Organic-PLUS - grant agreement No [774340]

Pathways to phase-out contentious inputs from organic agriculture in Europe

Deliverable 6.3

Environmental sustainability report (LCA)

Versions

Version: 1.3 (30th April 2021).

Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No [774340 — Organic-PLUS]

Project Details:

Programme: **H2020. SUSTAINABLE FOOD SECURITY – RESILIENT AND RESOURCE· EFFICIENT VALUE CHAINS**

Call topic: **SFS-08-2017, (RIA) Organic inputs – contentious inputs in organic farming**

Project Title: **Pathways to phase-out contentious inputs from organic agriculture in Europe**

Project Acronym: **Organic-PLUS**

Proposal Number: **774340-2**

Lead Partner: **Coventry University**

Time Frame: **01/05/2018 – 30/10/2022**

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Deliverable Details

WP: 6 MODEL

Task(s): 6.3 Environmental assessment

Deliverable Title: Environmental sustainability report

Lead beneficiary: IRTA[1]

Involved partners: ORC[2], CU[3], INRA[4], UNIPD[5], NORSOK[6], UTH[7]

Additional partners: AU[8], CUT[9], IFAPA[10], MFAL[11], SEGES[12], UNICT[13], ABioDoc[14]

Deadline for deliverable: month 36 (30/04/2021)

Date of deliverable: 30/04/2021

Page 3: Additional information related to the COVID-19 pandemic

As a consequence of the COVID-19 pandemic, field trials were delayed and laboratories of partners were closed, slowing down analysis of data and samples from field trials.

The delivery date of this deliverable, D6.3, was not affected.

However, for the environmental assessment we have used preliminary data, if final data were not available. The current document has been built based on spreadsheet (Excel) files, which allow updating results when newly collected data is available.

Therefore, we will update this document, as applicable, and also include the ongoing scientific discussion of the results with all project partners, and insights from the work of the sister project RELACS.

Our internal ongoing reflection on the results is evidenced by the forthcoming webinar on 11th May 2021.

WEBINAR: **Environmental Assessment ORG+ scenarios**

DATE: Tuesday 11th May

TEAMs webinar

BACKGROUND

Task 6.3 Environmental Assessment aimed to provide an environmental assessment of contentious inputs and their possible alternatives in organic production systems following a life cycle perspective, therefore using Life Cycle Assessment (LCA) tools. On the one hand, this is the internationally recommended tool for conducting environmental quantifications (UNEP, EC), but on the other hand, several criticisms could be made towards LCA studies when applied to organic production systems in particular (since several aspects (e.g. biodiversity indicators) may not be accounted for. Therefore, being aware of its potential, but also the limitations of the tool, it was the ambition of Organic-PLUS to take advantage of the holistic vision of LCA, for both the whole production chain concept and multicriteria environmental indicators, and to contribute to improving the methodology to make it more suitable for organic production systems.

OBJECTIVE

This webinar is addressed to ORG+ partners in order to provide information regarding the environmental assessment conducted, the results obtained, highlight methodological problems and to seek feedback on how to advance the environmental assessment of organic production systems.

AGENDA

Schedule	Session	Chair
10:00 – 10:15	Welcome & short introduction	Ulrich Schmutz, coordinator of Organic-PLUS
10:15 – 10:40	Summary of LCA Methodology used to conduct environmental assessment	Assumpció Antón (IRTA)
10:40-11:00	Example for vegetables (Lemon from Sicily)	Marta Ruiz (IRTA)
11:00-11:20	Example for animals (sheep from Norway)	Erica Montemayor (IRTA)
11:20-11:30	Break	
11:30-11:45	Summary of main environmental conclusions followed by a more detailed explanation for relevant issues:	Assumpció Antón (IRTA)
11:15 – 11:40	- Secondary datasets	Erica Montemayor (IRTA)
11:40 - 12:05	- Toxicity assessment	Ralph Rosenbaum (IRTA)
12:05 -12:30	- Biodiversity indicators	Erica Montemayor (IRTA)
12:30 -13:00	Discussion	Assumpció Antón (IRTA)
13:00-13:15	Closure (how sustainability assessment will go on)	Claus Aage Grøn Sørensen (AU)

Registration: this is a closed webinar for all ORG+ partners but if you are interested in attending, please send an e-mail to assumpcio.anton@irta.cat before the 5th MAY, with the following information: Full name; Affiliation; and role in the Organic-PLUS project.

Partners involved

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EXECUTIVE SUMMARY

This deliverable corresponds to work conducted in Task 6.3 on Environmental assessment. Environmental assessment is conducted following a life cycle perspective, specifically using the Life Cycle Assessment (LCA) tools recommended by the European Commission and the United Nations Environmental Programme in the frame of the Environment Footprint and Life Cycle Initiatives. This tool was selected due to its holistic vision, including both the whole production chain concept and multi criteria environmental indicators, as well as its quantitative, scientific approach to estimating environmental impacts. However, being aware of the limitations of LCA tools in its ability to assess the comprehensive sustainability of organic production systems, the current deliverable must be seen as part of a wider sustainability assessment, complemented by the additional assessments conducted in WP6 (e.g. Response Inducing Sustainability Evaluation (RISE) tool). In addition, it is the ambition of the Organic-PLUS project to contribute to improving the LCA methodology to make it more suitable for organic production systems.

Therefore, facing the reality of highly variable practices within agricultural production systems, and that information about alternative inputs will increase over time; it is our ambition with this publication to provide a dynamic and easily adaptable deliverable. This means providing a transparent methodological guideline of the assessments conducted with reference scenarios, and the provision of calculation forms Excel files, which may be easily updated. We aim for a tool which will be useful beyond project completion and may facilitate stakeholder interaction.

LCA has been applied in accordance with ISO standards 14040 and 14044 (2006a and b) and consequent amendments (2020 a, b, c). The methodological guideline established in the frame of EF initiative (EU-JRC, 2018) has been followed. Section 2 provides a detailed description of the methodology and models applied.

According to the geographical distribution of the Organic-PLUS project partners and based on data availability, four different baseline scenarios were selected for organic production of aubergine, tomato, citrus and olive, as well as three scenarios for organic livestock production, sheep, pig and poultry. These scenarios were used as case studies to test the environmental performance of contentious inputs (e.g. copper, synthetic vitamins, peat) compared to their potential alternatives (e.g. potassium bicarbonate, thyme oil, composted organic matter). Section 3 explains the calculation forms created with the idea to have a dynamic deliverable tool, which allows changes in inputs, characterisation factors and the addition of new datasets. The practitioner can change the values in the LCI sheet for both the current scenario and alternative scenario.

Section 4 provides a preliminary assessment of the suggested alternatives to replace or reduce the use of contentious inputs, whose information is being constantly improved and provided through experimentation. It is foreseen that this preliminary assessment will act as a feedback and aims to contribute to address environmental improvement of potential alternatives. A new alternative may not only mean a substitution of contentious inputs but could also include a change in practices. Therefore, because of the holistic perspective of LCA tools, consequences of implementing alternatives to contentious inputs in crop or livestock management may be accounted for.

Results from the assessment of baseline scenarios show that application of copper and mineral oil leads to emissions which may be of major importance for freshwater ecotoxicity. For other impact categories, other inputs may become relevant. According to experimental trials conducted by 'WP3 PLANT' partners and feasibility data, we tested the substitution of copper and mineral oil with following products: Potassium hydrogen carbonate, low-copper fertilisers and thyme essential oil extracted from *Thymus vulgaris*. Results have shown that the alternative inputs cause very minor environmental impact. However, this shall be considered as a preliminary result since we have seen that for copper-based plant protection products, the toxicity effect depends on the type of metal

speciation, which in turn depends on physic-chemical characteristic of the surrounding environment (soil and water), and in that regard specific studies are being conducted to include this behaviour in LCA (e.g. Peña et al 2017).

The current LCA method does not include the characterisation of antibiotic impacts due to the lack of information regarding their effects on environmental factors assessed in LCA, therefore consequences on health and productivity remains unaddressed in LCA. In any case, the phasing out of these contentious inputs in organic agriculture seems to imply changes in livestock management rather than replacement with alternative products. The calculation forms created can be used to compare practices and add new models, which will result in a useful tool when more information is provided.

Besides the traditional use of manure fertilisers coming from organic production systems, Organic-PLUS aims to study alternative products used as alternative fertilisers. From an environmental and circular economic perspective, we would consider the use of by-products or residues from other processes as potential alternative fertilisers, hence we discuss the different methodological approaches to this and highlight the importance of the potential treatments (e.g. composting, pelletising and anaerobic digestion) used to valorise these by-products into fertilisers, with a special emphasis on how emissions should be accounted for (section 4.3 and 4.4).

The comparisons between peat-based growing media (seen as contentious) and compost made from locally derived materials (forest residues, horse manure), and fossil fuel-based mulching plastic foil vs. degradable plastic foil made from potato starch, showed that although the normalised and weighted value for the alternatives was lower than for the contentious inputs, there was no clear winner when looking at all the impact categories separately (section 4.5). Through a contribution analysis of the alternative compost growing media, the hotspots in its life cycle were found to be diesel consumption, transport of forest residues and emissions, all within or going to the compost plant. For the case of bio-plastic (section 4.6), an important parameter that can influence results was the thickness of the bio-plastic, thus, if the thickness was reduced, it would reduce the quantity of material manufactured (e.g., potato starch), and subsequently, the impacts could be reduced.

The main critical aspects found within the life cycle inventory (LCI) of organic crop and livestock products include the lack of manufacturing datasets for inputs used in organic production systems such as several common plant protection products (PPPs) and alternative animal welfare products (e.g., antimicrobial essential oils) (Section 5.1). There are no available manufacturing datasets for biological control agents (BCAs), plant-derived essential oils (thymol, carvacrol, neem), mineral oil, pyrethrin, Spinosad and copper oxychloride. To advance in this aspect, new manufacturing LCI datasets for prevalent PPPs used in OA in Europe were developed in the frame of Organic-PLUS project (Spinosad, *Bacillus subtilis*, Chitosan and neem oil, specific LCIs can be found in Montemayor et al. (a, in preparation).

Moreover, through the assessment conducted, other contentious inputs or hotspots aspects than the ones focused on in the Organic-PLUS project emerged. Section 5.2 provides a list of these, which are largely related to energy consumption, transport and water consumption, the latter mainly in Mediterranean regions.

Toxicity and biodiversity impact categories have shown to be of special interest for organic production systems, and therefore relevant for Organic-PLUS. We have devoted special sections for each (section 5.3 and 5.4). In particular, biodiversity was found to be one of the most important and distinguishing aspects between organic and conventional systems in LCA. Hence, this aspect has been addressed in Organic-PLUS.

After a review of existing approaches to deal with biodiversity loss in LCA studies, we have selected the work conducted by Knudsen et al. (2017). These authors developed characterisation factors (CFs) to include biodiversity impacts for organic and conventional agricultural production, based on standardised sampling of plant species richness in organic and conventional farms across six countries in Europe within the temperate broadleaf and mixed forest biome. However, in the context of Organic-PLUS and for agriculture in Europe, one limitation of this model is that it does not have CFs for the Mediterranean biome, one of the most agriculturally productive areas in Europe. Therefore, we have developed CFs for the Mediterranean biome using the methods described in Knudsen et al. (2017) and secondary plant richness data from organic grape, olive and arable crop farms in Spain, Italy, France and Greece (Montemayor et al., b, in preparation).

An important output of the activities conducted to produce this deliverable (Task 6.3) was the detection of potential shortcomings as well as a provision of some solutions. LCA tools will continue to be developed and improved in the scientific community thus, we have also identified and prioritised potential aspects for further research beyond Organic-PLUS (Section 6). The LCA method was strictly used where it was appropriate for organic production, thus not forcing one sustainability analysis tool, like LCA, as a singular answer to all issues of organic (and conventional) production.

In conclusion, through the environmental assessments conducted in Task 6.3 we can conclude that:

1) From a holistic environmental perspective, it can be stated that there are further environmental hotspot aspects, which may have major importance other than those being focussed in the Organic-PLUS project. We would highlight fossil fuel-based energy consumption such as diesel for labour operations, electricity consumption and transport. Additionally, water consumption, in particular, for dry Mediterranean regions could be an input with negative environmental implications, and hence should be seen as a contentious input. These issues are relevant for organic and conventional agriculture.
2) When alternatives to contentious inputs developed and studied in the Organic-PLUS project were considered, e.g. composted organic matter for peat in growing media, degradable plastic from potato starch for covering of soil, these products presented an improvement for some environmental aspects, but showed a worse behaviour for others. From the revealed "hot-spots", it can be derived where efforts can be put if the goal is to develop alternatives which score better in LCA.
3) LCA methodology may be useful to assess environmental effects of agricultural production, but requires more development to better grasp the particularities of organic production systems. Hence, additional sustainability assessment tools (e.g., RISE) will be applied to account for other aspects of organic agriculture at the farm-level.
4) The present publication includes adaptable calculation forms (implemented in a spreadsheet programme e.g. Microsoft Excel), which can allow for updating and creation of new scenarios.
5) Several proposals to improve datasets for organic production have been presented.
6) We have contributed to the development of characterisation factors for biodiversity indicators in agricultural production following the work initiated by Knudsen et al (2017).
7) Proposals for further research to improve the environmental assessment of organic production systems were made, emphasising that the current dominating impact categories are not well suited to discriminate between various farming practices.

1. INTRODUCTION

The overall aim of the Organic-PLUS project is to provide high quality, trans-disciplinary, scientifically informed decision support to help all actors in the organic sector, including national and regional policy makers, to reach the next level of the EU's organic success story. Organic agriculture is endorsed by the European Commission's Green Deal, aiming to have at least 25% of the EU's agricultural land under organic farming by 2030 (European Commission, 2020). However, this sustainability needs to be proven, considering the different aspects included in sustainability. This deliverable presents the environmental assessment of relevant contentious and alternative products and production systems studied in the Organic-PLUS project. As the same contentious inputs can be used (and are used) in conventional agriculture, our research contributes to improve sustainability in both farming systems.

In particular, Task 6.3 Environmental assessment was conducted following a life cycle perspective, therefore using Life Cycle Assessment (LCA) tools. This tool is recommended by the United Nations Environmental Programme (UNEP 2020) and the European Commission to conduct environmental quantifications in the frame of the Environmental Footprint (EF) Initiative (European commission 2013). EF's main goal is to provide a standardised methodology that allows environmental comparisons. Currently, EF is under the transition phase, evaluating potential methodological improvements. However, organic production systems are overlooked in the EF initiative, which makes it challenging to assess environmental effects of converting to such production. This is the main reason why we incorporated this type of assessment in the Organic-PLUS project. On the other hand, several criticisms (Meier et al., 2015; van der Werf et al., 2020) were made on LCA studies when applied to organic production systems in particular because several aspects (e.g. biodiversity indicators, multifunctional system) may not be accounted for. Therefore, being aware of its potential, but also the limitations of the tool, it is our ambition to take advantage of the holistic vision of LCA, for both the whole production chain concept and multicriteria environmental indicators, and to contribute to improve the methodology to make it more suitable for organic production systems. Further, being conscious of the limitations in LCA WP6 decided to complement LCA with the Response Inducing Sustainability Evaluation (RISE) tool, which can address not only environmental aspects but also the other pillars of sustainability – social and economic – so as to have a more comprehensive sustainability assessment in Organic-PLUS.

Facing the reality of highly variable practices within agricultural production systems, and that the information needed for alternative inputs could be not established over the limited time period of the project (an aspect which COVID-19 circumstances have added to), it is our ambition in the present publication to provide a dynamic and adaptable deliverable. This means providing a transparent methodological guideline of the assessment conducted with reference scenarios and the provision of calculation forms, which may be easily corrected as far as additional and available information is collected, which in fact also addresses the need to provide tools beyond project completion, facilitating stakeholder interaction.

Work conducted under this task could be summarised as:

- Assessment of baseline scenarios
- Create calculation tools to conduct current and further environmental assessments.
- Critical analysis of LCA tools used to assess organic production systems (challenges and proposals when conducting an LCA on organic farming, datasets, emission modelling, and impact categories).
- Assessment of alternatives for contentious inputs using the baseline scenarios as samples for testing.
- Review state-of-the-art biodiversity indicators and propose an indicator for application in organic production systems.

2. LCA METHODOLOGY

LCA has been applied in accordance with ISO standards 14040 and 14044 (2006a and b) and consequent amendments (2020 a, b, c). We applied the methodological guideline established in the frame of EF initiative (EU-JRC, 2018).

As a first step we established some reference scenarios, based on information available from partners trying to cover different production systems and geographical situations. Information collected has allowed us, on the one hand, to create baseline scenarios upon which alternatives could be compared/referenced and, on the other hand, to identify main gaps to conduct an environmental assessment. These scenarios are for:

Crops:

- Olive, Greece
- Tomato, Spain
- Aubergine, Turkey
- Citrus, Italy

Livestock:

- Pork, Denmark
- Sheep, Norway
- Poultry, Poland

For all these scenarios environmental assessment has been conducted following the four phases of LCA tools, the Goal and Scope, Life Cycle Inventory, Life Cycle Impact Assessment and Interpretation (Figure 1).

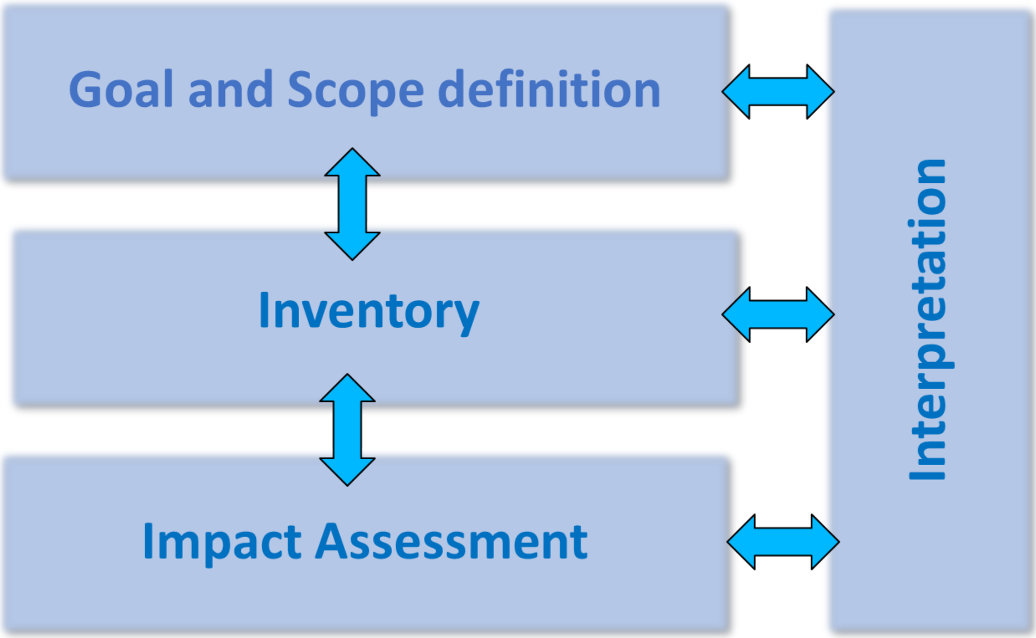


Figure 1. Phases of Life Cycle Assessment according to ISO 14040 (2006)

2.1 Goal and scope

In this phase, the features and assumptions of the assessment were defined, where each baseline scenario provided its own information following the general scheme of box 1 and 2 below. We conducted an attributional LCA, which means we captured a “snapshot” of the current situation without considering consequences of potential changes in other systems. We would also remark that though EF rules recommend the inclusion of the utilisation stage of produced goods (*i.e*., the consumer buys and consumes the agricultural product), for the purpose of the current work the impacts were considered from cradle to the farm gate. This was done in order to focus on the processes in the agricultural stage, which is also the main scope of the Organic-PLUS project. Additionally, when looking at the whole life cycle of a food product (Figure 2), the (farm) production stage often dominates the results, representing 61% of food's GHG emissions (81% including deforestation), 79% of acidification, and 95% of eutrophication and covering ~37% of the world's ice- and desert-free land (Poore and Nemecek, 2018). These are examples of some of the many impact categories that were analysed within the different organic production scenarios in this study. Figure 3 shows the general system boundaries, which were followed for the different scenarios.

In the critical analysis of LCA in application to organic agricultural systems, van der Werf et al. (2020) found that LCAs need a broader perspective for the functions of the systems. Depending on functional unit (the unit by which all the impacts are referenced to) is focussed on productivity such as yield in kg, or area in hectares required to produce one unit of product, results could change. Most agricultural LCAs only look at yield or area, whereas van der Werf et al. (2020) recommend reporting both. This is what we have done for each case study in Organic-PLUS, which can be seen in each Excel file.

Box 1. Aspects covered in Goal definition of studies conducted

Intended application: Identifying hotspots, performing comparisons

Reasons to carry out the study: environmental importance of contentious inputs, assessment of alternatives

Target audience: Organic-PLUS partners; organic production farmers**;** scientific community

Limitations of study: lack of background data for organic farming, impact methods not fully developed for organic production

Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: the study will be used to compare with alternatives for contentious input developed or suggested in the frame of Organic-PLUS project and it is intended to be released to the general public.

Commissioner of the study and other influential actors: Organic-PLUS H2020 project

Box 2. Aspects covered in Scope definition of studies conducted

Identification of the product system to be studied:

Location:

Time period:

The functions of the product system/s:

The functional unit(s):

Reference flow:

The system boundaries: from the cradle to the farm gate

Allocation procedures:

Impact categories to be covered and methodology of impact assessment: EF 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set (Fazio et al 2018)

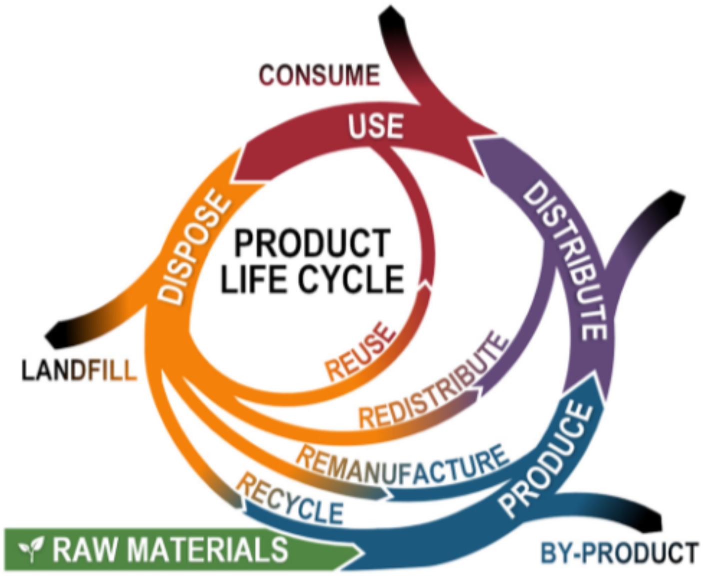
Data requirements: Primary data comes from questionnaires completed by Organic-PLUS partners; Secondary data: Ecoinvent + Agribalyse databases

Assumptions and limitations:

Alternative scenarios:

Type of critical review, if any: internal review by Organic-PLUS partners

Figure 2. Generic stages of a product's life cycle (Sieverding et al., 2020).



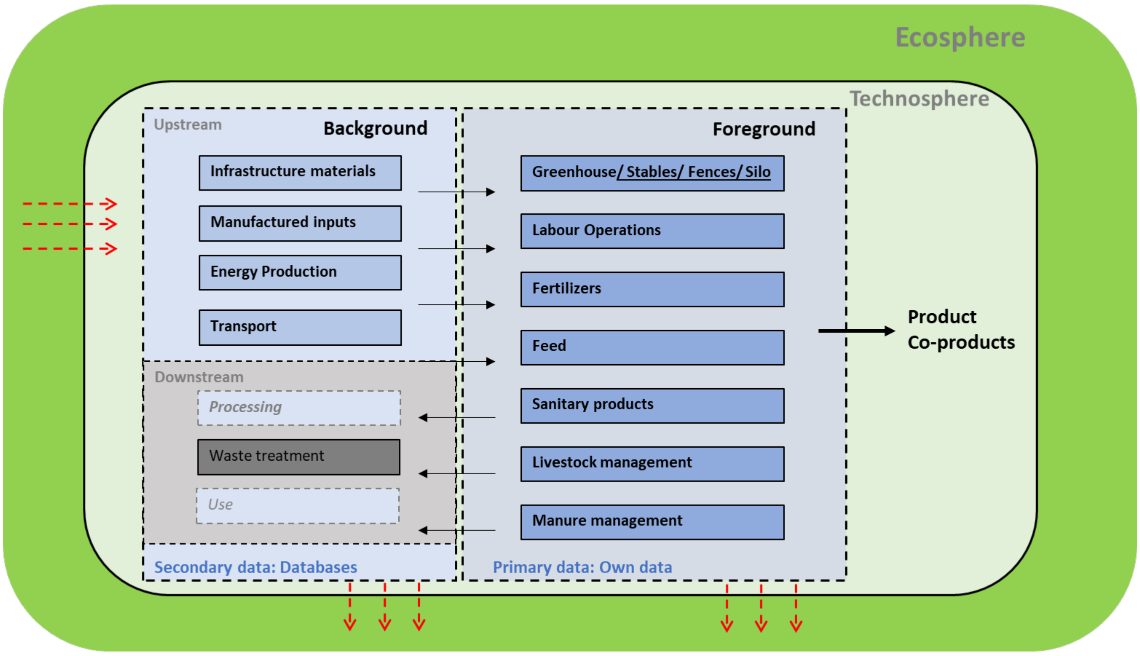


Figure 3. System boundaries general scheme. Limits are farm gate, In italics aspects out of the scope of the current study

2.2 Life Cycle Inventory

For the collection of primary data, IRTA prepared environmental questionnaires to be completed by the corresponding responsible partner (see Deliverable 6.1). Data collection included general information about the activity and the specific inputs used, which could be split into the natural resources used (i.e., land and water), product flows (e.g., seeds, plants, feeds, fertilisers, plant protection products, packaging, capital goods) and energy consumption inputs (e.g., electricity, heat, diesel for labour operations, transport). For secondary data we have used Ecoinvent (Wernet et al. 2016) and Agribalyse (2017) databases, as well as different bibliographic sources.

Regarding the outputs, we may differentiate between products, waste and emissions. The main outputs were the products and coproducts generated from each activity (e.g. tomato growing, raising of pork), for which we have applied allocation factors by economic value or mass, if necessary (specified in each scenario). In relation to the waste generated, the transport to processing plant (i.e., disposal or recycling) and disposal processes (i.e., landfill and incineration) are always accounted for. Additionally, treatment (i.e., composting, recycling, biogas) was considered as a resultant product and was part of the activity assessed. Another perspective may be the use of the Circular Footprint Formula (European Commission 2017) but given its immature status mainly for organic products (most of the generated sub-products in Organic-PLUS scenarios) we have prioritised cut-off criteria. This means that the production of a product is allocated to the primary user and if the material is recycled the producer does not receive credit for the provision of recycled materials. This is also done to omit non-relevant processes in a system. To estimate emissions, we have considered TIER I emission factors, as detailed emission accounting was not a goal of the Organic-PLUS project. To conduct their estimation, we have followed Product EF general rules (European Commission 2017) for fertiliser emissions, OLCA-Pest project for plant protection products (OLCA-Pest 2020), IPCC inventory guidelines for livestock management (IPCC 2019). Tables 1 to 7 present a summary of emission factors used.

Regarding plant protection products (PPPs), it is important to point out that: i) impact damage were modelled as their corresponding active ingredient, ii) it has been demonstrated that application method and crop growth stage are the most important parameters to be considered to estimate emissions (OLCA-Pest 2020), and iii) for the toxicity impact assessment method, no specific characterisation factor (CF) was yet available for PPP residues on crops, hence we considered these as emissions to soil, and soil CFs were used (section 5.3 deepens the toxicity assessment).

Table 1 Emission factors applied to account for fertiliser emissions and the corresponding information source.

Fertiliser emissions	Units	Emission Factor	Source
Air emissions			
NH_3 (organic fert)	kg NH_3/ kg N applied	0.24	EF (EC 2017)
N_2O (organic fert, wet climate)	kg N_2O/ kg N applied	0.009	Table 11.1 IPCC 2019
N_2O (organic fert, wet climate)	kg N_2O/ kg N applied	0.008	Table 11.1 IPCC 2019
NO_x (fertiliser and manure)	kg NO_x/kg N applied	0.04	Table 3.1 3.D EEA 2019
Water emissions			
NO_3	kg NO_3/ kg N applied	0.44	EF (EC 2017)
P leaching groundwater	kg P/ ha	0.03	Own Default value
P runoff Surface water	kg P/ kg P applied	0	Assuming best agriculture practices
P erosion Surface water	kg P / ha	0	Assuming best agriculture practices

Table 2. Emission factors applied to account for plant protection product emissions (OLCA-Pest, 2020). The acronym a.i. represents active ingredient.

Plant Protection Products	Units	Emission Factor
Air emissions		
Boom sprayer	kg a.i. emitted/kg a.i. applied	0.1
Air blast sprayer - early stages (leafless)	kg a.i. emitted/kg a.i. applied	0.2
Air blast sprayer - late stages (in leaf)	kg a.i. emitted/kg a.i. applied	0.08
Hand operated sprayer - crops that are < 50 cm	kg a.i. emitted/kg a.i. applied	0.06
Hand operated sprayer - crops that are > 50 cm	kg a.i. emitted/kg a.i. applied	0.1
Soil + crop emissions		
Boom sprayer	kg a.i. emitted/kg a.i. applied	0.9
Air blast sprayer - early stages (leafless)	kg a.i. emitted/kg a.i. applied	0.8
Air blast sprayer - late stages (in leaf)	kg a.i. emitted/kg a.i. applied	0.92
Hand operated sprayer - crops that are < 50 cm	kg a.i. emitted/kg a.i. applied	0.94
Hand operated sprayer - crops that are > 50 cm	kg a.i. emitted/kg a.i. applied	0.9

For livestock activities and according to IPCC guidelines (IPCC 2019), methane emissions due to enteric fermentation and methane and dinitrogen monoxide emissions due to manure management shall be considered. Since no type of animal feeds were considered as contentious inputs in Organic-PLUS, we apply TIER I emission factors (Table 3). In case further work needs to deal with feed components, we advise to apply TIER II or III according to guidelines (IPCC 2019) or further methodological advancement of PEF (EU 2017).

Table 3. Emission factors for methane emissions due to enteric fermentation (IPCC 2019)

	Kg CH_4 / Head / y	
	High prod*	Low prod*
Dairy	126	93
Cattle	64	58
Sheep	9	5
Goat	9	5
Swine	1..5	1
Poultry	Not developed	

** High and low productivity is defined at IPCC (2019) for the different livestock species. In general terms, high productivity systems are 100 percent market oriented with high level of capital input requirements and high level of overall herd (flock) performance. Feed is purchased from local or international market or intensively produced on farm. Low productivity systems are mainly driven by local market or by self-consumption, with low capital input requirements and low level of overall herd (fowl) performance typically using large areas for production or backyards. Locally produced feed represents the major source of feed utilised or animals are kept-free range for major part or all their production cycle, the yield of the activity being linked to the natural fertility of the land and the seasonal production of the pastures (IPCC 2019 pg 10.13)*

In relation to manure management, the main factors affecting methane emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significant quantity of methane. The temperature and the retention time of the storage unit greatly affect the amount of methane produced. When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less methane is produced (IPCC 2019). We apply equation 1 to estimate methane emissions related to manure management. Tables 4 and 5 provide default values to be applied depending on type of animal, manure management and climate conditions. We have extracted the values for the potential IPCC climate zones of European countries.

$$CH_4(g/head) = LW \cdot VS/1000 \cdot d \cdot EF_{mm} \qquad \text{(Eq. 1)}$$

where

LW: Live weight, kg

VS: Volatile Solid, kg VS/ 1 t animal/ d

d: days

EF_{mm}: emission factor for direct CH_4 emissions from manure management system, g CH_4 /kg VS)

Table 4. Default Values for Live Weights (LW) for Animal Categories & Values for Average Annual Volatile Solid (VS) Excretion Rate

	Volatile solid excretion Kg VS/ 1 t animal/ d		Liveweight, kg	
	West-EU	East-EU	West-EU	East-EU
Dairy	7.5	6.7	600	500
Cattle	5.7	7.6	405	389
Sheep	8.2	8.2	40	40
Goat	9	9	40	36
Swine	4.5	4	76	77
Poultry	12.3	12.6	1.4	1.3

Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. Nitrification (the oxidation of ammonia nitrogen to nitrate nitrogen) is a necessary prerequisite for the emission of N_2O from stored animal manures. Nitrification is likely to occur in stored animal manures provided there is a sufficient supply of oxygen. Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NOx. Equation 2 is used to calculate total N_2O emissions and Table 6 and 7 for the corresponding default values of the variables involved.

$N_2O\ (g/head) = LW \cdot N_{ex}/1000 \cdot d \cdot (EF_{mm} + (Fr_{vol} \cdot EF_{vol}) + (Fr_{l\text{-}r} \cdot EF_{l\text{-}r})) \cdot 44/28$ (Eq 2)

Where

LW: Live weight, kg

d: days

EF_{mm}: emission factor, kg N / 1 ton LW / d

Fr_{vol}: volatilization fraction, kg NH_3-N +NO_x-N / kg N applied or deposited

EF_{vol}: volatilization emission factor, kg N_2O-N /Kg NH_3-N +NO_x-N

$Fr_{l\text{-}r}$: leaching-runoff fraction, kg NH_3-N +NO_x-N / kg N applied or deposited

$EF_{l\text{-}r}$: leaching-runoff emission factor, kg N_2O-N /Kg NH_3-N +NO_x-N

Table 5. Methane Emission Factor by animal category, manure management system and climate zone (g CH_4 /kg VS) (IPCC 2019)

	Uncovered anaerobic lagoon		Liquid/Slurry, pit storage >1 month		Liquid/Slurry, pit storage < 1 month		Solid storage		Dry lot		Daily spread		Anaerobic Digestion – Biogas	
	High prod	Low prod	High prod	Low prod	High prod	Low prod	High prod	Low prod	High prod	Low prod	High prod	Low prod	High prod	Low prod
Cool Temp Moist														
dairy	96.5	52.3	33.8	18.3			3.2	1.7	1.6	0.9	0.2	0.1	3.2	9.2
cattle	72.4	52.3	25.3	18.3			2.4	1.7	1.2	0.9	0.1		2.4	9.2
sheep							2.5	1.7	1.3	0.9				
goat							2.4	1.7	1.2	0.9				
pigs	180.9	116.6	63.3	40.8	18.1	11.7	6	3.9	3	1.9	0.3	0.2	6	20.6
poultry	156.8	156.8	54.9	54.9			5.2	2.4	2.6	2.4			5.2	2.4
Warm Temp Moist														
dairy	117.4	63.6	59.5	32.2			6.4	3.5	2.4	1.3	0.8	0.4	3.7	9.5
cattle	88	63.6	44.6	32.2			4.8	3.5	1.8	1.3	0.6	0.4	2.7	9.5
sheep							5.1	3.5	1.9	1.3				
goat							4.8	3.5	1.8	1.3				
pigs	220.1	141.8	111.6	71.9	39.2	25.3	12.1	7.8	4.5	2.9	1.5	1	6.8	21.1
poultry	190.7	190.7	96.7	96.7			10.5	2.4	3.9	2.4			10.5	2.4
Warm Temp Dry														
dairy	122.2	66.2	65.9	35.7			6.4	3.5	2.4	1.3	0,8	0,4	3.7	9.5
cattle	91.7	66.2	49.4	35.7			4.8	3.5	1.8	1.3	0,6	0,4	2.7	9.5
sheep							5.1	3.5	1.9	1.3				
goat							4.8	3.5	1.8	1.3				
pigs	229.1	147.7	123.6	79.7	45.2	29.1	12.1	7.8	4.5	2.9	1.5	1	6.8	21.1
poultry	198.6	198.6	107.1	107.1			10.5	2.4	3.9	2.4			10.5	2.4

Table 6. Default values for nitrogen excretion rate, N_{ex} (kg N /1000 Kg animal mass/ day) (table 10.19 IPCC 2019)

	$N_{ex,}$ Kg N/1 ton LW / d		Liveweight, kg	
	West-EU	East-EU	West-EU	East-EU
Dairy	0.50	0.42	600	500
Cattle	0.42	0.47	405	389
Sheep	0.36	0.36	40	40
Goat	0.46	0.44	40	36
Pigs	0.65	0.63	76	77
Poultry	0.99	0.96	1.4	1.3

Table 7 Indirect N_2O Fr (Kg NH_3-N +NO_x-N / kg N applied or deposited) & EF (kg N_2O-N /Kg NH_3-N +NO_x-N) from manure management (table 11.3 IPCC 2019)

Fr_{vol} volatilisation		$Fr_{l\text{-}r}$ Leaching /runoff		EF_{vol} volatilisation		$EF_{l\text{-}r}$ Leaching /runoff	
synthetic	organic	Wet climate	Dry climate	Wet climate	Dry climate	Wet climate	Dry climate
0.11	0.21	0.24	-	0.014	0.005	0.011	-

2.3 Life Cycle Impact Assessment

Life Cycle Impact Assessment (LCIA) is defined as the phase in the LCA aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a production system. In LCIA, impact models are used to calculate characterisation factors or impact factors that can be used to connect elementary flows (emissions and resource consumptions) to the corresponding environmental impacts in different categories.

Because of the proliferation of different impact models, several initiatives seek to strengthen and harmonise methods to be applied. Among these initiatives, we would highlight those conducted by the FAO-Livestock Environmental Assessment and Performance (LEAP 2020), UNEP-SETAC Life Cycle Initiative (UNEP 2018) and the European Platform for Life Cycle Assessment (EPLCA 2020). Due to the EU scope of Organic-PLUS project, we will follow recommendations in relation to impact assessment models to be applied from the Environmental Footprint (EF) (EU 2018), which is derived from the International Life Cycle Data system, ILCD scheme (EU-JRC, 2011) and guidance from the afore mentioned initiatives.

Table 8 lists the current environmental impact categories to be considered and presents the recommended methods for each impact category according to EF initiative. Table 8 also includes level of robustness for each impact category, which gives an idea of the certainty of the method. Robustness corresponds to EF's level of recommendation, based on scientific judgement performed across the different existing methods. It ranges from level I for models and characterisation factors which are recommended for all types of life cycle-based decision support, to level III recommended (or interim), recommended but only with caution given the considerable uncertainty, incompleteness or other shortcomings, aspects that need to be considered when performing an LCA. Being aware of the importance of biodiversity indicators for organic production systems but lack of assessment methods we have deepened the present study by proposing a set of potential biodiversity indicators (see section 5.4).

Table 8. Recommended Impact categories, indicator, units default Impact assessment model and level of robustness (Fazio et al., 2018)

Impact category	Indicator	Unit	Recommended default impact model	Robustness
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg CO_2 eq	Baseline model of 100 years of the IPCC (based on IPCC, 2013)	I
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11eq	Steady-state ODPs as in (WMO, 1999)	I
Human toxicity, cancer effects*	Comparative Toxic Unit for humans (CTUh)	CTUh	USEtox model (Rosenbaum et al., 2008)	III/interim
Human toxicity, non- cancer effects*	Comparative Toxic Unit for humans (CTUh)	CTUh	USEtox model (Rosenbaum et al., 2008)	III/interim
Particulate matter/Respiratory inorganics	Human health effects associated with exposure to PM2.5	Disease incidences	PM model recommended by UNEP (UNEP, 2016)	I
Ionising radiation, human health	Human exposure efficiency relative to Uranium-235	kBq U235	Human health effect model as developed by Dreicer et al., 1995 (Frischknecht et al., 2000)	II
Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS (Van Zelm et al., 2008) as applied in ReCiPe 2008	II
Acidification	Accumulated Exceedance	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006. Posch et al., 2008)	II
Eutrophication, terrestrial	Accumulated Exceedance	mol N eq	Accumulated Exceedance (Seppälä et al., 2006. Posch et al., 2008)	II
Eutrophication, aquatic freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe	II
Eutrophication, aquatic marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe	II
Ecotoxicity (freshwater)*	Comparative Toxic Unit for ecosystems (CTUe)	CTUe	USEtox model, (Rosenbaum et al., 2008)	III/interim
Land use	Soil quality index (Biotic production, Erosion resistance, Mechanical filtration and Groundwater replenishment	Dimension less, aggregated index of: (kg biotic production, kg soil, m^3 water, m^3g water)/ (m^2*a)	Soil quality index based on LANCA (Beck et al., 2010 and Bos et al., 2016)	III
Water scarcity	User deprivation potential (deprivation-weighted water consumption)	kg world eq. deprived	Available Water Remaining (AWARE) in UNEP, 2016	III
Resource use, minerals and metals	Abiotic resource depletion	kg Sb eq	CML Guinée et al. (2002) and van Oers et al. (2002).	III
Resource use, energy carriers	Abiotic resource depletion – fossil fuels	MJ	CML Guinée et al. (2002) and van Oers et al. (2002)	III

The impacts for each scenario (baseline crop or animal production system with the contentious inputs, compared to the alternatives using the same crops or animal system) were characterised in the LCIA using the impact characterisation factors given in the corresponding recommended default impact model in Table 3. For example, the characterisation factors for each greenhouse gas in the climate change category were created by comparing the Global Warming Potentials (IPCC, 2013) of each greenhouse gas in terms of carbon dioxide equivalents (e.g. the GWP of N_2O is 298x the GWP of 1 kg CO_2, thus the CF for N_2O is 298 kg CO_2 eq/kg N_2O). To calculate the Impact Score for a specific category, Equation 3 was used.

Impact Score = $\sum_c (Characterisation\ Factor) \times Emission\ Inventory$ Eq.3

Where subscript *c* denotes the chemical or substance emitted.

Equation 3 linearly expresses the contribution of a unit of mass (1 kg) of an emission to the environment using corresponding characterisation factors, where each emission quantity from the inventory is multiplied by their CF, resulting in values with the same units, which are then aggregated to get a final Impact Score. Each characterisation model quantitatively calculated the characterisation factors based on scientific analysis of the relevant environmental processes.

2.4 Interpretation

In the interpretation phase, the identification of the significant issues based on the results of the LCI and LCIA phases are conducted. Identification shall be done among processes, impact categories (normalised and weighted values), potential bottlenecks, limitations and finally evaluating if the proposed alternatives to contentious inputs performed better or worse from an environmental perspective.

Table 9 provides the main substances/flows, which usually represent the major contributors for each impact category, this helps to identify major contributors.

The global perspective of LCA, the high requirements of data, as well as the need to provide answers to the different environmental issues produces results with high levels of uncertainty. In order to carry out an accurate interpretation, guidelines and recommendations on how to improve activities from an environmental perspective, as well as a transparent description of the limitations of the assessment must be carried out.

In addition to this, normalisation and weighting methods are used. Results for each impact category from the LCIA are usually expressed in their corresponding units (e.g., kg CO_2eq, CTUh, kg CFC-11 eq., etc), which makes it difficult to allow comparisons among the categories. To normalise the results, each impact result was divided by normalisation factor provided by EU-JRC (2018), which are based on the emissions produced and resource used per capita. This allows us to provide each impact category in the same unit and therefore comparing between them. The categories were then weighted by the importance of each category allows us to compare magnitudes and prioritise the importance of the damage. To do this, the normalisation and weighting factors (Table 10) defined by the PEFCR (EU-JRC, 2018) were used.

Table 9. Main flow contributors for each environmental impact category (excluded Human Toxicity impact categories due to long list)

Impact category	Units	Substances
Climate change	kg CO_2 eq	Carbon dioxide, CO_2, fossil Dinitrogen monoxide, N_2O Methane, CH_4
Ozone depletion	kg CFC-11eq	CFCs HCFCs
Particulate matter/respiratory inorganics	Disease incidences	Ammonia, NH_3 Nitrogen oxides, NO_x Particulates, < 2.5 um Particulates, > 2.5 um, and < 10um Sulphur dioxide, SO_2
Ionising radiation, human health	kBq U235	Nuclear source for electricity
Photochemical ozone formation	kg NMVOC eq	Carbon monoxide, CO Sulphur dioxide, SO_2 Methane, CH_4
Acidification	mol H+ eq	Ammonia, NH_3 Nitrogen oxides, NO_x Sulphur dioxide, SO_2
Eutrophication, terrestrial	mol N eq	Ammonia, NH_3
Eutrophication, aquatic freshwater	kg P eq	Phosphorus, P
Eutrophication, aquatic marine	kg N eq	Ammonia, NH_3 Nitrogen oxides, NO_x Nitrate, NO_3
Ecotoxicity (freshwater)	CTUe	Copper Sulphur Pesticides Heavy metals Oil crude
Land use	Pt	Crop/Pasture field Occupation Peat
Water scarcity	kg world eq. deprived	Water consumption (Irrigation) Hydropower electricity
Resource use, minerals and metals	kg Sb eq	Copper Phosphate Rock Sulphur
Resource use, energy carriers	MJ	Coal Gas, natural Oil crude

Table 10. Normalisation and weighting factors (EU-JRC, 2018)

Impact category	Normalisation units	Normalisation reference	Weighting factor, %
Climate change	Pt/kg CO_2eqCO_2eq	1.24E-04	21%
Ozone depletion	Pt/kg CFC-11eq	1.86E+01	6%
Human toxicity, cancer effects	Pt/CTUh	2.37E-04	5%
Human toxicity, non- cancer effects	Pt/CTUh	2.46E-02	5%
Particulate matter/ respiratory inorganics	Pt/Disease incidences	1.68E+03	9%
Ionising radiation, human health	Pt/kBq U235	4.35E+03	2%
Photochemical ozone formation	Pt/kg NMVOC eq	5.92E+04	2%
Acidification	Pt/mol H^+eq	1.80E-02	6%
Eutrophication, terrestrial	Pt/mol N eq	6.22E-01	3%
Eutrophication, aquatic freshwater	Pt/kg P eq	5.12E-02	3%
Eutrophication, aquatic marine	Pt/kg N eq	5.66E-03	4%
Ecotoxicity (freshwater)*	Pt/CTUe	2.34E-05	2%
Land use	Pt/Pt	1.22E-06	8%
Water scarcity	Pt/kg world eq. deprived	8.72E-05	9%
Resource use, minerals and metals	Pt/kg Sb eq	1.54E-05	8%
Resource use, energy carriers	Pt/MJ	1.57E+01	8%

In addition, and due to the previous concerns regarding the application of LCA to organic production, particular attention has been focused on the limitations of the LCA methodology regarding dataset gaps, assumptions conducted, emission factors applied and other relevant aspects, which could hamper the final results (section 5). These limitations may be used to define and prioritise further research (see section 6).

3. REFERENCE SCENARIOS

According to the geographical distribution of Organic-PLUS project partners and based on data availability, four different baseline scenarios for agricultural crops has been selected: aubergine, tomato, citrus and olive, as well as three scenarios for organic livestock production, sheep, pig and poultry.

The idea was to use these products as case studies to test the impact on important environmental categories from various contentious inputs applied in the production process and compare these inputs with potential alternatives. We also wanted to evaluate the usefulness and limitations of life cycle assessment tools and provide improvements to the tool if possible.

A calculation form has been created for each scenario, with the idea to have a “live” and adaptable deliverable tool, which allows changes in inputs (and characterisation factors and addition of new datasets if needed). The calculation forms are implemented in Excel. Each calculation form contains 12 parts as follows:

1. Introduction: Brief presentation of calculation form/method and how it is organised in the Excel file.
2. Goal & Scope.
3. System Boundaries: Diagram of processes included in the assessment.
4. Farm Info: Location, edaphoclimatic conditions and general data of farm management practices.
5. LCI: Inventory data for current and alternative scenario.
6. EF+CF: Emission factors and corresponding Characterisation factors.
7. LCIA model: Impacts of 1 unit of processes involved.
8. LCIA: Detailed results of impact assessment for current scenario/product.
9. LCIA ALT: Detailed results of alternative scenario with substitution of contentious inputs.
10. RESULTS I: Graphical comparison of current and alternative scenario.
11. RESULTS II: Graphical results specific for current scenario, including contribution of the different processes (e.g. infrastructure, fertilisers, …) for the different impact categories and importance of the different impact categories once normalised and weighted.
12. CONCLUSIONS: Interpretation of outputs, with identification of most affected environmental issues and limitations of the assessment.

Practitioners may change the values in the LCI sheet for both the current scenario (column B) or alternative scenario (column G). Only, processes assessed during the project are included (see section 4), but new processes can be added as rows in the LCI sheet, and their corresponding dataset reference for one unit (column LCIA model) and results (corresponding columns at LCIA and LCIA ALT sheets). The contribution of each process in the cultivation and production system from cradle to gate, as well as the normalisation and weighting of impact categories was displayed in RESULTS II sheet.

3.1 Tomato (Spain)

Goal
Intended application: Detect critical environmental points in the organic tomato production
Reasons to carry out the study: Environmental importance of contentious inputs, assessment of alternatives
Target audience: Organic-PLUS partners; organic production farmers; scientific community
Limitations of study: lack of background data for organic farming inputs (e.g. manufacturing of some plant protection products and treatment of organic fertilisers), some environmental impact methods not fully developed for organic production
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: The study will be used to compare with alternatives for contentious input developed in the frame of Organic-PLUS project and it is intended to be released to the general public
Commissioner of the study and other influential actors: Organic-PLUS H2020 project
Scope
Identification of the product system to be studied: Cherry Tomato
Location: Almeria, Spain
Time period: 2016 – 2018
The functions of the product system/s: Certified organic tomato production
The functional unit: 1 ton organic cherry tomato cv. "Creativo"
Reference flow: 1 ha
The system boundaries: from the cradle to the farm gate, inclusion of greenhouse infrastructure, maintenance and dismantling of the equipment, inputs and energy required during cultivation and estimation of field emissions
Allocation procedures: It does not apply
Impact categories to be covered and methodology of impact assessment: Environmental Footprint (EF) 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set
Data requirements: primary data come from a questionnaire filled in by Organic-PLUS partners; secondary data from Ecoinvent + Agribalyse databases
Assumptions and limitations: manure inputs and green waste compost were considered as having no environmental load, since production burdens have been attributed to the system that generates the waste; hence called "Empty process " in Table 11.
Specifications: Steel "Raspa y amagado" greenhouse
Type of critical review, if any: internal review by partners involved in data collection and sustainability assessment

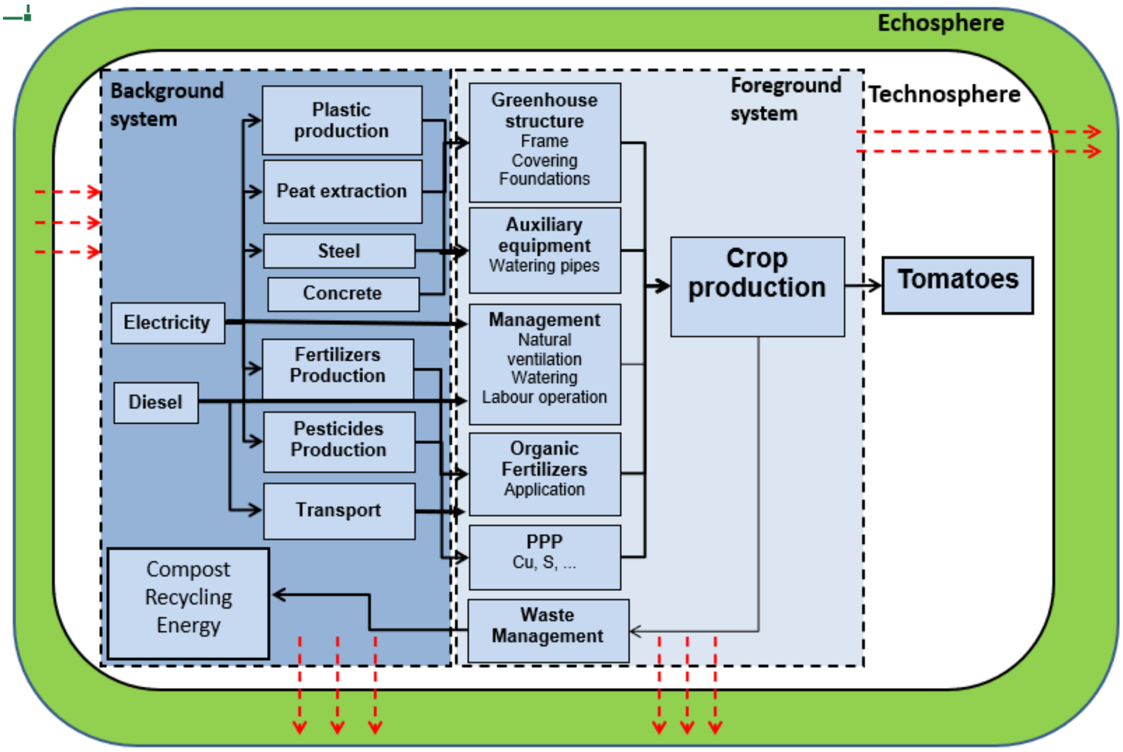


Figure 4. System Boundaries and processes involved for the organic tomato production; Spain

Table 11. Main inputs of LCI for tomato cultivation in Spain, referred to reference flow in hectares.

Products	amount	units	Comments
Tomato, organic, Almeria, Spain	1	ha	
Coproducts			
Natural Resources			
Land occupation	10000	m^2	
Water, well, ES	3750	m^3	75% of total quantity (5000m3/ha)
Water, rain	250	m^3	5% of total quantity (5000m3/ha)
Products Flows			
Plants	18000	u	
Peat	5.4	m^3	30 g peat/seedling (density 100 kg/m^3 dry peat moss in loose form) Ecoinvent database
Fertilisers			
Sheep manure, as N	134	kg	Empty process
Green manure	160	kg	Empty process
Calcareous marl	105	kg	Liquid fertiliser (Ca and Mg) 1500 L/ha.
Potassium sulphate, as K_2O	400	kg	
Plant Protection Products (PPP)			
Copper	3.75	kg	Copper sulphate used as a proxy for copper oxychloride (data not available).
Sulphur	125	kg	
Potassium hydroxide	0.2	kg	potassium soap, normally with 1-2% of potassium salt
Infrastructure			
Greenhouse structure	1	ha	'Raspa y amagado' Almeria
Machinery	1	ha	
Emissions Machinery	0	ha	
Irrigation equipment	1	ha	Watering system
Mulching, LDPE	194.25	kg	
Solarization			
Low Density Polyethylene	175	kg	3.5 rolls; 1 roll ca. 50 kg (0.001 mm)
Water	648	m^3	added to the watering, water well
Energy			
Electricity			
Electricity	66.7	kWh	Operation of opening and closing windows
Electricity	800.0	kWh	Watering pumps Default values =0.50 kWh /m^3 drip for groundwater 0.10 kWh/m^3 drip and surface water, that it would be 2000 kWh but farmer reported 800 kWh
Others			
Water desalination	1000	kg	20% of total quantity (5000m^3/ha)
Waste			
Default waste management	1	ha	Best practices assumed

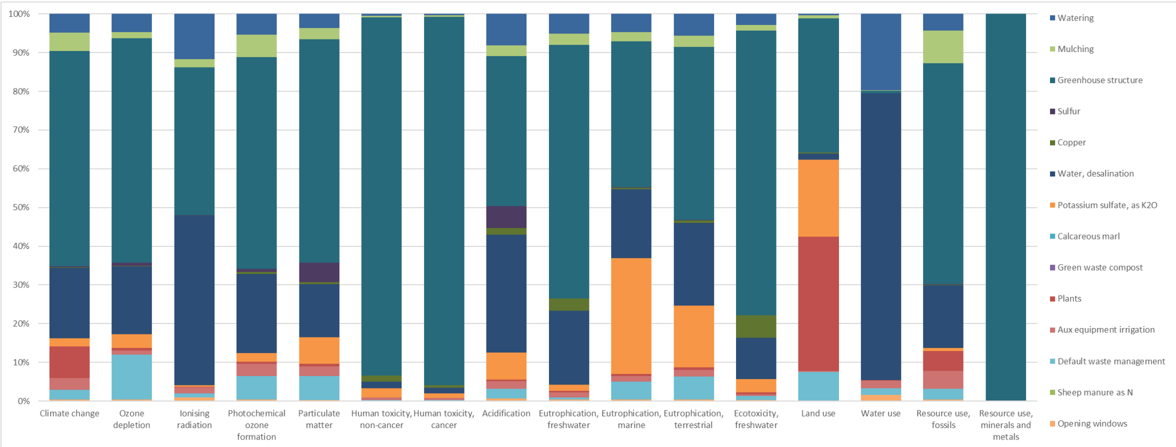


Figure 5. Contribution, %, of the different stages for each impact category for Spanish certified organic tomato cultivation.

CONCLUSIONS

- Greenhouse (GH) infrastructure (steel, concrete) had the largest impact (Mendoza-Fernández *et al.*, 2021) on most of the impact categories

- When greenhouse structure was excluded, the largest impacts came from machinery, potassium fertiliser and the process of water desalination for watering

- Peat in growing media and plastic foil for soil covering contribute most to fossil resource depletion

- Normalised and weighted values were dominated by the metal infrastructure of the GH, in particular by the coating process of the steel.

- Excluding GH structure, the normalised and weighted value was dominated by ecotoxicity of copper applied as PPP

LIMITATIONS

- Fertiliser and PPP emissions factors have not been developed and calibrated for greenhouse production systems.

- Manure application has been assumed without treatment and as an empty process because it is considered a waste from sheep production

3.2 Aubergine (Turkey)

Goal
Intended application: Detect critical environmental points in the organic aubergine production
Reasons to carry out the study: Environmental importance of contentious inputs, assessment of alternatives
Target audience: Organic-PLUS partners; organic production farmers; scientific community
Limitations of study: lack of background data for organic farming, inputs (e.g. manufacturing of some plant protection products and treatment of organic fertilisers), some environmental impact methods not fully developed for organic production
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: The study will be used to compare with alternatives for contentious input developed suggested in the frame of Organic-PLUS project and it is intended to be released to the general public
Commissioner of the study and other influential actors: Organic-PLUS H2020 project
Scope
Identification of the product system to be studied: Aubergine
Location: Menemen-IZMIR-TURKEY
Time period: 2016 – 2018
The functions of the product system/s: Aubergine production, AYDIN SIYAHI variety
The functional unit: 1 ton organic aubergine
Reference flow: 1 ha
The system boundaries: from the cradle to the farm gate, inputs and energy required during cultivation and estimation of field emissions
Allocation procedures: It does not apply
Impact categories to be covered and methodology of impact assessment: Environmental Footprint (EF) 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set
Data requirements: primary data come from a questionnaire filled in by Organic-PLUS partners; secondary data from Ecoinvent + Agribalyse databases
Assumptions and limitations: manure inputs and green waste compost were considered as having no environmental load, since production burdens have been attributed to the system that generates the waste; hence called “Empty process“ in Table 11.
Specifications: for this scenario we have tested the use of photovoltaic solar energy for watering
Type of critical review, if any: intern review by partners involved in data collection and sustainability assessment

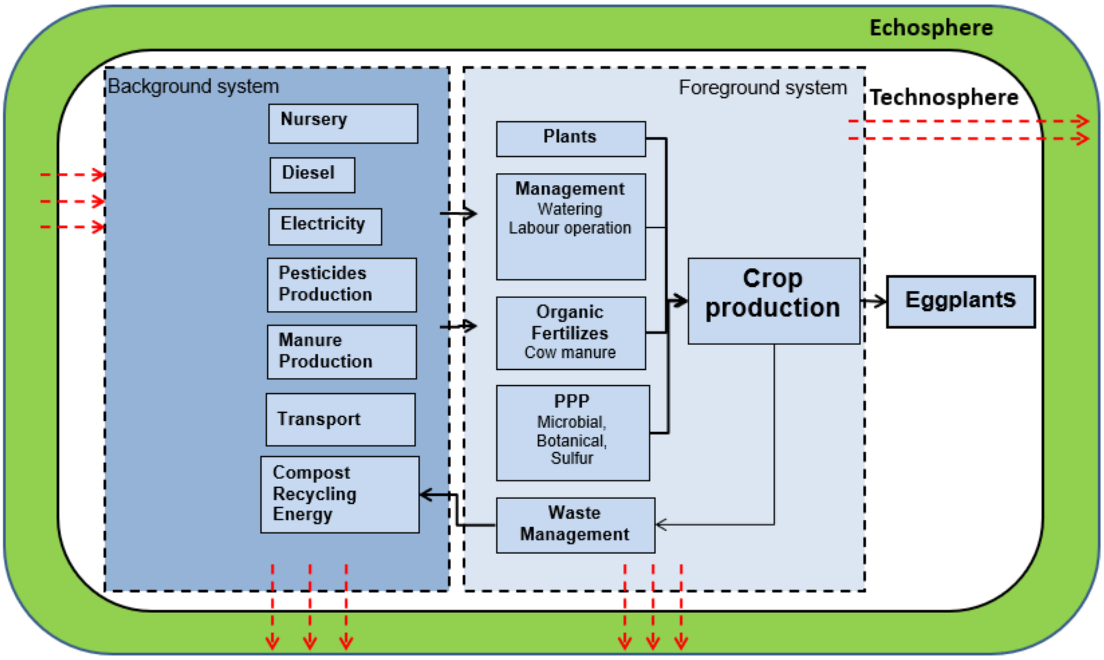


Figure 6. System Boundaries and processes involved for aubergine production in Turkey

Table 12. Main inputs of LCI for aubergine cultivation in Turkey, referred to reference flow in hectares.

Products	amount	units	Comments
Aubergine, organic, Izmir, Turkey	1	ha	
Co products			
Aubergine biomass	3000	kg	Pruning of Annual Plants to composting
Natural Resources			
Land occupation	10000	m^2	Green manure + aubergine 1 year
Water, well, TK	10000	m^3	1000 L/m^2
Products Flows			
Aubergines Plants	16000	u	Local producer
Peat	4.8	m^3	30 g peat/seedling (density 100 kg/m3 dry peat moss in loose form) ecoinvent database
Fertilisers			
Cow manure	1000	kg	Empty process, 5.5:2:7.9 Kg N:P_2O_5:K_2O /1000 kg
Plant protection products (PPP)			
Microbial PPP	0.00225	kg	7.5 g/ 1 kg seeds , Manual sprayer, *Trichoderma harzianum* T-22 does not have any harmful effects on human or animal health or on groundwater or any unacceptable influence on the environment, EU Pesticide Database
Reynoutria spp, microbial	0.4492	kg	224.6 g/l Reynoutria spp, 200ml/100l , Manual sprayer, NOT APROVED EU
Botanical PPP, *Azadirachtin*	0.09	kg	*Azadirachta indica* A. 10g/lt, 3 treatments * 300 ml/100 lt and 1000 L/ha Manual sprayer
Infrastructure			
Machinery	1	ha	
Emissions Machinery	1	ha	
Aux equipment irrigation	0	ha	Furrow
Energy			
Labour Operations			
Diesel	2.55	kg	Incorporate farmyard manure into the soil
Diesel	5.1	kg	Incorporate green manure into the soil
Total diesel	7.65	kg	
Electricity			
Electricity, solar, for irrigation	1500.0	kWh	Furrow and well, default value 0.15Kwh/m3)
Electricity crop storage, GR	40.0	kWh	2 days 4ºC, default value 0.5 kWh/d/ton

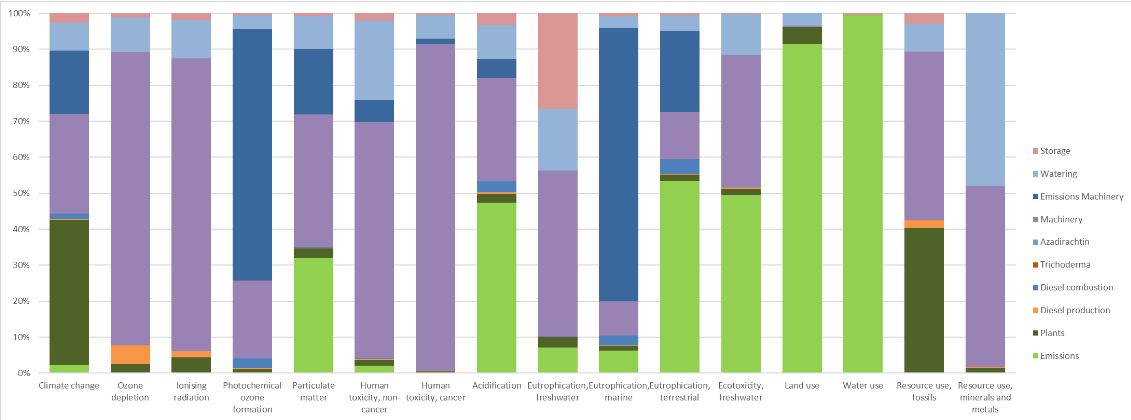


Figure 7. Contribution, %, of the different stages for each impact category for aubergine cultivation in Turkey

CONCLUSIONS
- Fossil fuel-based electricity consumption for watering could be an important contributor across categories such as Resource carrier energy use, or ozone depletion, but due to the use of photovoltaic panels it can cause a good reduction in impact (see figure at RESULTS I). However, the use of photovoltaic panels could mean an important contribution to Resource use, mineral and metals impact category. - The absolute values are quite low due to the no fertilisers consumption (LCIA column C) - *Azadirachtin* is a major contributor to ecotoxicity impacts - Normalised and weighting value was dominated by the water consumption, it is worth mentioning the high CF for Turkey (see CF EF3.0 and RESULTS II)
LIMITATIONS
- Lack of datasets for botanical and microbial pesticide production - Lack of toxicity characterisation factors for microbial pesticides - No dataset of Electricity Production Mix for Turkey, Used the Greek Mix - Manure application has been assumed without treatment and as an empty process because it is considered a waste from cow production

3.3 Citrus, Italy

Goal
Intended application: Detect critical environmental points in the organic citrus production
Reasons to carry out the study: Environmental importance of contentious inputs, assessment of alternatives
Target audience: Organic-PLUS partners; organic production farmers; scientific community
Limitations of study: lack of background data for organic farming inputs (e.g. manufacturing of some plant protection products and treatment of organic fertilisers), some impact category methods not fully developed for organic production
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: The study will be used to compare with alternatives for contentious input suggested in the frame of Organic-PLUS project and it is intended to be released to the general public.
Commissioner of the study and other influential actors: Organic-PLUS H2020 project
Scope:
Identification of the product system to be studied: Organic production of Lemon from Sicily
Location: Syracuse, Sicily, Italy
Time period: 2018 – 2019
The functions of the product system/s: Lemon production
The functional unit: ton lemon, Femminello siracusano
Reference flow: 1 ha
The system boundaries: from the cradle to the farm gate, inputs and energy required during cultivation and estimation of field emissions
Allocation procedures: It does not apply
Impact categories to be covered and methodology of impact assessment: EF 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set
Data requirements: Primary data comes from questionnaire filled by Organic-PLUS partners; Secondary data: Ecoinvent + Agribalyse databases
Assumptions and limitations: manure inputs compost and green manure were considered without environmental load, which have been attributed to the system that generates the waste, but recycling or any treatment as well as transport is included.
Specifications: Old plantation 60 years
Type of critical review, if any: intern review by partners involved in data collection and sustainability assessment

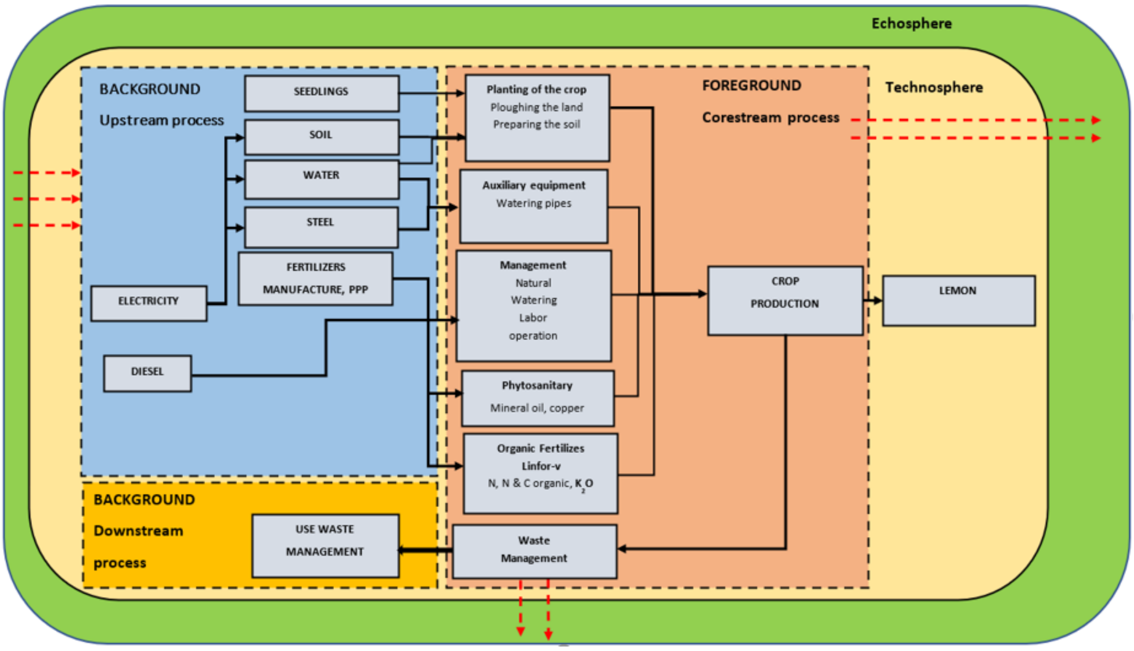


Figure 8. System Boundaries and processes involved for the lemon production in Sicily

Table 13. Main inputs of LCI for lemon cultivation in Sicily, referred to reference flow in hectares.

Products	amount	units/y	Comments
Lemon, organic, Sicily, Italy	1	ha	
Coproducts			
Citrus Crop residues	3.703	kg	Left on the ground and chopped
Natural Resources			
Land occupation	10000	m^2	
Water, well, IT	6500	m^3	Irrigation
Products Flows			
Trees	3.4	u	Permanent crop 60 years old
Fertilisers			
Cow manure in pellet	1000	kg	4.5 Kg N/ton, dataset from pelletisation of poultry manure
Green manure	3.703	kg	Empty process, pruning residue
Liquid Vegetable fertiliser (Linfor-v)	0.2	kg	3 % NITROGEN (N) of which: 3.0% organic, POTASSIUM OXIDE (K2O) Soluble in water 5.0%; ORGANIC CARBON (C) 18.0%
PPP			
Copper	1.4	kg	Copper sulphate used as a proxy for Bordeaux mixture (not available). Copper oxychloride usually is in dilution, with 37.5% Cu content.
Mineral oil	180	kg	Oliocin Treatment 1)Scales; Treatment 2) Scales and mites; Treatment 3) white fly
Packaging			
plastic crates	550	kg	Crates for harvesting; crate weight: around 2.2 kg,
Infrastructure			
Machinery	1	ha	
Emissions Machinery	1	ha	
Aux equipment irrigation	1	ha	Default value drip irrigation Almeria
Energy			
Labour Operations			Tractor potential (60 hp)
Diesel	102	kg	Till surface
Diesel	102	kg	Cut grass/chop pruning waste
Total diesel	204	kg	
Electricity			
Electricity, storage	66.7	kWh	lemons are refrigerated only in spring-summer. In Winter fruits are kept unrefrigerated for 6-7 days
Electricity, pumping	650.0	kWh	Watering pumps Default values =0.50 kWh /m^3 drip and well; 0.10 kWh/m^3 drip and surface
Others			
Tap water	3.0	m^3	washing 100 ml water/ kg fruit
Transport			
Transport	771.4	tkm	to storage facilities 3500 kg/ trip, 3 km
Transport	800.2	tkm	fertilisers cow manure + linfor, 800 km
Transport	0.0795	tkm	recycling plant 5 km distance, 14.8 kg/ha plastic + 1.1 kg /ha carboard

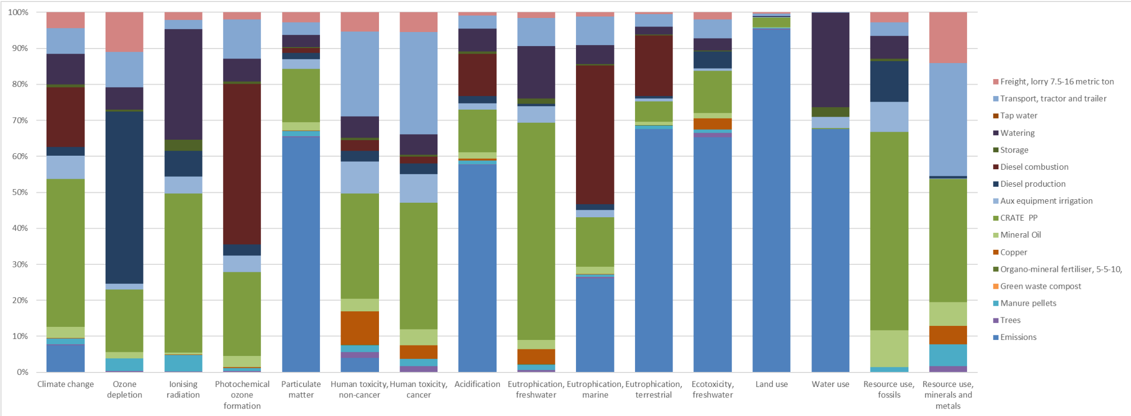


Figure 9. Contribution, %, of the different stages for each impact category for lemon cultivation in Sicily

CONCLUSIONS
- Importance of field emissions to impact categories Particulate matter, air acidification (NH_3), eutrophication (NO_3 emissions)
- Importance of Labour operations because of the diesel consumption and production to impact categories climate change, ozone depletion and eutrophication
- Major contribution crates to climate change, ionizing radiation, eutrophication freshwater and resources minerals and fossil
- Major importance of copper emissions to freshwater ecotoxicity impact category
- Normalised and weighting value were dominated by water consumption
LIMITATIONS
- Dataset ORGANO FERTILISER granulate assumed for Linfor liquid
- Dataset for biopesticides to be developed
- Manure application has been assumed without treatment and as an empty process because it is considered a waste of cow production, but pelletisation has been included from poultry manure pelletisation

3.4 Olive (Greece)

Goal
Intended application: Detect critical environmental points in the olive production
Reasons to carry out the study: Environmental importance of contentious inputs, assessment of alternatives
Target audience: Organic-PLUS partners; organic production farmers; scientific community
Limitations of study: lack of background data for organic farming inputs (e.g. manufacturing of some plant protection products and treatment of organic fertilisers), some impact category methods not fully developed for organic production
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: The study will be used to compare with alternatives for contentious input developed suggested in the frame of Organic-PLUS project and it is intended to be released to the general public.
Commissioner of the study and other influential actors: Organic-PLUS H2020 project
Scope:
Identification of the product system to be studied: Olives, Variety: Chondrolia Chalkidikis
Location: Aerino Central Greece
Time period: Crop data from 2018-2019
The functions of the product system/s: Olive production
The functional unit: 1 kg of olives (3100 kg/ha)
Reference flow: 1 ha
The system boundaries: from the cradle to the farm gate, inputs and energy required during cultivation and estimation of field emissions
Allocation procedures: It does not apply
Impact categories to be covered and methodology of impact assessment: EF 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set
Data requirements: Primary data comes from questionnaire filled by Organic-PLUS partners; Secondary data: Ecoinvent + Agribalyse databases
Assumptions and limitations: This particular farm had some mineral fertiliser inputs and synthetic PPPs, thus was not considered to be organic by European standards.
Specifications: Old plantation 60 years
Type of critical review, if any: intern review by partners involved in data collection and sustainability assessment

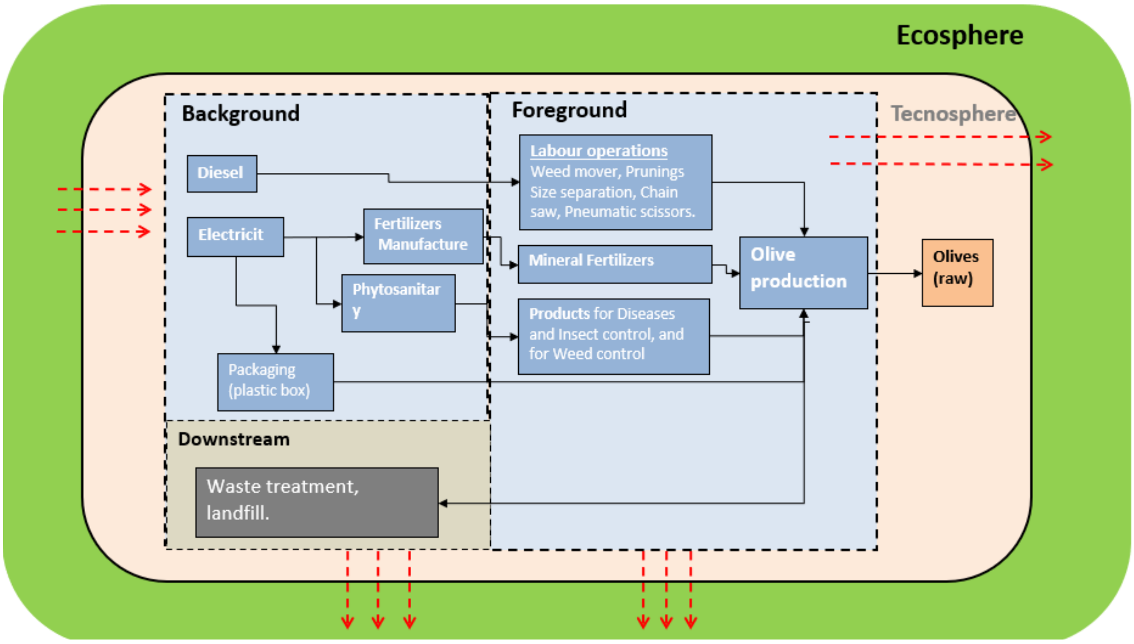


Figure 10. System Boundaries and processes involved for Olive cultivation in Greece.

Table 14. Main inputs of LCI for olive cultivation in Greece, referred to reference flow in hectares.

Products	amount	units/year	Comments
Olives, Triglia, Greece	1	ha	
Natural Resources			
Land occupation	10000	m^2	
Water, well, GR	1400	m^3	Irrigation, it looks a low value 0.14 L/m^2. I guess is 0.14 m^3/m^2
Products Flows			
Trees	3.2	u	160 trees/ha, expected life span 50 years
Fertilisers			
Nitrogen fertilisers, as N	86.4	kg	320 kg/ha 15-15-15 (Yara Mila)
Phosphorus fertilisers, as P_2O_5	86.4	kg	3 treatments * 3 kg/ha 20-20-20 Nutrileaf
Potassium fertilisers, as K_2O	86.4	kg	
Ammonium Nitrate, as N	53.6	kg	160 kg ammonium nitrate
Urea, as N	0		
PPP			
Copper	4.8	kg	4 treatments 4 kg/ha Bordeaux mix extra 20 % WP (Nov, Dec, Jan, Feb) + 1 treatment copper hydroxide 20% 8 kg/ha post-harvest
Sulphur	4	kg	April, June, Before bloom, Fruitlet
Mineral oil	8	kg	summer oil
Deltamethrin, Pyrethroids	0.135	kg	3 treatment 1.5% Decis 3 kg/ha
Packaging			
plastic crates	308	kg	
Infrastructure			
Machinery	1	ha	
Emissions Machinery	1	ha	
Aux equipment irrigation	1	ha	Watering system,
Energy			
Labour Operations			Tractor potential (70 hp)
Total Diesel	87		
Electricity			
Electricity, storage	0.0	kWh	
Electricity, pumping	1400.0	kWh	0.14 kWh/m^2
Transport			
Transport, tractor and trailer	160.2	tkm	wholesale processor 15 km , trips 900 kg
Freight, lorry 16-32 metric ton	2.4	tkm	fertilisers transport 5 km
Freight, lorry 7.5-16 metric ton	0.045	tkm	landfill transport assuming 15 km distance
Waste			
Landfill	3	kg	plastic

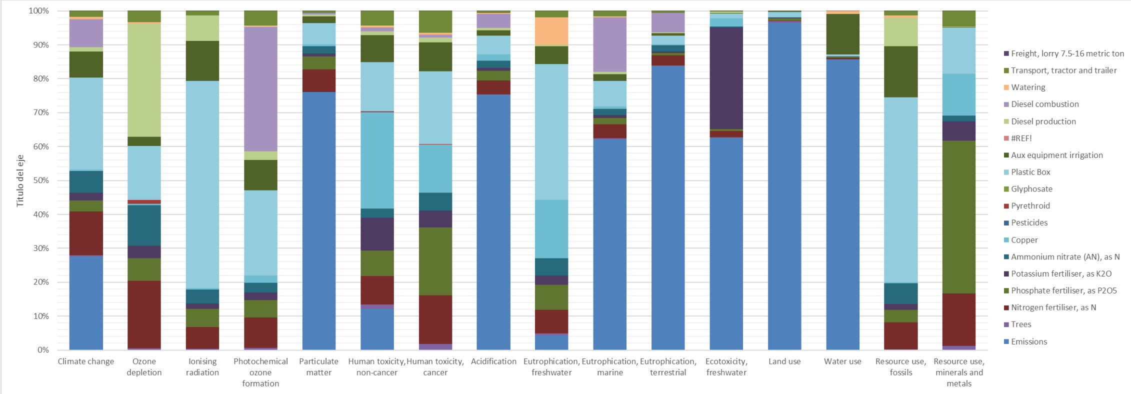


Figure 11. Contribution, %, of the different stages for each impact category for olive cultivation in Greece.

CONCLUSIONS
- Importance of field emissions for some of the impact categories climate change, particulate matter, acidification, eutrophication,
- Importance of plastic boxes and electricity consumption for watering to some of the impact categories ionising, photochemical, eutrophication, water use, resource fossils
- Importance of Labour operations because of the diesel consumption and production to impact categories climate change, ozone depletion and eutrophication
- Major contribution of pesticide emissions + Potassium fertiliser to ecotoxicity
- Normalised and weighting value was dominated by water consumption
LIMITATIONS
- This is not a real organic scenario, several inputs such as synthetic fertilisers and plant protection products from conventional agricultural

3.5 Intensive organic pig farming (Denmark)

Goal
Intended application: Detect critical environmental points in the organic pig production
Reasons to carry out the study: Environmental importance of contentious inputs, assessment of alternatives
Target audience: Organic-PLUS partners; organic production farmers; scientific community
Limitations of study: lack of background data for organic farming inputs (e.g. manufacturing of some plant protection products and treatment of organic fertilisers), some impact category methods not fully developed for organic production
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: The study will be used to compare with alternatives for contentious input developed in the frame of Organic-PLUS project and it is intended to be released to the general public**.**
Commissioner of the study and other influential actors: Organic-PLUS H2020 project
Scope:
Identification of the product system to be studied: Organic pig production
Location: Koldingvej, Lunderskov, Denmark
Time period: 2018
The functions of the product system/s: pig production
The functional unit: 1 kg carcass weight
Reference flow: farm, 13000 animals/year
The system boundaries: from the cradle to the farm gate, inputs and energy required during cultivation and estimation of field emissions and transport to slaughterhouse
Allocation procedures: No multifunctional process, all burden allocated to carcass weight
Impact categories to be covered and methodology of impact assessment: EF 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set
Data requirements: Primary data comes from questionnaire filled by Organic-PLUS partners; Secondary data: Ecoinvent + Agribalyse databases
Assumptions and limitations: Lack of specific secondary datasets (mostly assumed from AGRIBALYSE database, organic production)
Specifications: Intensive organic farming
Type of critical review, if any: intern review by partners involved in data collection and sustainability assessment

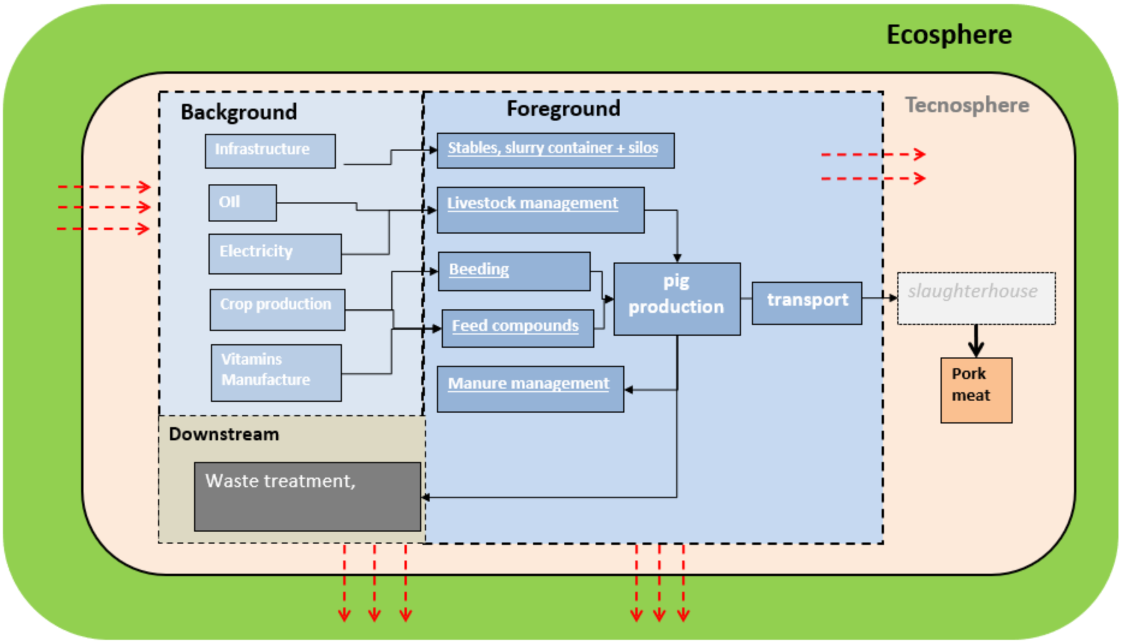


Figure 12. System Boundaries and processes involved for pig production in Denmark.

Table 15. Summary main inputs for the Life Cycle Inventory of organic production pig farm in Denmark.

Products	amount	units/year	Comments
Pig production	13000	animals	
Natural Resources			
Land occupation	5232100	m^2	The area for finisher production is 531.28 ha
Water, well, DK	13000	m^3	
Products Flows			
Straw, rye	140156.3	kg	186.875.00 kg/y total, (75% rye/25% barley)
Straw, barley	46718.8	m^3	
Fertilisers			
Slurry, as N	69.965	kg	empty process, manure coming from different farms (pig, cattle, mixed) of same farmer
Feed			
Soy cake, organic	741.5	ton	kg feed per finisher total = 280 kg 65% livestock feed + 35% compound feed
Oat,	546.0	ton	
Wheat, organic	546.0	ton	
Barley, organic	546.0	ton	
Corn, organic	429.5	ton	
Fava beans,	334.9	ton	
Barley,	182.0	ton	
Alfalfa, organic	0.0	ton	
Alfalfa green pills, organic	134.7	ton	
Bran, organic	72.8	ton	
Calcium carbonate, chalk	40.0	ton	
Mono-calcium phosphate	29.5	ton	
Rock salt	18.9	ton	
Formic acid and lactic acid	10.9	ton	
Premixed vitamins	7.3	ton	
Infrastructure			
Farm structure	2.86	ha	Housed with outdoor porches, (7 Stables*1260 m2) for 4000 heads = 2.2 m2/head
Silage silo	3.5	$m^2\cdot$ year	300 Ton diameter 4.5 m means 15.9 m^2 2000 ton= 106 m^2; lifespan 30 years
Slurry pit	403.3	$m^3\cdot$year	(1100+ 4000+3000+1600+2400) m^3 and lifespan 30 years
Energy			
Labour Operations			
Total diesel	26683.71	kg	6 h/ha and Default value 10 L/ h
Electricity			
Cleaning and feeding	3250.0	kWh	
Mill & drier	310000.0	kWh	total for the farm incl. grain mill (185000 kWh) and dryer
Others			
Oil	403125.0	MJ	In stables and for grain drying: 10 tons oil total, 30% for stables and 70% for grain
Transport			
Transport manure	35.0	tkm	assuming 5 km distance and average of 10 kg N/ton manure
Transport to waste management plant	0.2	tkm	assuming 15 km distance
Transport to slaughterhouse	9464741.2	tkm	load 22.800 kg/journey 100 km
Waste			
Recycling	14.5	kg	empty process following cut off criteria

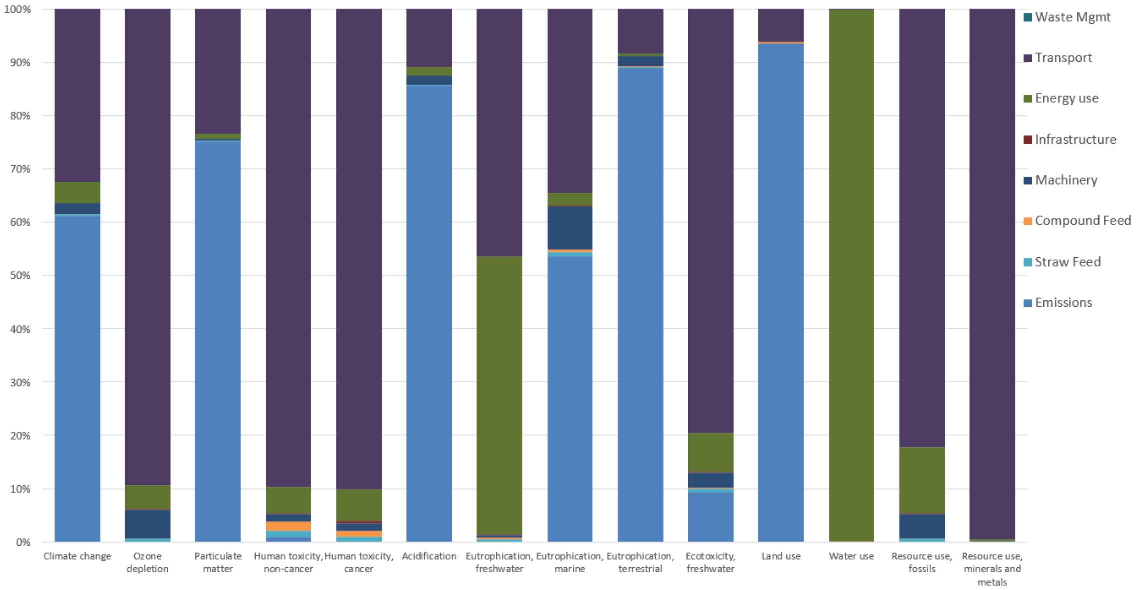


Figure 13. Contribution, %, of the different stages for each impact category pig production in Denmark.

CONCLUSIONS

- Importance of other contentious inputs mainly in relation to fossil consumption and field emissions
- Importance of transport to slaughterhouse for most of the impact categories
- Importance of diesel consumption for impact categories ozone depletion, ionising radiation, photochemical oxidation and fossil resources consumption
- Importance of field emissions for climate change, air acidification, eutrophication, particulate matter impact categories
- Importance of electricity consumption for impact categories ionising, eutrophication and water consumption
- Soy, corn, barley and oat are the main environmental contributors for feed, corn mainly for the water consumption impact category
- Normalised and weighting value was dominated by water consumption, major contributors to this impact is the water consumption involved in electricity production, absolute value could be adjusted in accordance with updated DK values but the general tendency will remain.

LIMITATIONS

- Lack of antibiotic datasets and corresponding effects
- Lack of specific or updated datasets (e.g. electricity)
- Organic feed datasets correspond to Agribalyse database (France)
- TIER I adopted for emission estimations, if study focus on Climate Change emissions it would be advisable to apply TIER2
- More information/research/guidelines would be advisable to model flows/direct emissions related to feed digestion
- Need of agreement on the consideration of manure (other organic wastes) as empty processes or allocation rules
- Due to no clear methodology developed to account for Heavy metal balance, heavy metal manure content excluded from the assessment
- Assuming best agriculture practices P water emissions are considered 0 for runoff and erosion, default value for leaching

3.6 Poultry (Poland)

Goal
Intended application: Detect critical environmental points in the organic poultry production
Reasons to carry out the study: Environmental importance of contentious inputs, assessment of alternatives
Target audience: Organic-PLUS partners; organic production farmers; scientific community
Limitations of study: lack of background data for organic farming inputs (e.g. manufacturing of some plant protection products and treatment of organic fertilisers), some impact category methods not fully developed for organic production
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: The study will be used to compare with alternatives for contentious input developed suggested in the frame of Organic-PLUS project and it is intended to be released to the general public**.**
Commissioner of the study and other influential actors: Organic-PLUS H2020 project
Scope:
Identification of the product system to be studied: Organic poultry production
Location: Poland: average organic production of Dolnośląskie, Małopolskie, Mazowieckie, Kujawsko-Pomorskie an Wielkopolskie Voivodeships
Time period: 2008
The functions of the product system/s: poultry production (chicken meat + eggs)
The functional unit: 1 kg carcass weight and 1 kg eggs production
Reference flow: farm, 3000 animals/year
The system boundaries: from the cradle to the farm gate, inputs and energy required on average organic poultry farm feed with own pasture grazing producing chicken meat and eggs, including field and manure management emissions
Allocation procedures: physical allocation between meat and eggs considering half of the hens farm for each
Impact categories to be covered and methodology of impact assessment: EF 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set
Data requirements: Primary data comes from questionnaire filled by Organic-PLUS partners; Secondary data: Ecoinvent + Agribalyse databases
Assumptions and limitations: lack of specific secondary datasets (mostly assumed from Ecoinvent database, organic production)
Specifications: Intensive organic farming

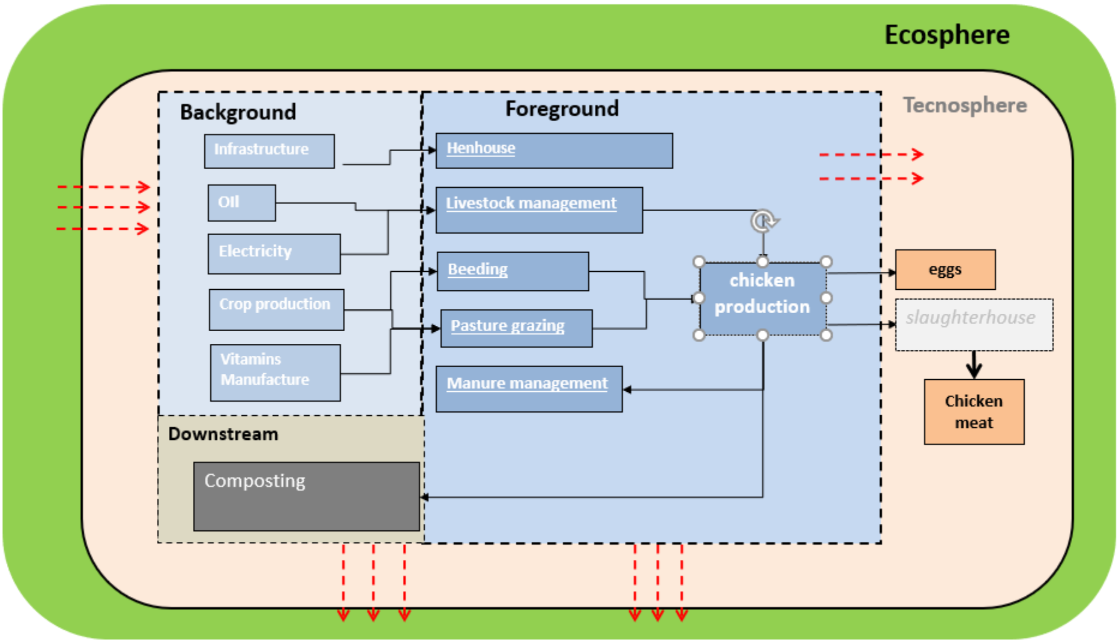


Figure 14. System Boundaries and processes involved for the organic poultry production in Poland

Table 15. Summary main inputs for the Life Cycle Inventory of organic poultry production.

Products	amount	units/y	Comments
Chicken meat	1.050	kg	From one Chicken carcass (Röss) we have 0.7 kg, so from 1500 chicken we have 1 t
Coproducts			
eggs	13.92	ton	From 1 hen we have 160 eggs per year (58g per one egg), so from 1500 hens we have 13.92 t
Natural Resources			
Land occupation	20500	m^2	Stable 6 hens per 1 m2 + grazing grass 20 ha
Water, well, PL	209.0	m^3	Watering: 328 500 l/year; Henhouse cooling: 12 538 l/year; Henhouse cleaning: 7 223 l/year; All: 348 261 L/year, 60% from well
Water, rain	0.7	m^3	348 261 L/year, 0.2% from well
Products Flows			
Seeds		kg	
Hens	3000	u	
Bedding, straw	12261.9	kg	12261.9 / kg for 3.000 hens will be needed per 500 m2.
Fertilisers			
Chicken manure	250	kg	10-15 t/ha, empty process, Default values for N= 20.8 kg N/ton; for P= 27.8 kg P_2O_5
Feed			
Plant-based (crop) feed grown on-site	164250	kg	Estimated: 150 g of forage * 365 days = 54750 g / one hen per year, and we have 3000 hens, so 54750 g of forage * 3000 hens = 1642500 g of forage / 3000 hens = 164250 kg = 164.25 t/year/3000 hens which corresponds to 20 ha.
Sanitary treatments			
		kg	Prophylactic, extracts from plant may be administered from: wild rose fruit, hawthorn, rowan or pine needles and garlic
Infrastructure			
Farm structure	0.05	ha	Chicken coop
Machinery	1328	kg	own calculations based on lifespan and working time (machinery_erica.xls)
Fences	50	m	Metal chain-link
Energy			
Labour Operations			
Diesel	1000	L	grinding, spreading, 700 h/ha/yr; Default value 1 L/ ha * 50 times year
Diesel	600	L	for ploughing the field 2-4 h/ha/yr. Default value 10 L/h
TOTAL DIESEL	1360	kg	
Electricity			
Electricity, farm management	9809	kWh	
Others			
Tap Water	138.6	m^3	Waterworks (tap water) 39.8%
Transport			
Transport to slaughterhouse	97.5	tkm	Assuming 1.3 kg body weight (IPCC) and 50 km distance
Waste			
Composting	138000	kg	

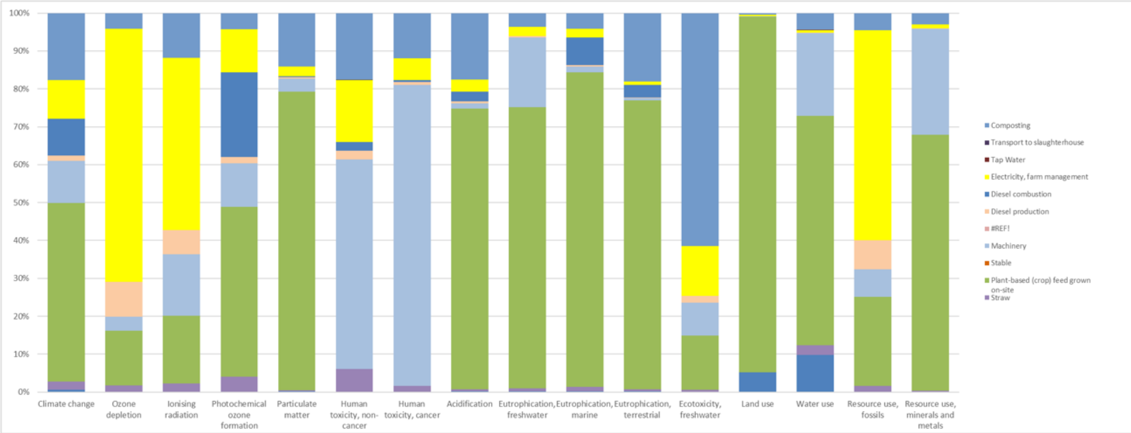


Figure 15. Contribution, %, of the different stages for each impact category for organic poultry production in Poland

CONCLUSIONS

- Relevance of feed compounds as the most relevant input

- Importance of other contentious inputs such as electricity, composting, machinery

- Importance of electricity consumption for impact categories ozone depletion, ionising radiation and resources consumption

- Normalised and weighting value was dominated by land use, major contributors to this impact is the required extension of pasture grazing to feed hens

LIMITATIONS

- Need for more updated datasets (e.g., electricity, composting, chicken coop)

- A more detailed assessment of feed compounds will be advisable

- TIER I adopted for emission estimations, if study focus on Climate Change missions it would be advisable to apply TIER2

- Need for agreement on the consideration of manure (and other organic wastes) as empty processes or allocation rules

- Due to no clear methodology Heavy metals manure content excluded from the assessment

- Assuming best agriculture practices P water emissions are considered 0 for runoff and erosion, default value for leaching

3.7 Sheep production (Norway)

Goal
Intended application: Detect critical environmental aspects in organic sheep production
Reasons to carry out the study: Study environmental effects of contentious inputs applied in the production and their alternatives
Target audience: Organic-PLUS partners; organic production farmers; scientific community
Limitations of study: lack of background data for organic farming inputs (e.g. manufacturing of some plant protection products and treatment of organic fertilisers), some impact methods not fully developed for organic production
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public: The study will be used to compare with alternatives for contentious inputs developed and suggested in the frame of Organic-PLUS project. It is intended to be released to the general public
Commissioner of the study and other influential actors: Organic-PLUS H2020 project
Scope
Identification of the product system to be studied: Organic production of Sheep from Norway for meat and wool (Mix of Old Norwegian Short Tail Landrace and Norwegian White Sheep)
Location: Vanse, Norway
Time period: 2018
The functions of the product system/s: Sheep meat and wool production
The functional unit: tons of lamb
Reference flow: farm
The system boundaries: from the cradle to the farm gate, inputs and energy required during cultivation and estimation of field emissions
Allocation procedures: Mass allocation was used to split the environmental impact between lamb and sheep meat. Economic allocation was used to distribute the environmental burden between meat (lamb and sheep) and hides; 62 % of the environmental burden was allocated to meat.
Impact categories to be covered and methodology of impact assessment: EF 3.0 Method (adapted) V1.00 / EF 3.0 normalisation and weighting set
Data requirements: Primary data comes from questionnaire filled by Organic-PLUS partners; Secondary data: Ecoinvent + Agribalyse databases
Assumptions and limitations: manure inputs and green waste compost were considered without environmental load, which have been attributed to the system that generates the waste, but recycling or any treatment as well as transport is included.
Specifications: 1 year

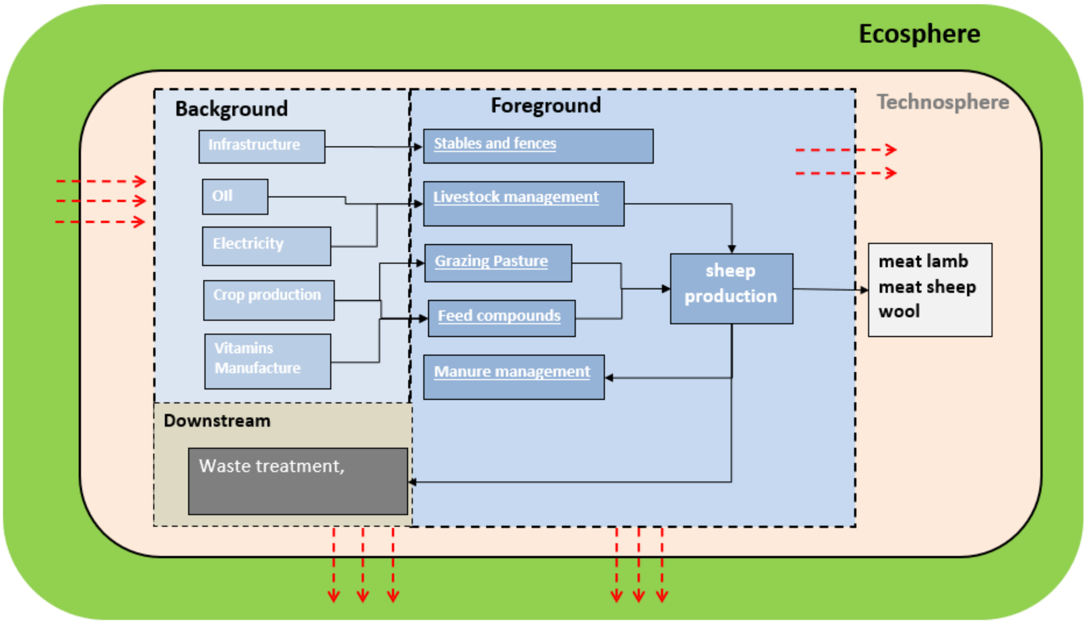


Figure 16. System Boundaries and processes involved for organic sheep production in Norway

Table 16. Summary main inputs for the Life Cycle Inventory for organic sheep production in Norway

Products		Units/ farm	Comments
Lamb animals	124	u	
Sheep meat	58	u	
Coproducts			
Wool to sell	0.267	ton	20 NOK per kg sales price
Wool as scrap	0.008	ton	Used for draining- cover drain pipes
Natural Resources			
Land occupation, animals	215172	m^2	Total area (area for animals + area for feed)
Land occupation, feed	115138	m^2	
Water, surface	20.44	m^3	40% of total, 140 L/day
Water, rain	5.11	m^3	10% of total, 140 L/day
Products Flows			
Animals	182	u	Born on the farm,
Bedding, wood chips	5	m^3	Not included in assessment as they come burden free from previous system and no treatment needs to be done for its use
Bedding, hay	8	balls	
Deep litter	40	ton	
Fertilisers			
Chicken manure	8000.0	kg	Ladybird 8-4-5 – crop area, enriched with meat and bone meal, conventional
Chicken manure	5000.0	kg	Ladybird 4-1-2 – grazing, not enriched, conventional
Chicken farm manure	110000	kg	Not included in assessment as they come burden free from previous system and no treatment needs to be done for its use
Sheep Deep litter	40000	kg	Use on farm
Feed			
Pasture grazing, Grassland	2.045	ha	From 15th April to 15th October 100%
Compound feed			
Natura Drøv	0.4	t	Wintertime 15.10.-15.4.: 400 kg/(40 kg Wilomix+56.4 tonnes big balls + 8 tonnes pea/rape big balls)* 100= 1 %
Vitamins and minerals	0.04	t	
Grass	56.4	t	Own production
Pea+ rape	56.4	t	Own production
Natural coarse sea salt	0.025	t	Bought
Milk substitute	0.375	t	Bought
Sanitary Treatments			
Benzylpenicilinprokain	145.6	g	300 mg/ml, Normal dosage is 20 mg/kg body weight, default weight 40 kg
Antibiotic	3	g	3 grams, treatment just for one sheep
Dysect	7.28	L	Skin parasite rate of 40 ml for animals weighting 25 kg or more
Plastic products			
PVC Buckets	2	kg	
Tarp	4	kg	
Ear tags	1	kg	

Table 16. Summary main inputs for the Life Cycle Inventory for organic sheep production in Norway (cont.)

Infrastructure			
Stables	0.0292	ha	Life span 50 years, 1) 192 m^2+ 2) 100 m^2
Wood Fences	4500	m	800 poles of oak from own production on the farm and 800 poles of water- and fireproofed pinewood from Sweden
Electric fence	600	m	For the electric fence is used 200 poles of plastic and two wires are installed = 1200 m wire.
Machinery	11.5	ha	Crop area
Energy			
Diesel, Harrowing, grass moving + animal transport	1000	L	tractor 69 HP, 10 L/h x 100 h/y
Diesel, everything else and grass moving for bedding	800	L	tractor 105 HP 5 L/h x 160 h/y
Total diesel	1530	kg	
Electricity			
Electricity, illumination	636	kWh	
Others			
Tap water	25550	L	50% tap water
Transport			
Chicken manure	18450	tkm	150 km
Transport to slaughterhouse	386.2	tkm	163.8 km
Transport to waste management	1.963	tkm	13 km distance 151 kg plastic waste
Waste			
Incineration	30	kg	assuming incineration for the netting plastic collected by municipal waste

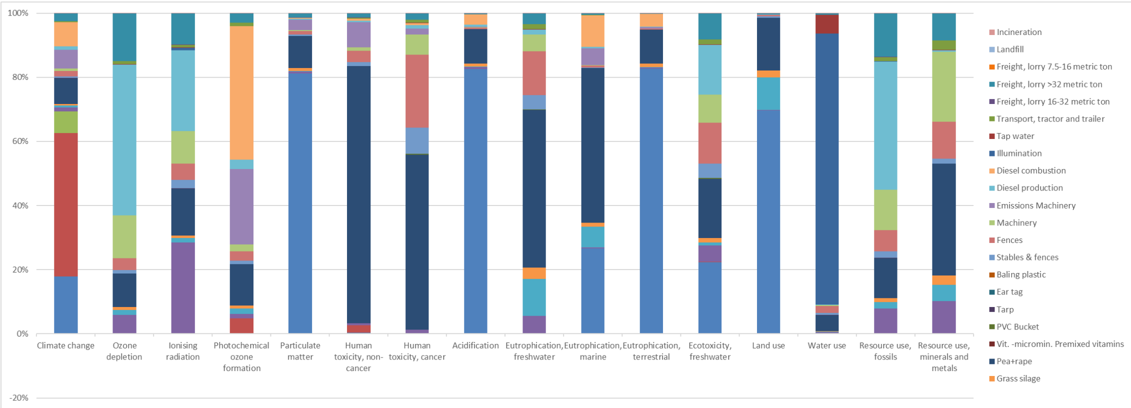


Figure 17. Contribution, %, of the different stages for each impact category for organic sheep production in Norway

CONCLUSIONS

- Importance of enteric emissions, methane on the climate change impact category

- Importance of field emissions to impact categories Particulate matter, air acidification (NH_3), eutrophication (NO_3 emissions)

- Importance of the pea-rape feed contribution across several impact categories, it needs to be highlighted that the dataset is just an approach of the real situation

- Important contribution of manure transport for most of the impact categories

- The high water use impact was due to electricity use for illumination and freshwater use for animal consumption. Norway's national electricity grid mix composes of high hydroelectricity contribution (~88%). However, water scarcity is not normally a problem in Norway

- Normalised and weighting value was dominated by those categories in relation with air emissions: i) ammonia emissions due to fertilization applied, which affects air acidification and particulate matter impact categories and ii) climate change impact category (CH_4 emissions) and (NO_3 emissions)

LIMITATIONS

- and freshwater use for animal consumption. Norway's national electricity grid mix composes of high hydroelectricity contribution (~88%). However, water scarcity is not normally a problem in Norway.

- We used market values of Swedish sheep production to create the ratios for economic allocation values between coproducts

- Organic feed datasets correspond to ecoinvent database (Switzerland), it would be interesting to build the real local dataset

- More information/research/guidelines would be advisable to model flows/direct emissions, mainly those related to feed digestion

- Need of agreement on the consideration of manure (other organic wastes) as empty processes or allocation rules

- Due to no clear methodology on how balance between inputs and outputs heavy metals manure content excluded from the assessment

- Assuming best agriculture practices P water emissions are considered 0 for runoff and erosion, default value for leaching

4. ALTERNATIVE INPUTS

Once the technological and operational feasibility of alternatives to contentious inputs has been proven, three main aspects are relevant for the environmental assessment following LCA methods: i) How the alternative could change the set of practices and yield; ii) does the manufacture dataset exists in the current databases and iii) Is there enough information regarding Characterisation factors for the different potential impact categories involved?

A new alternative may not only mean a substitution of contentious inputs but could also include a change in practices. So, because of the holistic perspective of LCA tools, consequences on agronomic or livestock practices should be accounted for. Sometimes alternatives are existing products that have corresponding manufacturing datasets. However, LCA is a relatively new methodology, so we have encountered several products, such as botanical or microbial plant protection products, that do not have manufacturing datasets. In Organic-PLUS, we have advanced on this, providing preliminary information to build these new datasets (see section 5.1). Toxicity and Biodiversity impact categories have shown to be of special interest for organic production systems, and therefore relevant for Organic-PLUS. We have devoted special sections for each (section 5.3 and 5.4).

In addition, because the technological and operational feasibility and clear recommendations for alternative inputs may not be operative in 3 years' time, in the current deliverable we focus more on providing tools and guidelines on how to conduct the assessment and recommendations for further research.

Deliverables 3.2. 4.2 and 5.2 provide a detailed description of potential alternatives to contentious inputs, and below the reader will find environmental comparisons for some of the products tested with higher operability according to efficacy scored by partners (see Table X for a summary and annex 6.3 A for a detailed survey).The use of more resistant varieties and the change of agronomic and livestock practices were excluded from the assessment, but we have provided the assessment scenarios, which can be used to test different varieties and scenarios and compare between them.

Table 17. List of alternative products with high efficacy score to be environmentally assessed (see annex 6.3.A for a more detailed list.

Contentious input	Alternative	Test crop	WP, Country, partner
Copper	Potassium hydrogen carbonate	Greenhouse tomato	WP3. Spain, IFAPA
Copper	Low copper fertiliser (Vitibiosap)	Citrus	WP3. Italy, UNICT
Copper	Low copper fertiliser (Dentamet)	Citrus	WP3. Italy, UNICT
Mineral oil	Essential oil (Thymol)	Aubergine	WP3. Italy, UNICT
Synthetic vitamins	Seaweed (Laminaria)	Pigs	WP4. Denmark, AU
Fossil plastic	Biopolymers PLA		WP5. Poland, CUT
Peat	Compost		WP5. Spain, IRTA

4.1 Copper and Mineral Oil

The assessment of baseline scenarios has shown that Copper and mineral oil emissions may have major importance in the impact category of freshwater ecotoxicity impact, while for the rest of impact categories other inputs are more relevant. Therefore, in this section we provide results in relation on freshwater ecotoxicity. Currently ecotoxicity is only represented by toxic effect on aquatic freshwater species in the water column. Impacts on other ecosystems, including sediments, are not reflected in current general practice. For the specific case of Copper-based fungicides, mineral oils and corresponding alternatives, current LCA methods may present several shortcomings, thus results must be interpreted with caution. First, for mineral oil, there are no characterisation factors, CFs, so we have used the default values for insecticides. EF3.0 provides CFs for paraffin waxes and hydrocarbon waxes, chloro and sulfochlorinated (CAS N 246-150-0 and 63449-39-8) (Table 18), which are not the corresponding to paraffin oils used in agriculture (CAS N 8042-97-5. 97862-82-3 and 64742-46-7) and present values are quite different between them. CFs for metals are specified according to their oxidation degree(s). Characterisation of the toxic effects of metal-based emissions in LCIA assumes that the toxicity is a function of the activity of the free metal ion, which is related to the relevant chemical species. Although metals can have several oxidation degrees, e.g. Cu ($^{+1}$ or $^{+2}$), only one for each metal is currently reported. Fortunately, there are CFs for some alternative inputs (Table 18), so we have conducted comparisons between contentious and alternative inputs.

Table 18 Characterisation factors for contentious and alternative inputs for freshwater ecotoxicity according to EF3.0 methodology (Fazio el al 2018)

Substance	CAS N	CF air emission	CF water emission	CF soil emission
Copper	7440-50-8	36400	99200	52400
Zinc	9029-97-4	504.5	1330.0	730.0
Potassium hydrogen carbonate	298-14-6	1.49	6.14	1.99
Thymol	89-83-8	43.5	7058.7	6.4
Paraffin waxes, and hydrocarbon waxes, chloro[1]	246-150-0	6.69	23156	26.84
Paraffin waxes, and hydrocarbon waxes, chloro, sulfochlorinated	63449-39-8	0.61337	82.96	1.05
Insecticides		n.a.	332160	6425.1
Fungicides		n.a.	50458	1020.7

[1] **Added** for information, no evidence they are used in agriculture

According to partners of WP3. Potassium hydrogen carbonate have shown to be efficient as a fungicide against *Botrytis cinerea* in tomato. Low copper fertilisers (Vitibiosap and Dentamet) have been effective against fungi (i.e. *C. gloeosporioides, A. alternata, P. digitatum*) and bacteria (i.e. *P. syringae and X. euvesicatoria pv. Perfora*ns) in *in vitro* tests. Different essential oils were identified to have the most efficient antifungal activity against both fungi (0.5 and 0.25%). *O. vulgare*, *T. vulgaris*, *C. zeylanicum* and *M. alternifolia* were identified to have the most efficient antibacterial activity against both bacteria. Among them, we have found information of characterisation factors for Thymol, the Thyme essential oil extracted from *T. vulgaris*. Once doses applied of active ingredient has been calculated, we estimated air and soil emissions according to Table 2 (section 2) and related with the corresponding CF (Table 18) to calculate final impact for freshwater ecotoxicity.

Table 19. Contentious and alternative tomato and citrus scenarios tested

Crop	Commercial Product	Active ingredient	Doses application active ingredient,	Crop growth stage
Tomato	Copper oxychloride	Cu, 50%	1.2 kg/ha	<50 cm
Tomato	Copper oxychloride	Cu, 50%	1.5 kg/ha	>50 cm
Tomato	Potassium hydrogen carbonate	$KHCO_3$. 85%	2.55 kg/ha	<50 cm (young) >50 cm (adult) Added in both stages
Citrus	Copper oxychloride	Cu, 50%	1 kg/ha	
Citrus	Low copper fertiliser (Vitibiosap)	Cu, 3.5% Zn, 1.5%	0.08 kg/ha 0.16 Kg/ha	
Citrus	Low copper fertiliser (Dentamet)	Cu, 3.5% Zn, 1.5%	0.12 kg/ha 0.24 kg/ha	
Citrus	Mineral Oil		26.2 kg/ha	
Citrus	Thyme essentials oil	Thymol	2.05 kg/ha	

Results clearly show that all the alternatives assessed here had the lowest ecotoxicity impact compared to the conventional inputs (figure X). Although, uncertainty in calculation is high because of the intrinsic uncertainty in characterisation models for toxicity and particularly for metal substances, results show that the small amount of alternative substance applied provides less damage for the alternative inputs (figure 18). However, this shall be considered as preliminary result because we have seen that for metals, the importance is metal speciation, which depends on several factors such as soil pH, texture, soil organic carbon (SOC), water pH, dissolved organic carbon (DOC) and water hardness (Peña et al., 2017). Therefore, beyond LCA studies specific and detailed local studies considering all these parameters would be advisable.

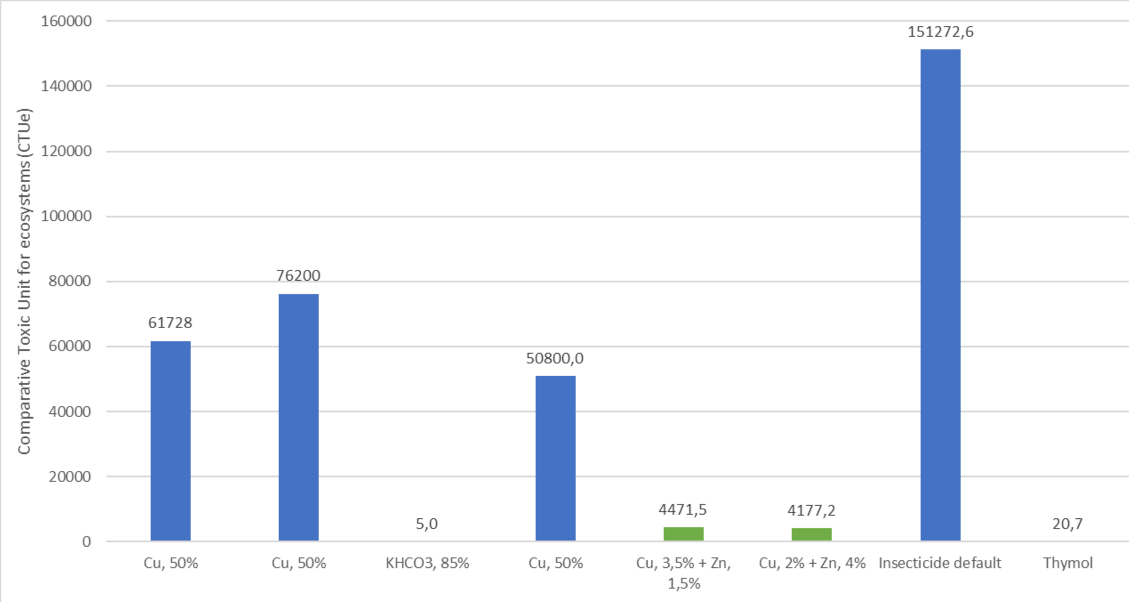


Figure 18. Results of ecotoxicity impact expressed as Comparative Toxic Unit for ecosystems (CTUe), in green alternative inputs and blue contentious inputs according to doses applied in Table 19. (NOTE: because there are no CFs for Mineral oil, we have applied the default CFs for insecticides)

4.2 Antibiotics, Antifungal & Anthelmintics

To conduct an environmental assessment of these type of products, we faced two problems. First, the current state of the LCA method does not include the characterisation of antimicrobial impacts (e.g., antibiotics) due to the lack of information regarding their effects on the environment remains unaddressed in LCA. Second, there is a lack of manufacturing information and the effectiveness of alternatives. In any case, the improvement for these contentious inputs seems to be more of a change in practices (or a conjunction of new products and practices) such as increased indoor spacing/animal conditions, separation of ill animals from others, careful planning of grazing on cultivated land, improve indoor gas emissions, etc. In this sense, it is expected that the Excel files provided with the current deliverable may allow comparison among practices.

For the case of vitamins, we have used a default dataset for vitamin production that would allow us to check the importance of dose quantity in the global assessment. This was compared to a natural vitamin source from seaweed (Laminaria) in the pig scenario, but again assessment of management practices and consequences on product quality would enhance the assessment.

4.3 Fertilisers

Besides the traditional use of manure fertilisers coming from organic production systems Organic-PLUS aims to study alternative products used (see deliverable 5.2). From an environmental perspective we may consider most of the potential products to be used as a by-product or residue from other processes (e.g. green waste, composts from household waste, biogas digestates from household waste, seaweed, cocoa husks, etc.) so the first methodological question comes from the allocation of corresponding burdens between the main product and by-products. Several approaches have been suggested: i) cut-off approach, where the producing activity is fully responsible for the disposal of its wastes, and that it does not receive any credit for the provision of any recyclable materials. That means “waste” comes free of environmental burdens to the second activity that is going to use this "waste" (or more precisely named by-product); ii)allocation at the point of substitution" is also known as APOS system model. It follows the attributional approach in which burdens are attributed proportionally to specific processes. The environmental footprint initiative has suggested the use of "Circular Footprint Formula" (CFF) to deal with the distribution of environmental burdens between supplier activity that generates the "by-product" and activity that uses it. The CFF is a combination of "material reused + energy recovered + final disposal". The formula uses different defined parameters for specific sectors. Currently, there is no adapted CFF for the use of by-products for organic fertiliser use, so for the present publication we assume the approach of zero burden from the producer (e.g., animal production system) for the by-product (e.g., manure), and consider transport and treatment of the manure. Therefore, we have focused on the potential treatments for by-products, these are composting, pelletizing and anaerobic digestion.

Based on the work developed by Avadi et al. (2020) Table 20 provides the main requirements for electricity, heat and water consumption for different residues treatments and agricultural residues.

Table 20. Average of main resources needed for different organic treatments, data are reported per 1 kg fresh mass input (own elaboration based on Avadi 2020 and Ecoinvent database

Process	Output, kg	Electricity, kWh	Heat, MJ	Water, kg
Composting	0.44	4.57E-03	3.99E-03	5.70E-03
Pelletizing	4.42E-04	4.87E-02	2.29E-01	
Digestate	0.93	6.00E-03	1.28E-01	
Coffee processing (hulls, spent grounds)		0.66	8.46	8.57
Olive processing		0.38	0.00	3.28
Pomace processing		0.03	3.83	0.00
Rendering of animal by-products		0.16	4.37	0.00

4.Peat

Peat is one of the contentious inputs to be substituted in Organic-PLUS WP5 .Peat is used in organic production systems as an important ingredient in growing media for transplants, to the same extent as in conventional growing (see del 5.1)). In the frame of the Organic-PLUS project, we have studied the environmental impact of compost substrate alternatives.

To conduct comparisons, we have used the ecoinvent peat dataset considering that peat is transported from Finland to Spain. We have used the tomato production scenario (see Excel TOMATO, SPAIN) to compare both peat and compost as growing media for the nursery.

Dataset for alternative compost growing media was built specifically based on studies developed under WP5. This was a local product produced with a proportion of 77% biomass forest fraction and 23% horse manure, including transport of material to compost plant and corresponding compost plant operations for a dynamic composting.

The substitution of peat has improved mainly the impact categories of climate change, fossil-based resource depletion and land use (Figure 17).Through a contribution analysis the hotspots in the life cycle of the compost substrate were found to be diesel consumption at compost plant, transport of forest residues and emissions from composting (Figure 18).

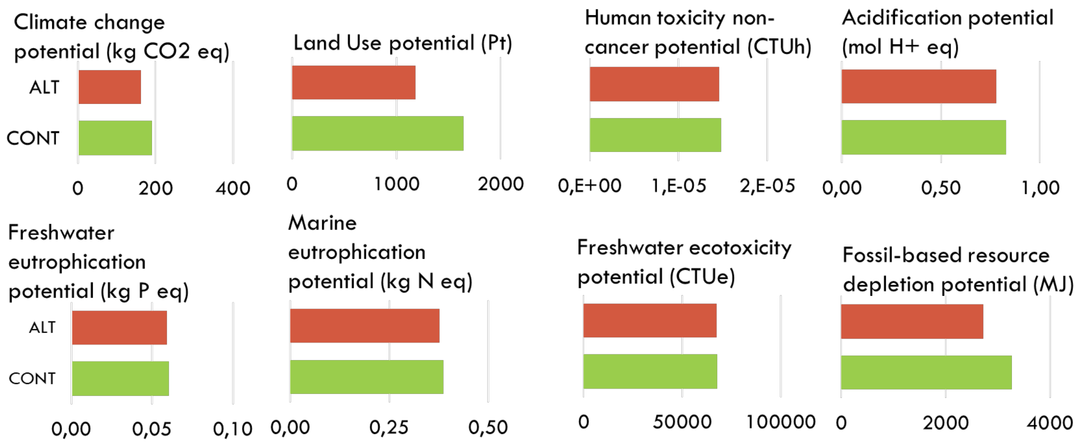


Figure 19. LCA results comparing compost growing substrate (ALT) with peat (CONT) in a Spanish tomato production scenario

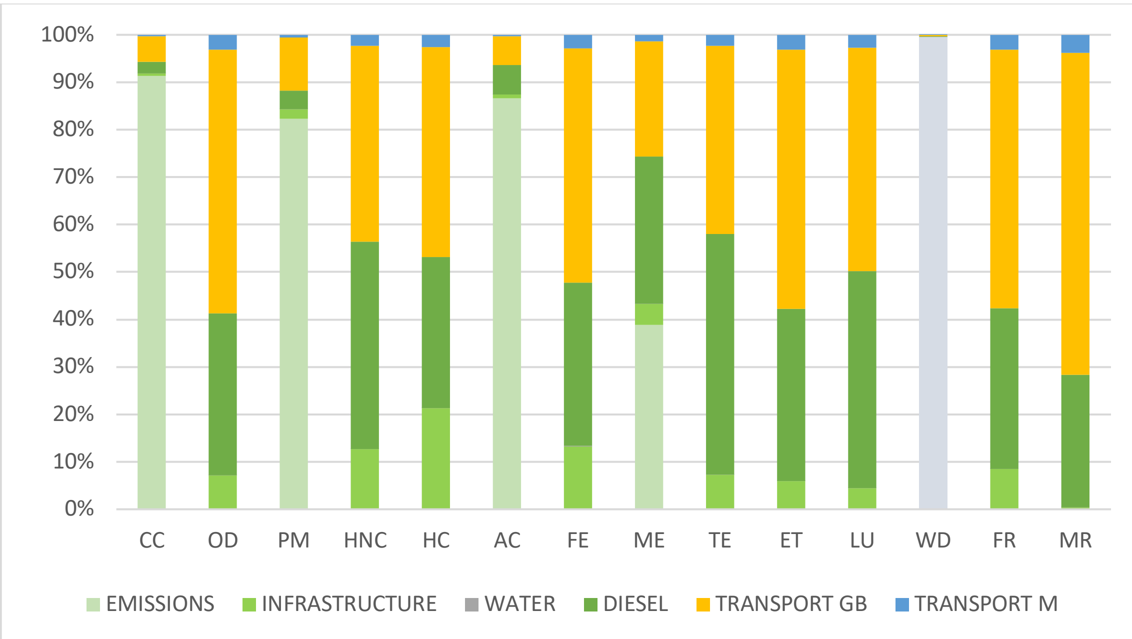


Figure 20. Contribution of different processes in the life cycle of compost substrate (combination of horse manure and forest residue) relative to the total impacts in each category, from cradle-to-grave.

A critical aspect during the assessment of new alternatives was the estimation of the emissions. Composting is a biological process with high variability in emissions, influenced by the applied substrates, physical infrastructure and management method, weather conditions etc. Thus, emissions during operation have been estimated using general default factors determined as general for any type of composting material, which is a very coarse assessment. The official emission (OE_{ref}) factors from the Ministry of Ecological transition (MITECO) in the Spanish system of Emission Inventory were used. To test the sensitivity of these emission factors, a sensitivity assessment for CH_4 and N_2O emissions were conducted, testing a reduction of 10% ($OE_{0.1}$) and 50% ($OE_{0.5}$) in accordance to experimental measurements and the optimum (possible) scenario without emissions (OE_{00}).Table 21 provides emission calculations for each OE and corresponding effects on climate change impact category.

The results show that for the $OE_{0.1}$ scenario the impact can be reduced by 68% and 38% for $OE_{0.5}$ when compared to the reference OE. Therefore, both the emission factors applied and the experimental measurements conducted at the compost plant are quite influential in terms of LCA results and indicates that emission measurements should be recommended for future research, in order to more accurately adjust the factors used in the models.

Table 21. Sensitivity assessment conducted to test influence in climate change impact

	OE_{ref}	OE_{00}	$OE_{0.1}$	$OE_{0.5}$	Units
CH_4	16.43	0	1.64	8.22	Kg/ m^3
N_2O	0.99	0	0.10	0.49	Kg/ m^3
Climate change Impact*	1190.8	293.0	382.7	741.9	kg CO_2eq

*Note: results of climate change impact include all the processes involved in the composting activity

4.5 Fossil-based Plastic

Fossil-based (Low-Density Poly Ethylene) plastic mulching was one of the contentious inputs considered in WP5 SOIL, due to its derivation from non-renewable fossil fuels and the terrestrial plastic pollution left on farmland. Partners at the Częstochowa University of Technology in Poland studied a possible bioplastic alternative made of compostable potato starch-based film. The characteristics of the bioplastic mulch and the LDPE can be found in Tables 22 and 23, respectively.

Table 22. Characteristics of the potato starch-based bioplastic mulch film used in this study (Częstochowa University of Technology).

Characteristic	Film
Thickness (microns)	25
Density of Bioplast (g/cm^3)	1.24
Film mass per 10000 m^2 of film (kg)	310
Film mass per ha of land covered with film (kg/1 ha covered)	186
Composition (Two types of layers: A & B)	
Mass of layer A: Bioplast 400 Elit (Thermoplastic starch-based polymer, TPS) (kg/1 ha covered)	119.0
Mass of layer B:	
Bioplast 400D (kg/1 ha covered)	174.9
Carbon black colouring (kg/1 ha covered)	3.6

Table 23. Characteristics of the LDPE-based plastic mulch film used in this study (Nessi et al., 2020).

Characteristic	Film
Thickness (microns)	35

Density (g/cm³)	0.925
Film mass per 10000 m² of film (kg)	323.75
Film mass per ha of land covered with film (kg)	194.25

An LCA was performed comparing the environmental performance of the contentious LDPE-based plastic mulch to the bioplastic mulch, where the complete results can be found in the Excel file in the Annex. To perform an LCA, the following specifications were used for each of the LCA phases, following guidance and default values for plastic and bioplastic LCAs in a European Commission report by Nessi et al. (2020).

In order to observe the performance of each in application, both films were applied in the Spanish tomato production case study as mulching for this LCA.

The results are shown in Figure 22. which illustrate that there is no clear "winner" in terms of environmental performance, where the alternative scenario (ALT) performs better in land use, ozone depletion, and fossil-based resource depletion, but may perform worse or similar to the contentious scenario (CONT) in climate change, acidification, eutrophication, and freshwater ecotoxicity.

An important parameter that can influence results was the thickness of the bioplastic. Partners at the Częstochowa University of Technology, produced film of 40µm or 25µm thickness in which we used the 25µm in this assessment, whereas fossil-based plastic mulching is usually 12 µm, so if the thickness was reduced, the impacts could be reduced.

A hotspot in bioplastic production was the manufacturing of the starch feedstock, especially potato production, from which the starch is extracted. We found that potato production contributes across all categories in bioplastic production, due to mineral fertiliser use. If potatoes came from organic farms, or if the starch was sourced from potato processing waste flows, this impact could change.

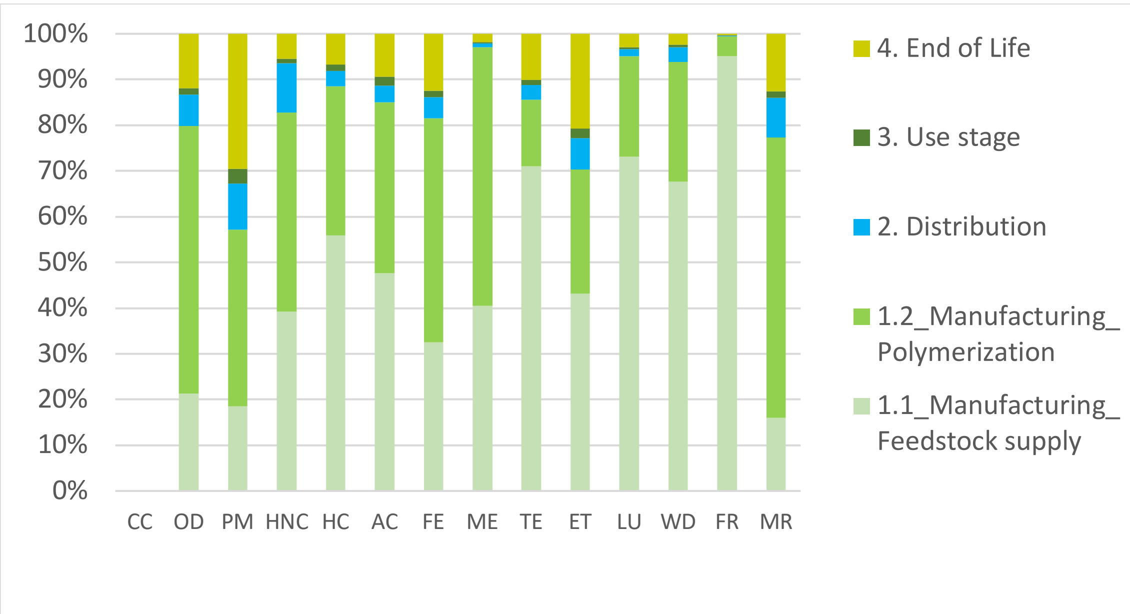


Figure 21. Contribution of different processes in the life cycle of potato starch-based bioplastic film relative to the total impacts in each environmental category, from cradle-to-grave.

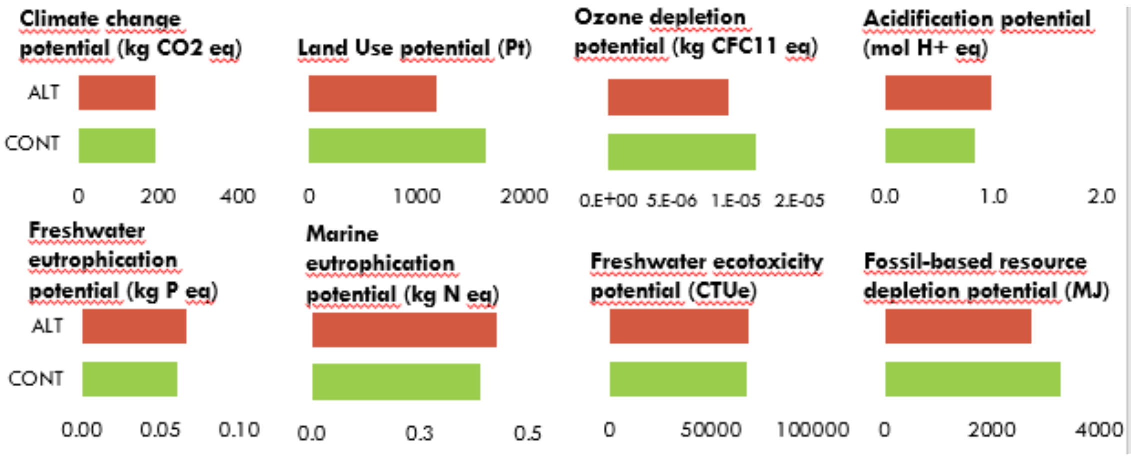


Figure 22. LCA results comparing LDPE-based plastic mulching (CONT) and starch-based bioplastic mulching (ALT) in Spanish tomato production.

To aid decisions on which system (contentious or alternative) can perform better, we normalised the results per EU-capita and weighed the categories by importance using weighting factors from the EF methodology (see section 2). We found that the alternative and contentious scenarios were along the same magnitude, with the alternative scenario being slightly lower (Figure 23).

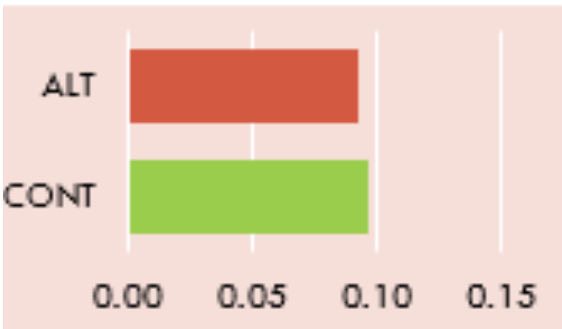


Figure 23. Normalised and weighted results in points (Pt) of the alternative (ALT) bioplastic mulching and contentious (CONT) fossil fuel-based plastics scenarios, in Spanish tomato production.

Main limitations identified in the assessment are in relation secondary datasets used (see section 5.1) and that impacts related to microplastics and general terrestrial plastic pollution (e.g. impacts on human toxicity, ecotoxicity, ecosystem services) are not yet modelled in LCA, thus not included.

5 RESULTS AND DISCUSSION (ADVANCEMENTS)

5.1 Datasets Review

Through an analysis of state-of-the-art organic crop life cycle inventories (LCIs) from current and recommended LCA databases, ecoinvent and AGRIBALYSE, and primary data from Organic-PLUS farm/trial sites, critical aspects of the LCIs were identified, and suggestions for improvement were made.

The main critical aspects found within the LCIs of organic crop and livestock products include the lack of manufacturing datasets for inputs used in organic production systems such as several common plant protection products (PPPs) and alternative animal welfare products (e.g., antimicrobial essential oils). There are no available manufacturing datasets for biological control agents (BCAs), plant-derived essential oils (thymol, carvacrol, neem), mineral oil, pyrethrin, Spinosad and copper oxychloride. Thus, impacts regarding their manufacturing would be excluded from any assessment that uses these databases. Only the electricity required for manufacturing for one biological control agent, Trichogramma, has been accounted for in Ecoinvent crops in terms of its production. Due to this gap, some organic crop LCIs such as in Agribalyse applied a general rule to use the “pesticide, unspecified” background dataset from EC as a proxy for unavailable PPP manufacturing datasets(Koch and Salou, 2016). This “pesticide, unspecified” manufacturing dataset represents a European average of all 78 synthetic PPPs, which are not authorised in European OA regulations, such as glyphosate (European Commission, 2008), hence indirectly including impacts from synthetic PPP manufacturing. This proxy could be improved by creating an OA version that averages all organic-authorised PPPs used in Europe, and would be an important item for further research.

To advance in this aspect, new manufacturing LCI datasets for prevalent PPPs used in OA in Europe were developed in the frame of Organic-PLUS project (Spinosad, Bacillus subtilis, Chitosan and Neem oil, specific LCIs can be found in Montemayor et al. (a, in preparation.

For livestock, there is a lack of manufacturing datasets for natural vitamin, antibiotic and antiparasitic sources. In the wider Organic-PLUS project, olive pomace, seaweed (A*scophyllum nodosum*), aromatherapy and good pasture and livestock management were studied. Olive pomace and *Ascophyllum nodosum* can be used as a natural source of vitamins E and C and polyphenol antioxidants, for organic livestock such as poultry. Since pomace is considered as a coproduct of oil production, an economic allocation factor from ecoinvent was used to assign impacts (1.73 €/kg for virgin oil and 0.01 €/kg for pomace). Aromatherapy only works in conjunction with good pasture and livestock management, thus the manufacturing processes and new managements practices should be accounted for, as well as the corresponding effect on the yield and, more importantly, quality of the yield.

Another relevant aspect is the complexity of accounting for the balance between heavy metals inputs into soil (seeds, fertilisers, pesticides and deposition) and outputs from the soil (exported biomass, leaching and erosion), the SALCA-heavy metal soil emission methodology (Prasuhn, 2006) is usually applied. However, the default uptake values are based on average heavy metals contents of specific crops and specific fertiliser types for France or Switzerland, thus a fertiliser with different heavy metals content or crops with different residue content could result in very different emission results. Due to the importance of a correct accounting of heavy metals emissions mainly for organic fertilisers, this has been an aspect not covered in the current assessment.

5.2 Detection of other contentious inputs

Life cycle assessment is an excellent tool for analysing the hotspots within the life cycle of a product, provided that all relevant processes affecting the environment are reliably described with measurable data. If the data which are usually measured for industrial products (e.g. cars) are also measured for agricultural products, but variability and complexity of agriculture makes LCA studies more challenged. In our case studies, the life cycle starts at the cradle to the farm gate. Thus, hotspots, other than the ones contentious inputs focused on in the Organic-PLUS project, have arisen through this assessment. Table 24 lists all the hotspots found through a contribution analysis of aggregated processes (e.g. Machinery use is a process made up of diesel production, diesel combustion and machinery production) to the total impact in the cradle-to-gate life cycle of each organic crop or livestock product.

Table 24. Summary of hotspots found through the environmental life cycle assessment for each case study.

WP	Scenario	Other contentious inputs	Results
WP3 - Plants	Tomato, Spain	• Greenhouse structure – steel	Figure 5
	Aubergine, Turkey	• Greenhouse structure – steel • Fertiliser application emissions – N_2O, NH_3. NO_3^- • Electricity use - irrigation	Figure 7
	Citrus, Sicily	• Machinery • Plastic crate for harvesting • Fertiliser application emissions – NO3-	Figure 9
	Olives, Greece	• Mineral fertiliser • Synthetic PPPs	Figure 11
WP4 - Animals	Pork, Denmark	• Diesel consumption related to transport to slaughterhouse • Field emissions • Electricity consumption • Soy, corn, barley and oat feed	Figure 13
	Poultry, Poland	• Machinery use • Diesel combustion • Electricity – farm management • Pasture	Figure 15
	Sheep, Norway	• Fertiliser application emissions – NH_3. NO_3 • Feed compounds	Figure 17
WP5 - Soil	Substrate/fertiliser – compost from forest residue and horse manure	• Diesel consumption at compost plant • Transport of forest residues • Emissions from composting	Figure 20
	Mulch – potato starch-based bioplastic film	• Potato cultivation (mineral fertiliser use) • Energy use from polymerization stage (starch production and film extrusion)	Figure 21

5.3 Dealing with Toxicity Assessment

For the PPPs used in organic agriculture, only the sulphur and copper-based PPPs had available characterisation factors for their human toxicity and freshwater ecotoxicity. Many of the other widely used?? PPPs in OA, such as biological control agents (BCAs) and plant-derived oils, do not have the characterisation factors (CFs) required to estimate toxicity impacts using the USETox model (Fantke et al., 2017; a UNEP-SETAC recommended model for LCA). Thus, impacts regarding their on-field application emissions would be excluded from any assessment, such as the assessments completed in this study. In other words, the modelling of these types of PPPs in LCA is limited only to background manufacturing processes (or not at all in the case of those PPPs without manufacturing LCIs), leaving foreground processes out of scope. In fact, there are 25 inorganic compounds (e.g. copper oxychloride); 16 BCAs (e.g. Bacillus thuringiensis, Trichoderma); four microorganism-derived PPPs (e.g. Spinosad, emamectin); seven plant-derived PPPs (e.g. azadirachtin, thyme oil); five metabolites (e.g. phosphonates); seven mineral oils (e.g. petroleum oil, paraffin); and 19 other PPPs (e.g. kaolin, chitosan, manganese) considered as important and relevant to OA that are either lacking CFs or current CFs are immature (Peña et al., 2019; a deliverable from the Operationalizing Life Cycle Assessment of Pesticides Taskforce, OLCA-Pest, on consensus building for pesticide effects in LCA). This taskforce is currently working towards creating CFs for the listed PPPs and is regarded as an important future research topic.

Nevertheless, BCAs, for example, are usually applied in smaller amounts compared to other PPPs, thus may have little contribution to impacts. Nonetheless, studies have found that entomopathogenic bacteria (e.g. Bacillus thuringiensis), fungi (e.g. Beauveria bassiana sensulato) and nematodes (e.g. Rhabdtitida), have very limited effects on human health and the environment, as they are targeted towards specific pests, thus are promising alternatives to chemical PPPs (Callaghan and Brownbridge, 2009; Lacey et al., 2015).

5.4 Including Biodiversity Indicators

Biodiversity is important not only because of its intrinsic value, but also in the provision of ecosystem services. Therefore, in order to conserve biodiversity, land management practices must be conducted in more sustainable ways. Agricultural practices such as nutrient input, pesticide use, field operations and field cover, are closely linked with soil quality and biodiversity.

In terms of biodiversity, OA systems have demonstrated higher species richness at field level than their conventional counterparts (Bengtsson et al., 2005; Hole et al., 2005). More recent analyses of species richness and abundance illustrated significant positive effects of OA at the field scale, but to a much lower extent when expanded to farm scale (Nascimbene et al., 2012; Schneider et al., 2014). Nevertheless, negative effects of high pesticide applications and mineral fertilization on species richness and abundance, and positive effects of hedges and other unproductive habitats, were widespread (Lüscher et al., 2017). Furthermore, a review of 94 studies concluded that OA increases species richness at field level by ~30% compared to conventional, where the result has been consistent over the last 30 years of peer-reviewed studies (Tuck et al., 2014).

As it has been said, LCA is able to capture the complexity of agricultural systems due to its comprehensive scope and large amount of data availability in databases. However, no impact categories for biodiversity are present due to lack of consensus on an agreed methodology. Biodiversity was found to be one of the most important and distinguishing indicators between organic and conventional systems in LCA (van der Werf et al., 2020) thus, this aspect was addressed in Organic-PLUS. Recent developments made by the UNEP-SETAC Task force resulted in the recommendation of global characterisation factors (Chaudhary and Brooks, 2018). This model calculates land use intensity-specific global characterisation factors for biodiversity damage potential (BDP) for five broad land use types (managed forests, plantations, pasture, cropland, urban) under three intensity levels (minimal, light, and intense use) in each of the 804 terrestrial eco-regions. This method is excellent for high-level hotspot analysis at the ecoregion level. However, it cannot distinguish between organic and conventional land use practices, and lumps together all types of land use classes into one "cropland" or "pasture" class, and, hence, do not reflect the real impact of the activities assessed. The aggregation of land use classes into broad classes is often a consequence of using models that rely on secondary data sources. Therefore, it is essential to use characterisation factors that can distinguish between farming practices when performing LCA's of OA products, but would require much more data.

Currently, only five biodiversity LCIA models can distinguish between organic and conventional agriculture (Jeanneret et al., 2014; Knudsen et al., 2017; Koellner and Scholz, 2008; Mueller et al., 2014; Schryver and Goedkoop, 2010).

The model proposed by De Schryver et al. (2010) estimates the relative change in plant species richness for land occupation compared with a reference situation - the semi-natural woodland that would occur without human interference. The limitations of this model include its geographical coverage (specific to the UK) and the use of field edges of intensive farms as a proxy for organic arable areas, and field centres as conventional areas.

Jeanneret et al. (2014) does not provide specific CFs for OA, but can account for differences between relevant land use practices such as intensive or extensive pesticide and fertilization use. However, this model is only valid for arable and grassland systems in Switzerland and surrounding regions.

Mueller et al. (2014), Koellner and Scholz (2008) and Knudsen et al. (2017) were the only other studies found that provided CFs that distinguish between organic and conventional agriculture and are valid over a larger biome. A limitation of the first two afore mentioned models is the use of secondary data from different studies, which use different sampling methods. Robust and reliable CFs should be validated against or better yet, based on field data and national case studies (Souza et al. 2015). Knudsen et al. (2017) filled this gap by developing CFs for organic and conventional agricultural production, based on standardised sampling of plant species richness in organic and conventional farms across six countries in Europe within the temperate broadleaf and mixed forest biome and hence, would be a well recommended method for calculating plant biodiversity impacts for OA in that biome. The data covered Austria, Germany, Switzerland, France, Hungary and Wales. Characterisation factors were developed for arable crops, mixed pastures, grass-dominated pastures and hedges using vascular plants as a proxy for biodiversity. The six case study areas provide a good representation of variations in the biome in

CFs for the Mediterranean biome using the methods described in Knudsen et al. (2017) and secondary plant richness data from organic farms in Spain, Italy, France and Greece, for common Mediterranean crops such as grapes, olives and arable crops (Montemayor et al. (b, in prep.).

The potential disappeared fraction of species richness under the specific land use compared to a reference situation, in other words, Biodiversity Damage Potential (BDP) can be calculated by multiplying the characterisation factor for land occupation (CF) by the affected area (A) and the time (t) (Koellner et al., 2013b):

$$BDP = CF \times t \times A \qquad \text{Eq. 5}$$

To calculate a land occupation CF for potential disappeared fraction of species using the model by Knudsen et al. (2017), equation 3 was used

$$CF = 1 - \left(\frac{Si}{S_{baseline}} \times \frac{A_{baseline}^{z}}{A_{i}^{z}} \right) \qquad \text{Eq. 6}$$

where

S_i: species number in sampling plot *i*

$S_{baseline}$: species number in the baseline semi-natural woodland that was present on site

A_i: area of plot size

$A_{baseline}$: area of semi-natural woodland that was present on site

z: species accumulation factor, assumed to be 0.25 (Schryver and Goedkoop, 2010)

The occupation CF was calculated for every sampling plot in every country. If the CF = 1. this would mean a total 100% loss of habitat value for biodiversity (Knudsen et al., 2017).

The strength of the Knudsen et al. (2017) model is that the same standardised sampling method was used across several European countries, which is not the case for De Schryver et al. (2010) and Mueller et al. (2014). However, this would be a downfall for the CFs developed for the Mediterranean biome; secondary datasets were used from different studies, which used different sampling methods. The exception would be the data gathered from Luscher et al. (2016), where the sampling method used was the same as in Knudsen et al. (2017), due to both participating in the same European Commission project BioBio (www.biobio-indicator.org) (more detailed CFs per study can be found in Montemayor et al. (in prep.).

Additionally, one must be aware that these are midpoint CFs that address occupation land use impacts on biodiversity in LCA, as opposed to biodiversity loss due to other pathways like air pollution. If carrying out an LCA to the endpoint level, double-counting of biodiversity loss may occur if using models that have overlapping pathways with non-additive results.

Habitat heterogeneity at the landscape level can also play a role in the species richness at field and farm level according to Island Biogeography (Simberloff and Abele, 1976) and Metapopulation Dynamics (Hanski, 1991). The representation of the land area under a certain land use type (e.g. organic farming) in the wider landscape can affect can affect the species richness in each study plot. Thus, the biodiversity potential of OA may not be fully achieved in a landscape of mainly conventionally managed farmland. To overcome this limitation, Knudsen et al. (2017) suggest to update the baseline plant data if there was a significant change in the proportion of different land use types.

6. FURTHER RESEARCH NEEDS

As it was stated in the introduction, the environmental assessment of not only alternative inputs and contentious inputs, but also conducted in the frame of organic production systems following life cycle assessment methodology, has presented several challenges. Task 6.3 has meant a significant advance in the detection of potential shortcomings and also in the improvement of some solutions. By the certainty that development of LCA tools will go on, following points have been identified as potential aspects for further research beyond Organic plus project:

- Implementation of specific organic production datasets through local databases, which can catch the variability of products and production systems.
- Improvement of emissions factors related to organic residue treatments (i.e. composting, anaerobic digestion, etc)
- Accounting for biological pest control technologies (all methods of plant protection using natural mechanisms): Organic "natural" compounds, new upcoming application technologies, dissemination and effects of "natural enemies", etc.
- Implementing new models to deal with the issues of formulation (adjuvants and surfactants, nanoparticles, etc.) and potential metabolites
- Better adjustment of emissions modelling and characterisation factors for toxicity of inorganic compounds (metals, sulphur, etc.)
- Enhancing LCIA through biodiversity and ecosystem services indicator models to include different agronomic and livestock practices.
- Development of more precise soil quality indicators.
- Inclusion of antimicrobial resistance indicator.
- Extension of assessment to processing, logistics and use phases

7. CONCLUSIONS

Through the environmental assessment conducted in task 6.3 we can conclude that:

1) From a holistic environmental perspective, it can be stated that various organic productions (tomato, citrus, aubergine, pork, poultry and sheep) possess different "hot-spots" where environmental effects which are accounted by current LCA methodology become evident. E.g. for organic tomato production, this is the greenhouse structure. Fossil fuel-based energy consumption such as diesel for labour/machine operations, electricity consumption, transport, and water consumption, in particular for Mediterranean regions, are other areas of concern.

2) When alternatives to contentious inputs developed and studied in the Organic-PLUS project were considered, e.g. compost for peat in growing media, degradable plastic from potato starch for covering of soil, these products presented an improvement for some environmental aspects, but showed a worse behaviour for others. From the revealed "hot-spots", it can be derived where efforts can be put if the goal is to develop alternatives which score better in LCA.

3) LCA methodology may be useful to assess environmental effects of agricultural production, but requires more development to better grasp particularities of organic production systems.

4) The present publication includes and adaptable calculation forms (implemented in a spreadsheet programme e.g. Microsoft Excel), which can allow for updating and creation of new scenarios.

5) Several proposals to improve datasets have been presented.

6) We have contributed to the development of characterisation factors for biodiversity indicators following the work initiated by Knudsen et al (2017).

7) Proposals for further research to improve the environmental assessment of organic production systems were made, emphasising that the current dominating impact categories are not well suited to discriminate between various farming practices.

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ANNEX A. Case Study Scenarios spreadsheet (Excel) files

Case study scenarios excel files can be consulted at Organic Plus website under Deliverable 6.3 Folder

There are 7 excel files:

- LCA Olive Crop, Greece. xls
- LCA Tomato, Spain. xls
- LCA Aubergine, Turkey. xls
- LCA Citrus, Italy. xls
- LCA Pork, Denmark. xls
- LCA Sheep, Norway. xls
- LCA Poultry, Poland. xls

ANNEX B. Alternatives suggested and scored in WP3. WP4 and WP5

Organic-PLUS: Survey conducted among partners of WP3, WP4 and WP5 about alternatives tested in each WP and efficacy score.

WP3 Plants

Alternative	Test crop	Against what pest?	Efficacy score[3] (Please check our score)	Country & Partner
Fertilisers with low or no-copper content (**Vitibiosap** 458 Plus, Kiram, Kiram AT, Kiram Film, **Dentamet**), essential oils (**Prev-am based on citrus oil** plus, 18 **essential oils**[4] locally produced), vegetable extracts (***Cynara cardunculus*** leaf extracts), plant defence stimulators (**Bion**, Chitosan), and biological control agents (**Amilo-X**, **Botector**, ***W. anomalus*** BS91, *Bacillus spp.* LIS1	in vitro	Fungi: C. gloeosporioides; A. alternata; P. digitatum Bacteria: P. *syringae; X. euvesicatoria* pv. *perforans*	Those alternatives in **bold** were effective against **fungi**, those underlined were effective against bacteria.	Italy, UNICT
Ozonated H2O		Copper, mineral oil	0 – no yield changes thus not recommended	Norway, NORSOK
Landraces (65 resistant varieties)	Aubergine	Alternaria solani	3 – high resistance and tolerance. High genetic diversity of aubergine can pave the way for resistant variety strategies.	Turkey, Dr. Alev Kir
BCAs and PDS: Mycorrhizae spore mix, Bacillis subtilis E007, vermicompost tea, maxicrop seaweed, Trichoderma citrinoviride, K2SiO3, Compost enriched w/ platanus orientalis, Mouldy bread mixed into soil.	Olives, in growth chamber and open field trials	Spilocaea oleagina	They need to re-conduct this experiment. Not enough disease incidence to conduct proper trials. Expected June 2020	Turkey, Dr. Alev Kir
Package of autumn applied lime sulphur (5%), spring applied biostimulants Ca+Si+kelp extract+amino acids and summer applied zeolite (all applied foliar)	Olive trees And in vitro	Spilocaea olegina, Venturia oleagina fungi In vitro: C. gloeosporiodes, A. alternata, X. perforans, P. syringae	Seemed to reduce disease damage but had no effect on tree physiology and fruit quality. Same experiment will be done in 2020, with the addition of soil applications of humic/fulvic acids to invigorate the soil beneath the olive trees.	Greece, UTH

Alternative	Test crop	Against what pest?	Efficacy score [3] (Please check our score)	Country & Partner
Copper gluconic (5%), Acacia extract, Silicon, Cinnamon, Equisetum, chitosan, KHCO3, Lime sulphur, Fertiliser zinc (6%), plant stimulators	In vitro	*Botrytis cinerea* *Collectotrichum gloeosporioides*	Cinnamon (2), KHCO3 (3), Copper gluconic (5%) (2) - all performed better or similar than Copper oxychloride (50%)	IFAPA Spain
Plant defence stimulator (PDS): *P. infestans* culture filtrate, CCF (There are 2 published papers)	Potato	Range of P. infestans strains	Works best on fast-growing strains when applied 48h before risk periods	INRA, France
Neem oil/Azadirachtin	In Organic-PLUS Neem is not tested as already widely studied and used, however LCA on it would be beneficial.			

[1]This could include lab-scale manufacturing (e.g. some partners are manufacturing their own fertilisers or substrates) or lab/pilot scale application. If you answer Yes, we will follow up with you later to find out more detailed information (with a much shorter, more streamlined questionnaire than before).

[2]In the case of resistant varieties, the questions would be: 1) do you have information on how the farm operations would change, Yes or No (e.g. less/more machinery operations, yield, other inputs that may be different from normal varieties, etc). 2) Do you have information on how the seedlings of these varieties made? e.g. in a greenhouse? Yes or No. If you answer Yes, we will follow up with you later to find out more detailed information (with a shorter, more streamlined questionnaire than before).

[3]We have provided a score for efficacy based on what we read in the deliverables or learnt during the Annual Meeting, but please WP3/4/5 experts confirm or correct according your experience, with scores being:

0: it does not work
1: Not enough evidence
2: Good alternative tested in vitro and
3: Good alternative tested on field

[4] O. vulgare, T. vulgaris, C. zeylanicum, O. basilicum, M. alternifolia, L. officinalis, P. cablin, T. occidentalis, C. bergamia and C. reticulata were identified to have the most efficient antifungal activity against both fungi (0.5 and 0.25%). O. vulgare, T. vulgaris, C. zeylanicum and M. alternifolia were identified to have the most efficient antibacterial activity against both bacteria. EOs were here tested at four different concentrations of 25, 17.5%, 10% and 5%.

WP4 LIVESTOCK

Alternative	Contentious input to be substituted	Do you have information on how it is applied to animals? [1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Do you have information on how it is manufactured? [1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Efficacy score [3] (Please check our score)	Contact person (email)
Grape pomace (Raisinox (R) 80Q)	Vitamins (E, C) and antioxidant	No: Experimental trial that will be conducted (September 2020??), we will have information regarding broilers' performance. Yes: animals' performance based on literature review (paper that is being prepared).	Commercial product Raisinox (R) 80Q - Aqueous extract of seeds, pulp and grape skin from Vitis Vinifera; rich in polyphenols; can be used in organic livestock	2	federico.righi@unipr.it massimo.demarchi@unipd.it carmenloreto.manuelianfuste@unipd.it
Ascophyllus nodosus	Vitamins and antioxidants	No: Experimental trial that will be conducted (September 2020??), we will have information regarding broilers' performance. Yes: animals' performance based on literature (https://www.sciencedirect.com/science/article/abs/pii/S0960308518306278; https://www.longdom.org/open-access/the-seaweed-ascophyllum-nodosum-as-a-potential-functional-ingredientin-chicken-nutrition-2167-0331-1000140.pdf; https://www.tandfonline.com/doi/full/10.1080/1828051X.2019.1703563; https://www.tandfonline.com/doi/full/10.4081/ijas.2012.e31).	No: Commercial product https://www.feedproteinvision.com/wp-content/uploads/2018/03/Day-1-Marinus-van-Krimpen.pdf	2	federico.righi@unipr.it massimo.demarchi@unipd.it carmenloreto.manuelianfuste@unipd.it
Aromatherapy	Antibiotic, antiparasitic, other allopathic treatment	Yes : testimony + bibliography = surveys carried out by ABioDoc (dissemination of future testimonials) + ABioDoc biographic lists This only works in conjunction with good pasture and livestock management.	No	3	Heliose & Sophie (VetAgro Sup, France)

Alternative	Contentious input to be substituted	Do you have information on how it is applied to animals? [1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Do you have information on how it is manufactured? [1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Efficacy score [3] (Please check our score)	Contact person (email)
Pasture management	Antiparasitic	Yes : testimony + bibliography = surveys carried out by ABioDoc (dissemination of future testimonials) + ABioDoc biographic lists	Yes	4	Heliose & Sophie (VetAgro Sup, France)
Livestock Management	Antibiotic, antiparasitic, other allopathic treatment	Yes : testimony + bibliography = surveys carried out by ABioDoc (dissemination of future testimonials) + ABioDoc biographic lists	Yes	4	Heliose & Sophie (VetAgro Sup, France)

[1]This could include lab-scale manufacturing (e.g. some partners are manufacturing their own fertilisers or substrates) or lab/pilot scale application. If you answer Yes, we will follow up with you later to find out more detailed information (with a much shorter, more streamlined questionnaire than before).

[2]In the case of resistant varieties, the questions would be: 1) do you have information on how the farm operations would change, Yes or No (e.g. less/more machinery operations, yield, other inputs that may be different from normal varieties, etc). 2) Do you have information on how the seedlings of these varieties made? e.g. in a greenhouse? Yes or No. If you answer Yes, we will follow up with you later to find out more detailed information (with a shorter, more streamlined questionnaire than before).

[3]We have provided a score for efficacy based on what we read in the deliverables or learnt during the Annual Meeting, but please WP3/4/5 experts confirm or correct according your experience being

0: it does not work
1: Not enough evidence
2: Good alternative tested in vitro and
3: Good alternative tested on field

WP5 SOIL

Alternative	Tested on what crop?	Do you have information on how it is applied to crops?[1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Do you have information on how it is manufactured?[1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Efficacy score[3] (Please check our score)	Contact person (email)
Fertiliser alternatives: Waste-derived Horn grit	Early cabbage, then spinach, winter wheat rotation	Yes	Yes	3 – increased yield	Sabine Zikeli, UoH (sabine.zikeli@uni-hohenheim.de)
Fertiliser alternatives: Clover + pig slurry Digestate	Cabbage, spinach, wheat rotation	Yes	yes	3 – good results, but not better than horn grit	Sabine Zikeli, UoH (sabine.zikeli@uni-hohenheim.de)
Fertiliser alternatives: Tofu whey	Cabbage, spinach, wheat rotation	Yes	No (but secondary data available from ecoinvent)	2 – worst of the 3 above	Sabine Zikeli, UoH (sabine.zikeli@uni-hohenheim.de)
Fertiliser alternatives: Digested food waste Pig Slurry	¿	Yes	Yes	2	Denmark (L&F, SEGES)
Fertiliser alternatives: Fish bones Seaweed Fish+algae	Oat, grass, clover mix yield	Yes	No	Fish bones: increased yield, better than fish bones+algae	Norway, NORSOK (Anne-Kristine)
Vegan fertiliser (e.g. Comfrey juice)	No tests done yet due to COVID-19			-	Coventry University

Alternative	Tested on what crop?	Do you have information on how it is applied to crops?[1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Do you have information on how it is manufactured?[1] (Yes/No, if yes, please specify if it is lab scale, commercial scale or literature-based info.)	Efficacy score[3] (Please check our score)	Contact person (email)
Peat alt: Compost (e.g. Horse manure+ pruning waste)		Yes – LCA completed	**Yes – LCA completed**	2	Rafaela Caceres (Rafaela.Caceres@irta.cat)
Peat alt: Composted woodchips		Yes	**Yes**	1	Rafaela Caceres (Rafaela.Caceres@irta.cat)
Peat alt: Composted leaves		Yes	**Yes**	2	Rafaela Caceres (Rafaela.Caceres@irta.cat)
Mulch plastic alt: Bioplastics (PLA)	Tomato	Yes – LCA completed	**Yes – LCA completed**	3	Krystyna Malińska (krystyna.malinska@pcz.pl)
Mulch plastic alt: Crushed woody plants + straw / hay	Plastic	Yes : testimony + bibliography = surveys carried out by ABioDoc (dissemination of future testimonials) + ABioDoc biographic lists	**Yes : testimony**	3	Heliose & Sophie (VetAgro Sup, France)
Peat alt: Green waste compost	Peat	Yes : testimony + bibliography = surveys carried out by ABioDoc (dissemination of future testimonials) + ABioDoc biographic lists	**Yes : testimony**	3	Heliose & Sophie (France)
Coconut substrate		YES	**DATA from ecoinvent**	3	Rafaela Caceres (Rafaela.Caceres@irta.cat)

[1]This could include lab-scale manufacturing (e.g. some partners are manufacturing their own fertilisers or substrates) or lab/pilot scale application. If you answer Yes, we will follow up with you later to find out more detailed information (with a shorter, more streamlined questionnaire than before).

[2]In the case of resistant varieties, the questions would be: **1)** do you have information on how the farm operations would change, Yes or No (e.g. less/more machinery operations, yield, other inputs/outputs that may be different from normal varieties, etc). **2)** Do you have information on how the seedlings of these varieties made? e.g. in a greenhouse? Yes or No. If you answer Yes, we will follow up with you later to find out more detailed information (with a shorter, more streamlined questionnaire than before).

[3]We have provided a score for efficacy based on what we read in the deliverables or learnt during the Annual Meeting, but please WP3/4/5 experts confirm or correct according your experience being

0: it does not work , 1: Not enough evidence, 2: Good alternative tested in vitro, 3: Good alternative tested on field