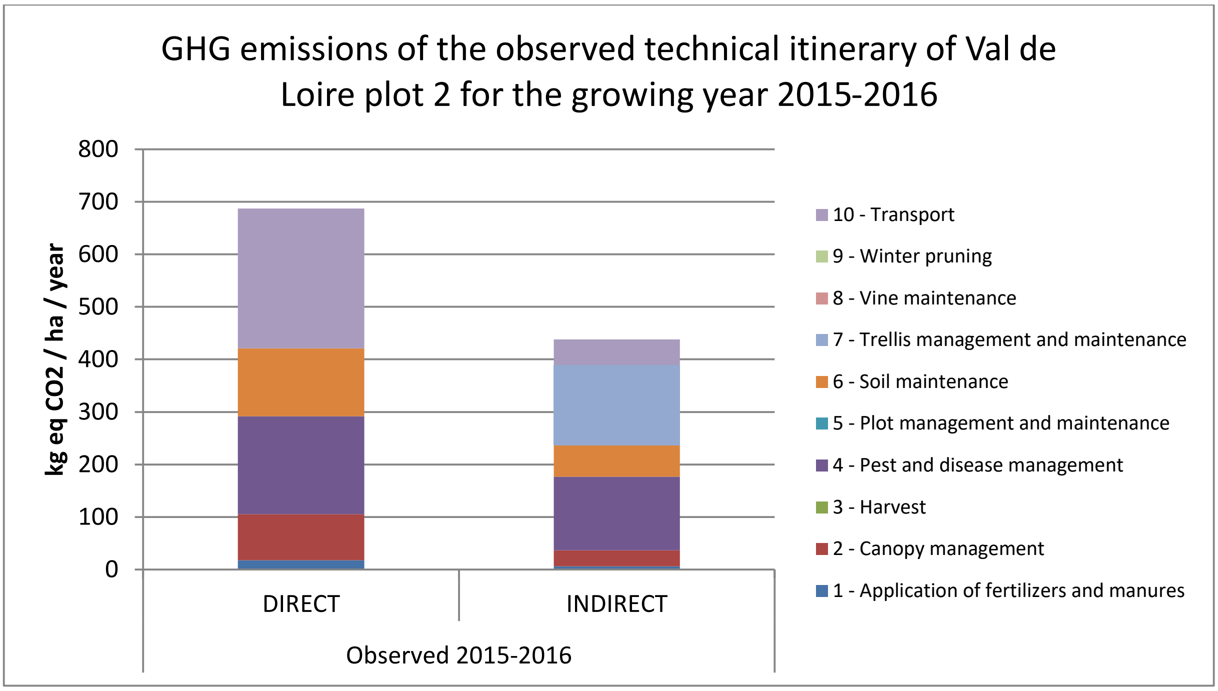

Figure 12 : Results of the GHG emissions assessment for the plot Val de Loire 2

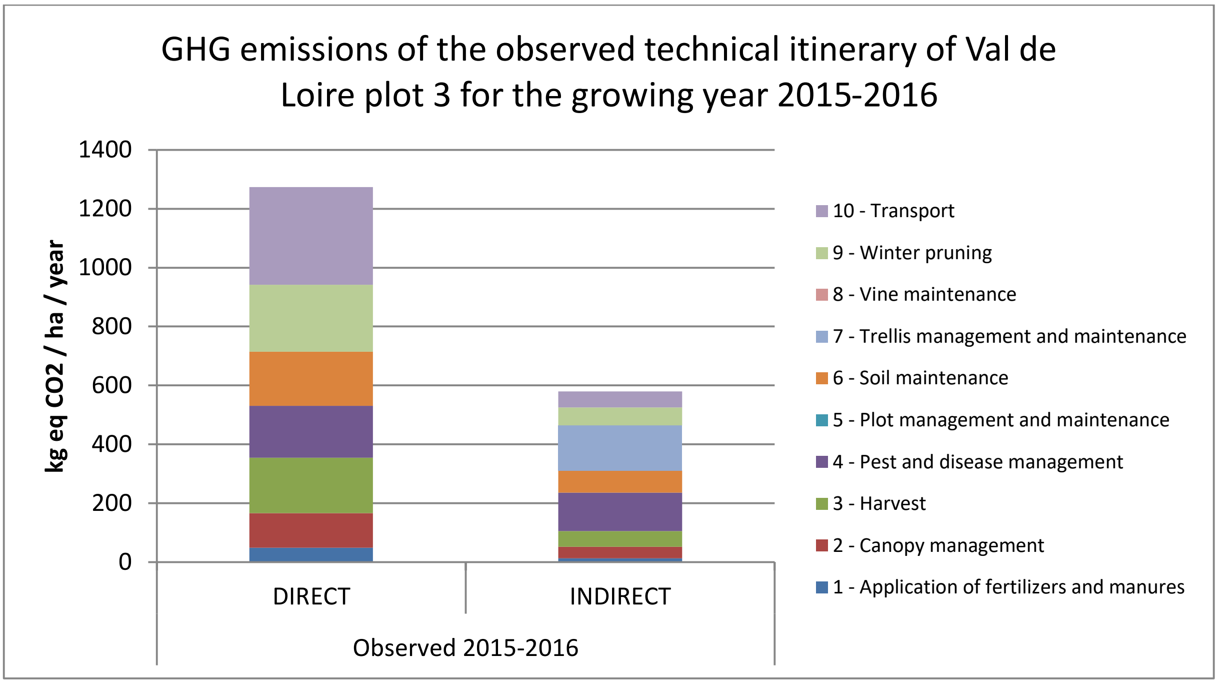

Figure 13 : Results of the GHG emissions assessment for the plot Val de Loire 3

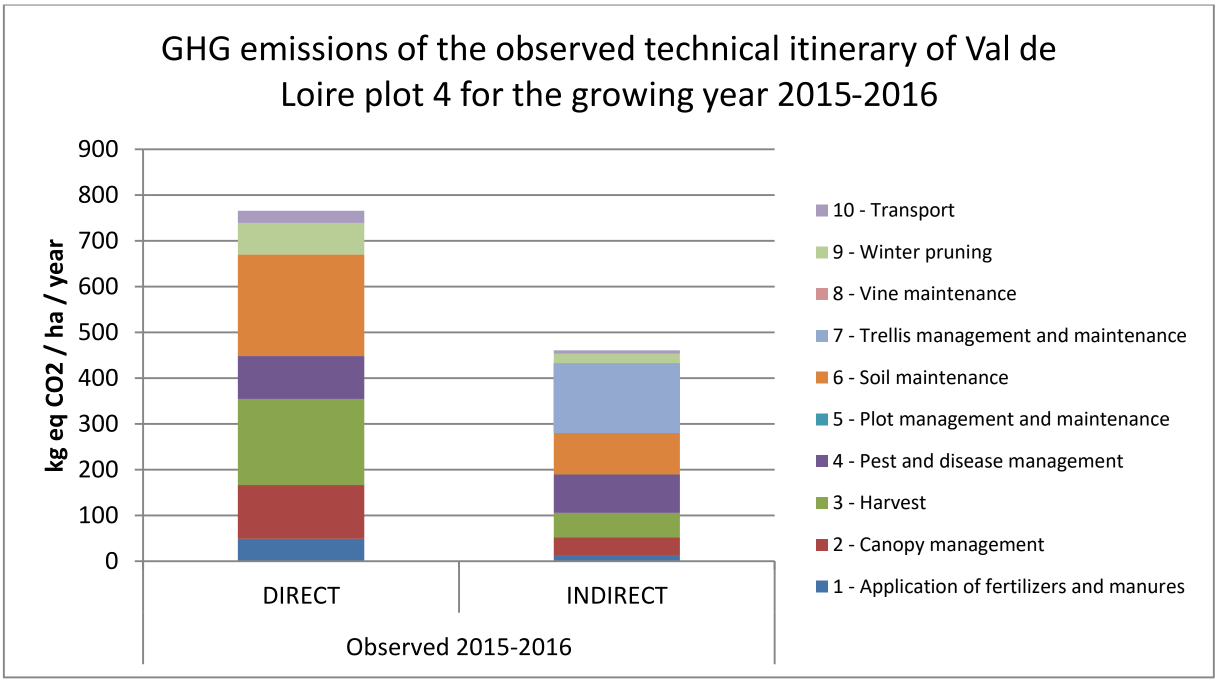

Figure 14 : Results of the GHG emissions assessment for the plot Val de Loire 4

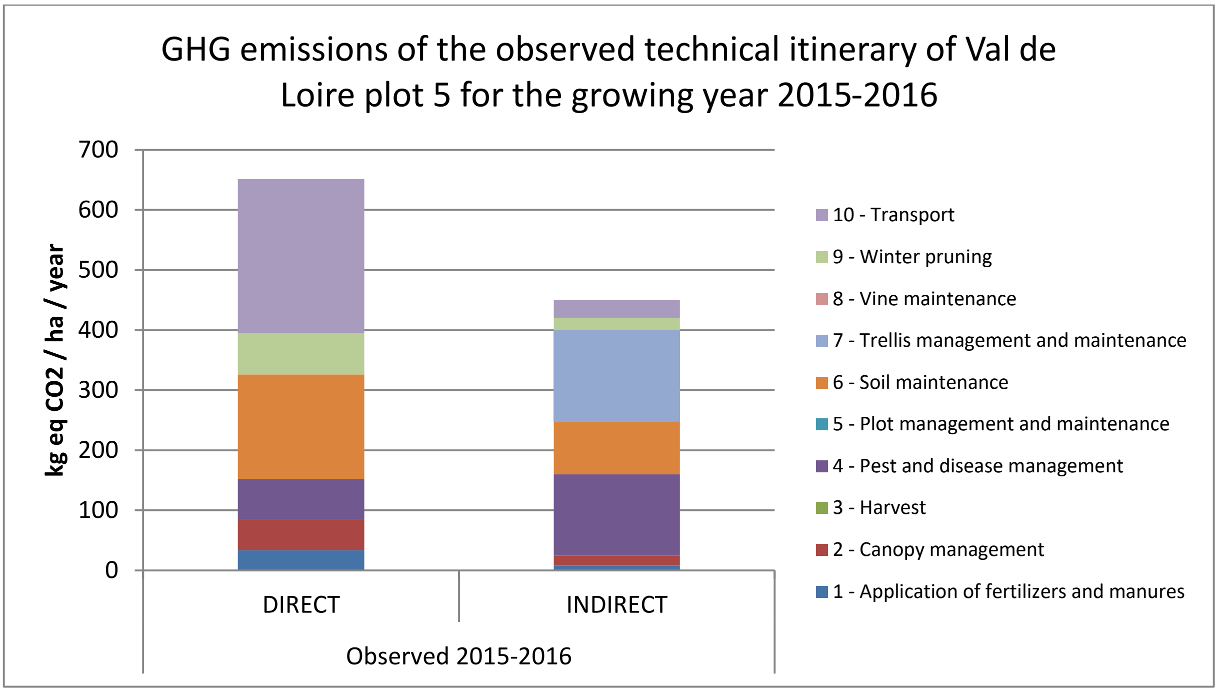

Figure 15 : Results of the GHG emissions assessment for the plot Val de Loire 5

2.4. Plumpton pilot site

2.4.1. Plots description

For Plumpton, GHG emissions assessment was processed for the cultural year 2016-2017. Only one representative plot of Plumpton has been assessed as all the plots are managed exactly the same way, whatever the planted variety. Some characteristics of the technical itineraries, useful to interpret the results, are presented in Table 9. The collected data didn't contain any information about trellising equipment. By default, the same classic wooden trellising as the one of Saint-Emilion plots has been modelled for Plumpton plot.

	Representative plot of Plumpton
9 – Winter pruning	1
8 – Vine maintenance	0
7 – Trellis management and maintenance	1
6 – Soil maintenance	11
5 – Plot management and maintenance	3
4 – Pest and disease management	7
3 - Harvest	0
2 – Canopy management	3
1 – Application of fertilizers and manure	0
Distance between winery and plot (km)	0-0,5
Motor rated power of the main tractor (hp)	70

Table 9 : Number of intervention days for each vineyard operation for the year 2016-2017 (Plumpton)

2.4.2. GHG emissions results

The Figure 16 first highlights the most emitting types of vineyard operation :

- Pest and disease management (39% of the total emissions)
- Soil maintenance (24%)
- Trellising management (23%).

The range of importance of each viticultural operation is the same, whether considering direct or indirect emissions (Figure 18).

In the case of Plumpton, the direct emissions are a bit more important (60%) than indirect emissions (Figure 17).

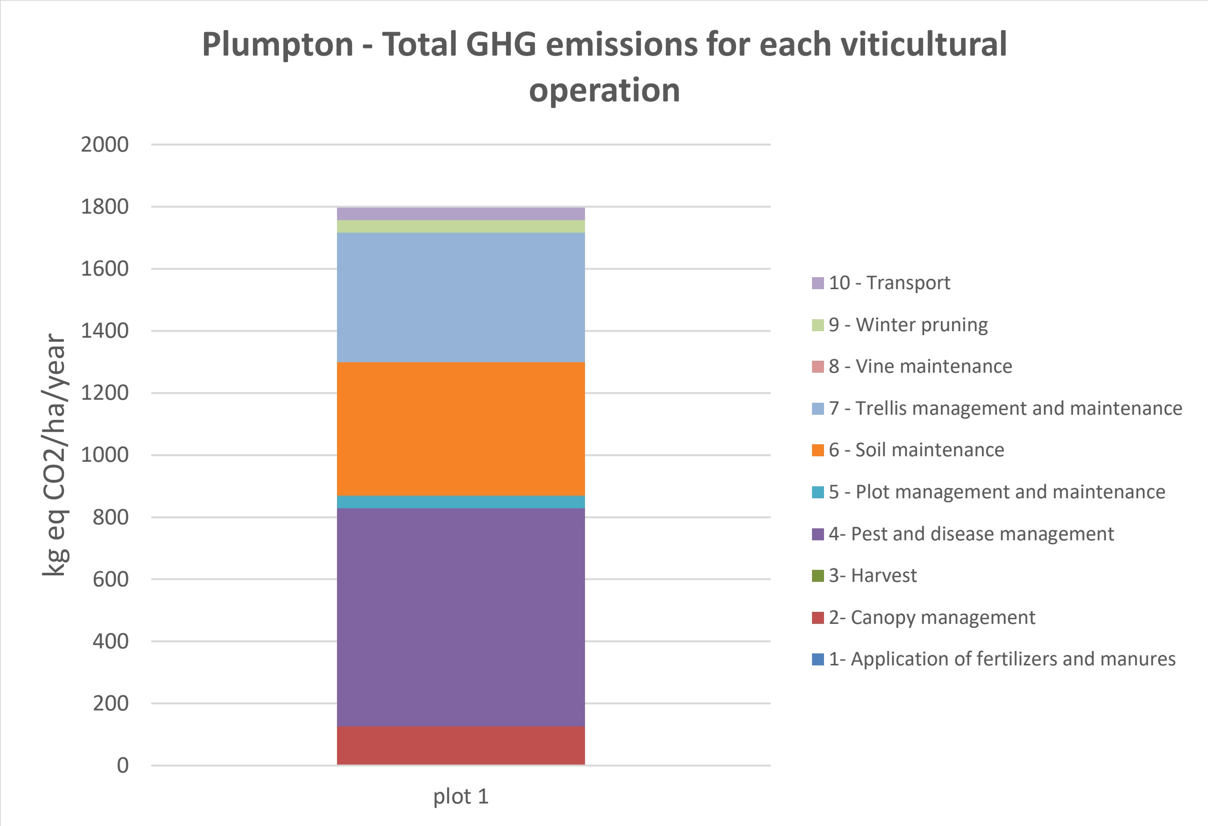

Figure 16 : Results of the GHG emissions assessment for the Plumpton plot and each vineyard operation

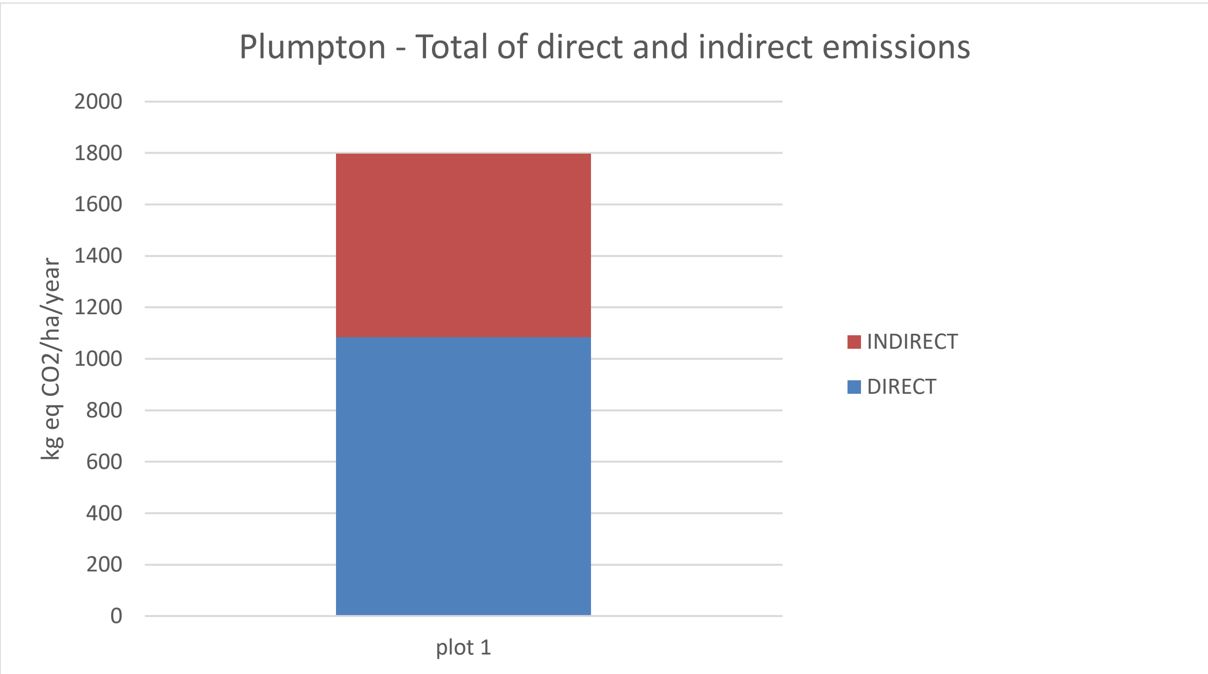

Figure 17 : Results of the GHG emissions assessment for the Plumpton plot (direct and indirect emissions)

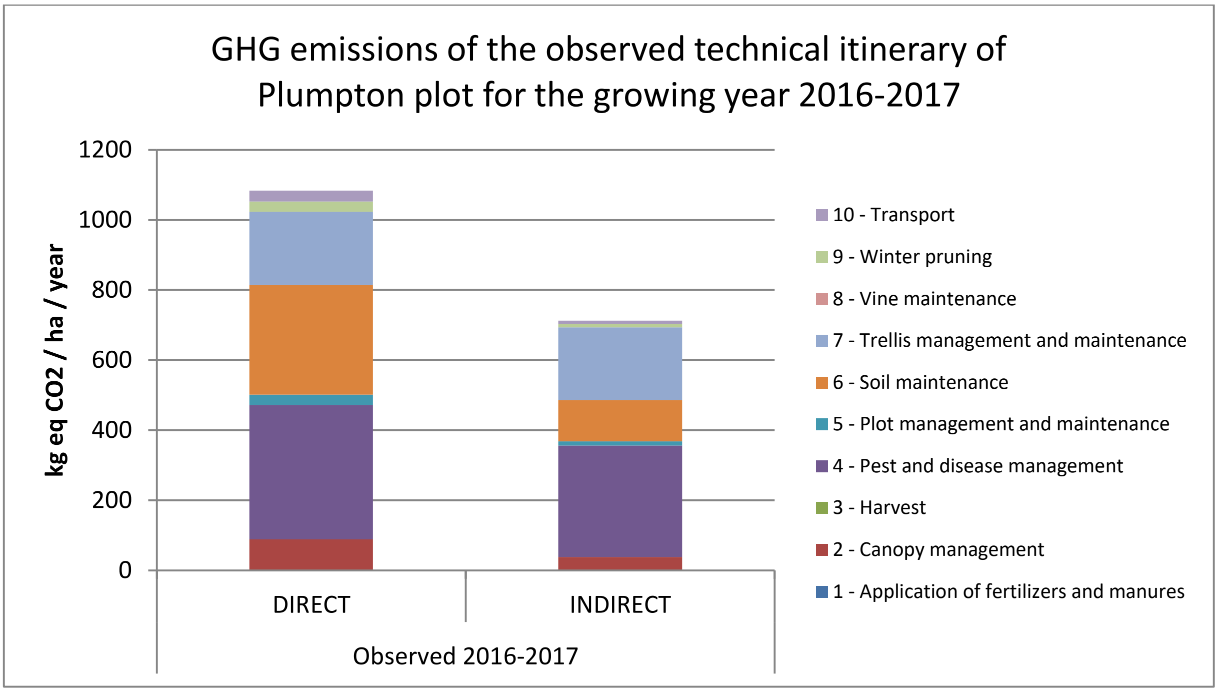

Figure 18 : Results of the GHG emissions assessment for the Plumpton plot and each vineyard operation (splitting direct and indirect emissions)

2.5. Gesenheim pilot site

2.5.1. Plots description

For Gesenheim, GHG emissions assessment was processed on three plots for the year 2017-2018. Some characteristics of the technical itineraries, useful to interpret the results, are presented in Table 10. The particularity of Gesenheim plots is that the main explicative factors of the GHG emissions variability are the same (number of interventions, motor rated power, distance from the winery). The collected data didn't contain any information about trellising equipment. By default, the same classic wooden trellising as the one of Saint-Emilion plots has been modelled for Gesenheim plots.

	Plot 1	Plot 2	Plot 3
9 – Winter pruning	1	1	1
8 – Vine maintenance	0	0	0
7 – Trellis management and maintenance	0	0	0
6 – Soil maintenance	2	2	2
5 – Plot management and maintenance	0	0	0
4 – Pest and disease management	7	7	7
3 - Harvest	0	0	0
2 – Canopy management	3	3	3
1 – Application of fertilizers and manure	0	0	0
Distance between winery and plot (km)	6	6	3
Motor rated power of the main tractor (hp)	101	101	101
Plot size (ha)	0.38	0.68	1.25

Table 10 : Number of intervention days for each vineyard operation and each plot for the year 2017-2018 (Gesenheim)

2.5.2. GHG emissions results

The Figure 19 shows that the difference of GHG emissions between the three plots is significant. Indeed the intervention duration for each operation is the same, but the size plot varies, so the time spent per ha varies proportionally. The Transport operation emissions are very different too, as the distance from the winery to the plot range from 3 to 6 km and the plot size range from single to triple.

Considering the total emissions, the two main emitting vineyard operation types are Pest and disease management and Soil maintenance. To a lesser extent, Canopy management and Winter pruning can be significant.

For all plots, the direct emissions are majority (Figure 20).

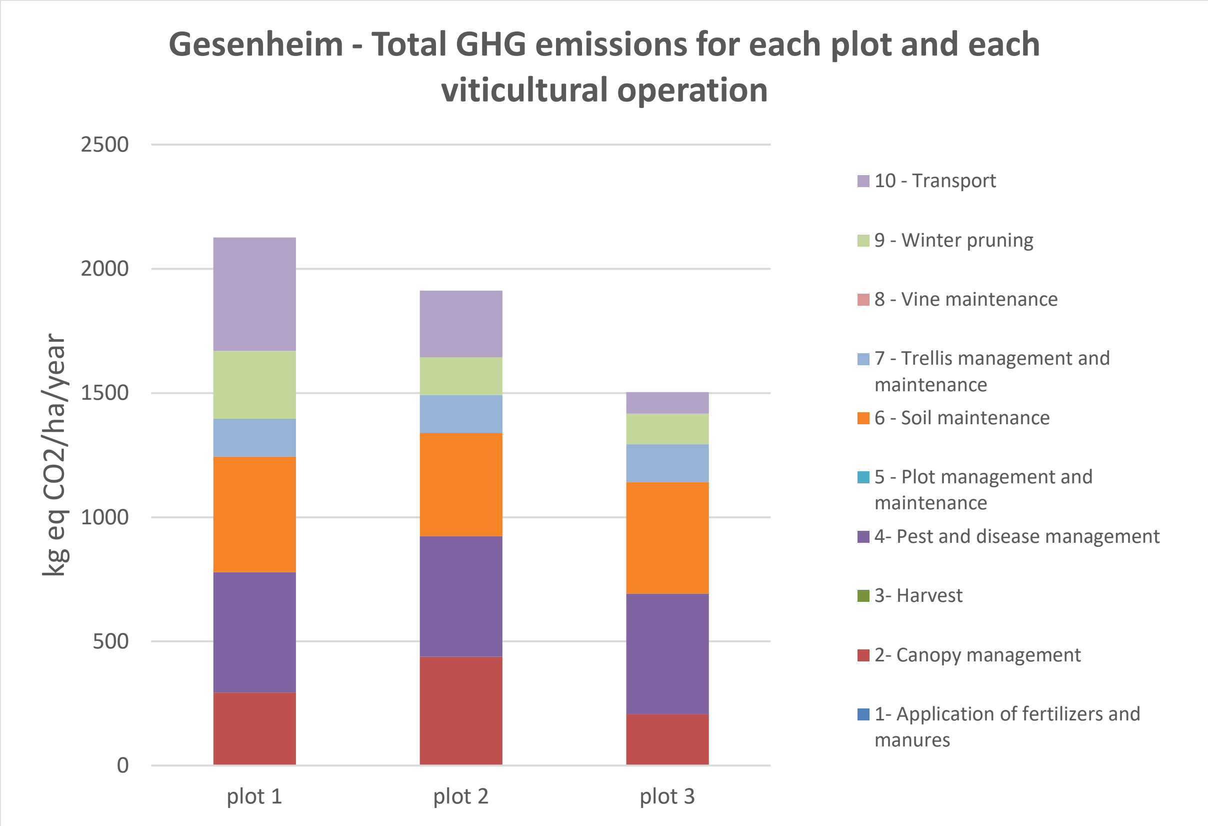

Figure 19 : Results of the GHG emissions assessment for the three Gesenheim plots and each vineyard operation

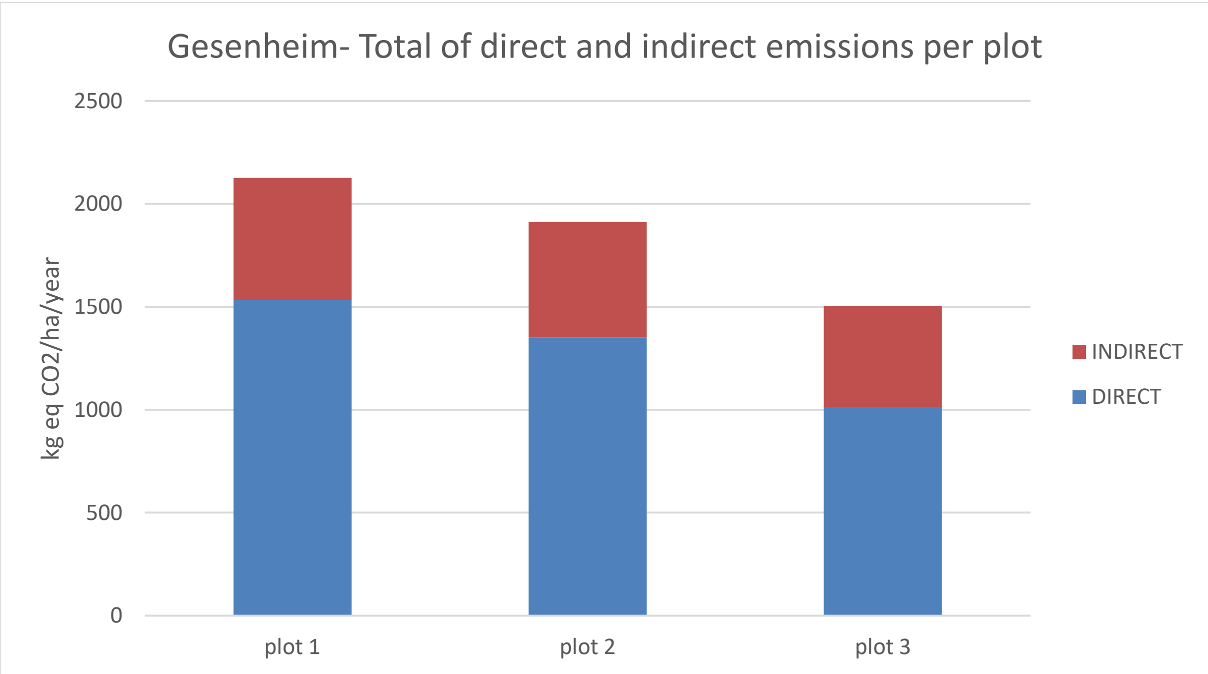

Figure 20 : Results of the GHG emissions assessment for the three Gesenheim plots (direct and indirect emissions)

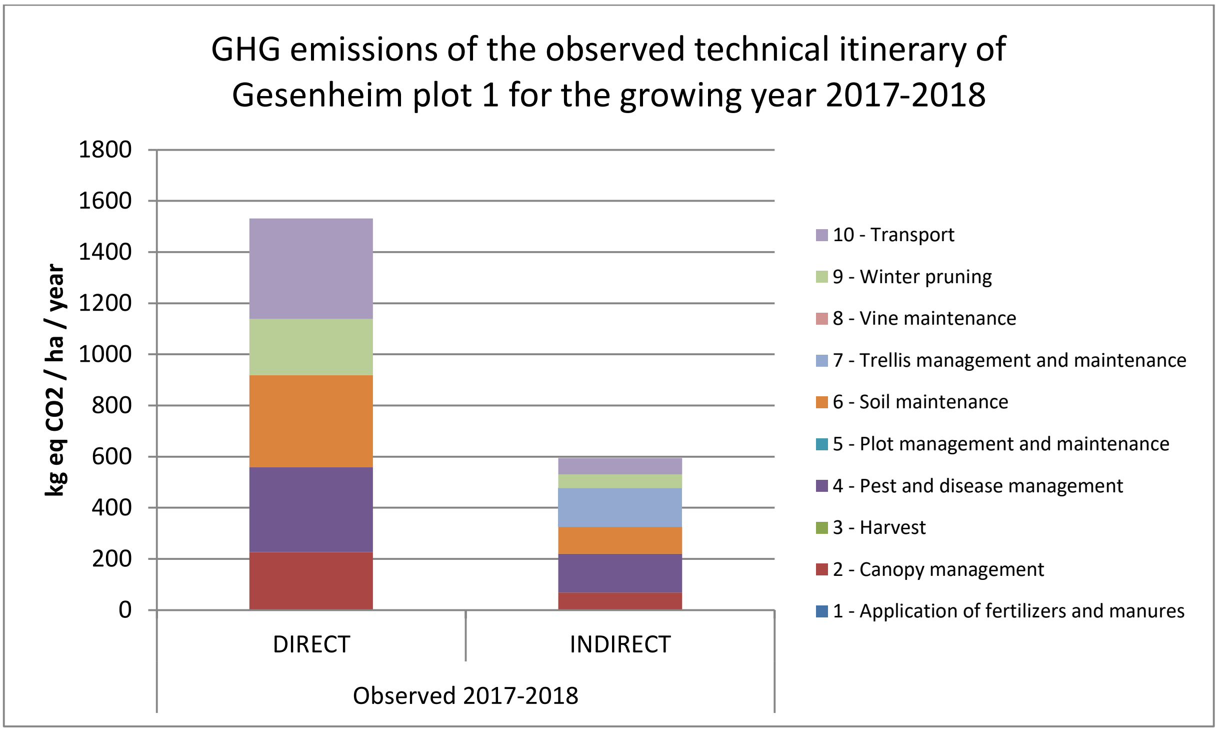

Figure 21 : Results of the GHG emissions assessment for the plot Gesenheim plot 1

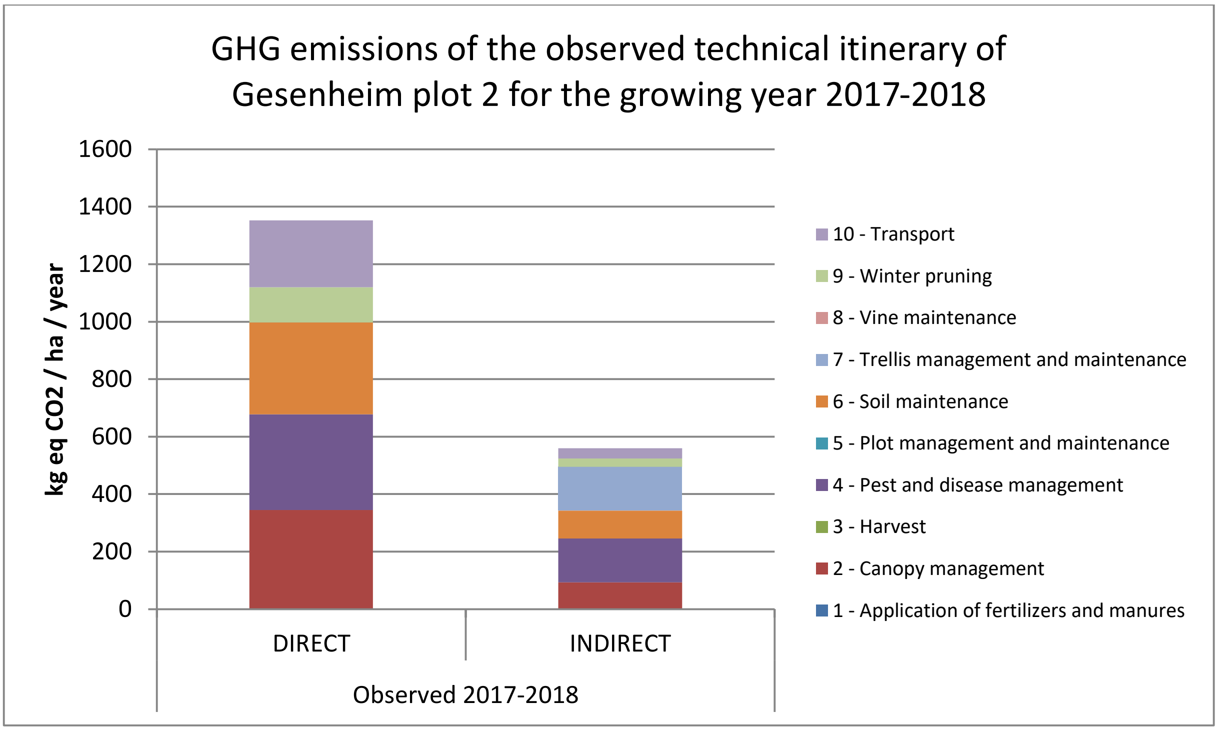

Figure 22 : Results of the GHG emissions assessment for the plot Gesenheim plot 2

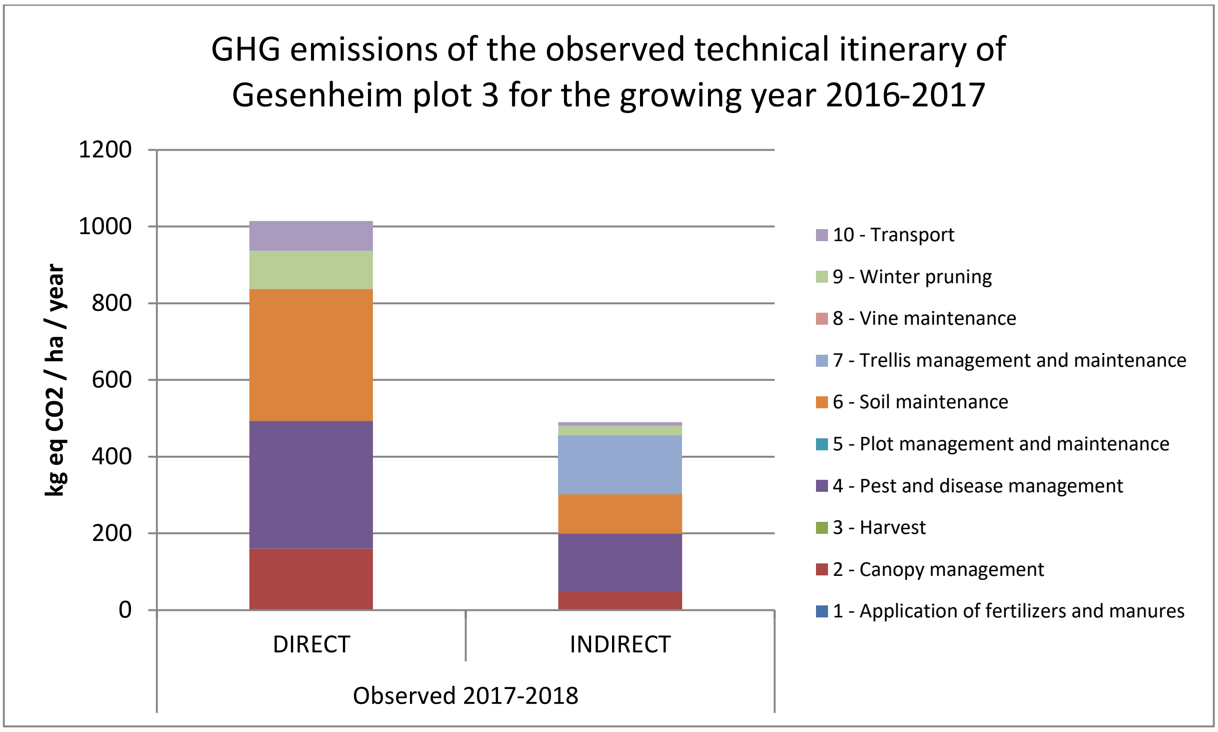

Figure 23 : Results of the GHG emissions assessment for the plot Gesenheim plot 3

Conclusion

Generic conclusions can be drawn from the results of GHG emissions assessment of the current situation on the five pilot sites:

- Direct emissions are, for most of the plots, more important than indirect emissions, excepting for Cotnari plots, due to metallic trellising.
- Total emissions are, for most of the plots, due to Pest and disease management and Soil maintenance, excepting for Val-de-Loire plots, where Transport and Winter pruning emit significant quantities of GHG.

The total emissions range between 800 and 3000 kg eq CO_2/ha. The variability between plots and pilot sites of the total emissions can be explained by :

- the number of interventions : 2 to 12 times for Soil maintenance, 6 to 16 times for Pest and disease management
- the motor rated power : from 45 to 150 hp
- the distance from the winery to the plot : up to 2,5 km
- the manual or motorized harvest,
- the climatic conditions between pilot sites.

For Gesenheim, viticultural practices are the same for all plots, but the time per ha varies among them.

Action B2 results showed the interest of getting deep inside the technical itineraries to distinguish the hotspots of GHG emissions between the vineyard operations. It also demonstrates that mitigation actions are, from the life cycle point of view, accessible for vine-growers, as the emissions are mainly direct emissions. However, this conclusion has to be crossed with the possibility of changes considering technical, economical, logistical and social aspects. It has to be kept in mind that the vinegrowers have to tackle several environmental stakes at the same time (climate change, water quality and quantity, pesticides use reduction, …), and the technical itineraries have to be ecodesigned in a systemic way.

Probably the first mitigation action that can be proposed, decreasing the number of interventions for Pest and disease management and Soil maintenance, is simplistic, as there is an agronomic and environmental logic behind it. However, the large variability of the number of interventions among the 27 plots suggests that there might be progress margins for some vinegrowers. A comprehension on how the vinegrowers manage the systems that need the least interventions would be very interesting to transfer to others.

Apart from optimization on current systems number of interventions, the most efficient mitigation actions seem to be in agronomic and technologic innovations, such as:

- operations combination (two operations during the same intervention),
- practices that reduces the need of an intervention (mulching for example)
- resistant vine varieties
- carbon storage (through vine shoot shredding for example, in the regions where it is not yet widespread)
- electrical robots, namely for Pest and disease management and Soil maintenance.

The assessment of adaptation scenarios regarding GHG emissions has not been possible during Adviclim project, but is still important to pursue, as some of adaptation actions can make the GHG balance changing (more trimming, more tillage or more equipments such as shading or irrigation systems).

Appendix 1: Loading rates references

Tool	Loading rate – inter-row tractor	Tool	Loading rate – straddle tractor
Pre-pruner	0,3	Pre-pruner	0,287
Vine shoot shredder	0,7	Vine shoot shredder	0,7
Fertilizer spreader	0,3	Fertilizer spreader	0,3
Soil maintenance tool	0,6	Soil maintenance tool	0,4
Mower	0,5	Mower	0,5
Intervine / Toothed tool	0,3	Intervine / Toothed tool	0,29
Intervine / Discs tool	0,3	Intervine / Discs tool	0,23
Intervine	0,3	Intervine	0,29
Intervine / Bladed tool	0,3	Intervine / Bladed tool	0,24
Intervine / Animated tool	0,4	Intervine / Animated tool	0,33
Intervine / Weeding tool	0,4	Intervine / Weeding tool	0,34
Boom sprayer	0,3	Boom sprayer	0,291
Thermic weeder	0,3	Thermic weeder	0,291
Chemical trunk cleaner	0,3	Chemical trunk cleaner	0,291
Mechanical trunk cleaner	0,5	Mechanical trunk cleaner	0,485
Trellising and wire lifting	0,3	Trellising and wire lifting	0,291
Trimmer	0,3	Trimmer	0,306
Leaf remover	0,5	Leaf remover	0,287
Pneumatique sprayer	0,8	Pneumatique sprayer	0,6
Air blast sprayer	0,7	Air blast sprayer	0,55
Nozzle sprayer	0,5	Nozzle sprayer	0,45
Tunnel sprayer	0,8	Tunnel sprayer	0,6

Appendix 2: Data sets for pesticide active ingredients

Active ingredient type	Active ingredient name	Data set	Unit
Fungicides	cymoxanil	[sulfonyl]urea-compounds, at regional storehouse/kg/RER	kg
	cyprodinil		
	thiophanate-methyl		
	bupirimate	[thio]carbamate-compounds, at regional storehouse/kg/RER	kg
	propamocarb hcl		
	iprovalicarb		
	acetochlor	acetamide-anillide-compounds, at regional storehouse/kg/RER	kg
	fenhexamid		
	méfénoxam		
	pyriméthanil		
	zoxamide		
	cyazofamid	benzimidazole-compounds, at regional storehouse/kg/RER	kg
	iprodione		
	prochloraz		
	captan	Captan, at regional storage/kg/RER	kg
	chlorothalonil	Chlorothalonil, at regional storage/kg/RER	kg
	copper sulphate	Copper oxide, at plant/kg/RER	kg
	cuivre de l'hydroxyde de cuivre		
	cuivre de l'oxyde cuivreux		
	cuivre oxychlorure		
	cuivre	Copper, primary, at refinery/kg/RER	kg
	cyproconazole	cyclic N-compounds, at regional storehouse/kg/RER	kg
	diméthomorphe		
	dodemorph acetate		
	epoxiconazole		
	fenbuconazole		
	fenpropidin		
	fenpropimorph		
	fluquinconazole		
	flusilazole		
	flutriafol		
	metconazole		
	penconazole		
	procymidone		
	propiconazole		
	prothioconazol		
	quinoxyfèn		

	tébuconazole		
	tétraconazole		
	triadiménol		
	azoxistrobine	Dinitroaniline-compounds, at regional storehouse/kg/RER	kg
	dimoxystrobin		
	fluoxastrobin		
	krésoxim-méthyl		
	picoxystrobin		
	pyraclostrobine		
	trifloxystrobin		
	thiram	dithiocarbamate-compounds, at regional storehouse/kg/RER	kg
	ziram		
	fosétyl-aluminium	Fosetyl-al, at regional storage/kg/RER	kg
	fosetyl		
	manèbe	Maneb, at regional storehouse/kg/RER	kg
	dithianon	nitrile-compounds, at regional storehouse/kg/RER	kg
	myclobutanyl		
	dodine	pesticide unspecified, at regional storehouse/kg/RER	kg
	fentin acetate		
	phosphite de potassium		
	tolylfluanid		
	clodinafop-propargyl	phenoxy-compounds, at regional storehouse/kg/RER	kg
	boscalid	Pyridine-compounds, at regional storehouse/kg/RER	kg
	fluazinam		
	souffre pour poudrage	Secondary sulphur, at refinery/kg/RER	kg
	soufre		
	soufre micronisé		
Herbicides	iodosulfuron	[sulfonyl]urea-compounds, at regional storehouse/kg/RER	kg
	iodosulfuron-methyl-sodium		
	mesosulforon-methyl (prop)		
	metoxuron		
	metsulfuron-methyl		
	nicosulfuron		
	tribenuron-methyl		
	triflusulfuron-methyl		
	diuron		
	carbetamide	[thio]carbamate-compounds, at regional storehouse/kg/RER	kg
	desmedipham		
	phenmedipham		
	prosulfocarb		
	tri-allate		

	2,4-d	2,4-D, at regional storehouse/kg/RER	kg
	diflufenican	acetamide-anillide-compounds, at regional storehouse/kg/RER	kg
	dimethachlor		
	florasulam		
	isoxaben		
	metazachlor		
	propyzamide		
	aclonifen	Aclonifen, at regional storage/kg/RER	kg
	ethofumesate	benzimidazole-compounds, at regional storehouse/kg/RER	kg
	bentazone	benzo[thia]diazole-compounds, at regional storehouse/kg/RER	kg
	molybdène	chemicals inorganic, at plant/kg/GLO	kg
	chlorotoluron	Chlorotoluron, at regional storage/kg/RER	kg
	aminotriazole	cyclic N-compounds, at regional storehouse/kg/RER	kg
	clomazone		
	flumioxazin		
	isoxaflutole		
	lenacil		
	quinmerac		
	chloridazon	Diazine-compounds, at regional storehouse/kg/RER	kg
	imazamox		
	dicamba	Dicamba, at regional storehouse/kg/RER	kg
	dimethenamid-p	Dimethenamide, at regional storage/kg/RER	kg
	oryzalin	Dinitroaniline-compounds, at regional storehouse/kg/RER	kg
	trifluralin		
	oxyfluorfène	diphenylether-compounds, at regional storehouse/kg/RER	kg
	glyphosate	Glyphosate, at regional storehouse/kg/RER	kg
	glyphosate acide		
	isoproturon	Isoproturon, at regional storage/kg/RER	kg
	linuron	Linuron, at regional storehouse/kg/RER	kg
	2.4 mcpa	MCPA, at regional storehouse/kg/RER	kg
	metamitron	Metamitron, at regional storage/kg/RER	kg
	s-metolachlor	Metolachlor, at regional storehouse/kg/RER	kg
	napropamide	Napropamide, at regional storage/kg/RER	kg
	bromoxynil	nitrile-compounds, at regional storehouse/kg/RER	kg
	ioxynil		
	sulfosate	organophosphorus-compounds, at regional storehouse/kg/RER	kg
	pendiméthaline	Pendimethalin, at regional storage/kg/RER	kg
	abamectin	pesticide unspecified, at regional storehouse/kg/RER	kg
	clethodim		
	cycloxydim		
	fluorochloridone		
	flurtamone		

	mefenpyr-diethyl		
	mesotrione		
	thiocyanate d'ammonium		
	2,4-db	phenoxy-compounds, at regional storehouse/kg/RER	kg
	diclofop-methyl		
	fenoxaprop-p-ethyl		
	fluazifop p-butyl		
	fluazifop-butyl		
	haloxyfop		
	propaquizafop		
	quizalofop p-ethyl		
	quizalofop-ethyl		
	clopyralid	Pyridine-compounds, at regional storehouse/kg/RER	kg
	fluroxypyr		
	paraquat		
	hexazinone	triazine-compounds, at regional storehouse/kg/RER	kg
	metribuzin		
	zinc	Zinc, primary, at regional storage/kg/RER	kg
Insecticides	diflubenzuron	[sulfonyl]urea-compounds, at regional storehouse/kg/RER	kg
	lufénuron		
	aldicarb	[thio]carbamate-compounds, at regional storehouse/kg/RER	kg
	benfuracarb		
	bifenazate		
	carbaryl		
	carbosulfan		
	fénoxycarbe		
	formetanate		
	isoprocarb		
	méthomyl		
	pirimicarb		
	pyrimicarbe		
	acide-alpha-naphtylacetique	acetamide-anillide-compounds, at regional storehouse/kg/RER	kg
	carbofuran	Carbofuran, at regional storehouse/kg/RER	kg
	copper oxide	Copper oxide, at plant/kg/RER	kg
	copper(ii)hydroxide		
	acetamiprid	cyclic N-compounds, at regional storehouse/kg/RER	kg
	fénazaquin		
	fenpyroximate		
	hexythiazox		
	imidacloprid		
	pyridabène		
	thiamethoxam		

	triazamate		
	thiabendazole	Diazole-compounds, at regional storehouse/kg/RER	kg
	thiacloprid		
	pyriproxyfen	diphenylether-compounds, at regional storehouse/kg/RER	kg
	folpet	folpet, at regional storage/kg/rer	kg
	acephate	organophosphorus-compounds, at regional storehouse/kg/RER	kg
	chlorfenvinfos		
	chlormephos		
	chlorpyrifos		
	chlorpyrifos ethyl		
	dimethoate		
	éthéphon		
	fenitrothion		
	fenthion		
	malathion		
	methidathion		
	parathion		
	phosmet		
	trichlorfon		
	chlorpyrifos méthyl	Pesticide unspecified, at regional storehouse/kg/RER	kg
	clofentézine		
	dinocap		
	endosulfan		
	flazasulfuron		
	fluazifop-p		
	flufénoxuron		
	indoxacarb		
	insektizide unspez		
	metiram-zinc		
	pyrethrine		
	rotenone		
	spinosad		
	terbuthylazine		
	acrinathrin	pyretroid-compounds, at regional storehouse/kg/RER	kg
	alphaméthrine		
	bétacyfluthrine		
	bifenthrin		
	cyfluthrin		
	cyperméthrine		
	deltaméthrine		
	esfenvalérate		
	fenpropathrin		

	lambda-cyhalothrin		
	tau fluvalinate		
	tefluthrin		
	flonicamid	Pyridine-compounds, at regional storehouse/kg/RER	kg
	tébufenpyrad		
	pymetrozine	triazine-compounds, at regional storehouse/kg/RER	kg