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

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Validity of sustainability assessment report (Part A: RISE, Part B: LCA)

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Content

1 Validity of sustainability assessment report – Part A: sensitivity and validity of RISE

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1.1 Abstract

The Response Inducing Sustainability Evaluation (RISE) tool was designed to give input to farm management after data evaluation. Validity of the RISE tool was tested by changing the input data used for the computation of dedicated indicators and calculating the change in scores for these indicators and the themes they belong to. This was done by using the RISE tool and designing 9 scenarios for 5 case farms (all dairy farms).

Changing the farm data input for some parameters used in the computation of the indicators by as much as 10%, changed the score of these indicators in a contrasting manner. For four of the indicators, the scores were lower than 10%, and for two other indicators the scores were higher than 10%.

These differences make it difficult to rely on the scores to check if the farm management improvements have increased the sustainability of the farm.

1.2 Introduction

Part of the sustainability reporting used in the Organic-PLUS project, was based on the RISE (Response Inducing Sustainability Evaluation) methodology, which is described in Deliverable 6.4: *Sustainability assessment report of case farms working with alternatives to contentious inputs* (Oudshoorn & Husted, 2021). The RISE method is used as an advisory tool for farmers who often actively want to improve their performance, if incentivised. Presentation of the results, visually and comprehensibly, and the possibility to show improvements, is essential.

RISE computes 10 main theme scores, which are based on the computation of scores from the indicators comprised in each theme. The scores can be from 0-100 points, referring to low performance (0-33 - red), medium performance (34-67 - yellow) and good performance (68-100 - green). It is possible in RISE to score more than 100 points, if the farm exceeds levels set as 100 points for certain thresholds. The scores are then always noted as 100%. These indicators themselves are again the product of many computations of parameters and sub indicators based on farm data. For a farmer or his/her advisor to understand progress in the improvements made (farm data), it is important that these improvements have an impact on the score.

Therefore, in this report, the objective is to discuss the sensitivity of the RISE tool for showing changes in farms results. The validity of the score itself, concluding if a farm is sustainable or not, is of lesser importance, as the tool is mainly used for benchmarking to previous years or when farms in the same sector and in the same country are compared (De Olde et al., 2016).

1.3 Methodology

To implement a sensitivity analysis in a tool which combines farm business data, general farm information, regional and generic thresholds, and regional data, a choice was made on which indicator the sensitivity test should be implemented.
The following criteria were used:

1. The indicator should primarily be determined by farm data, preferably available from databases
2. The indicator should be essential for a farm's sustainability (production, climate, environmental burden, biodiversity)

The following farm indicators were selected:

Theme: Soil use
- Indicator Crop productivity
- Indicator Soil reaction

Theme: Animal husbandry
- Indicator Livestock productivity
- Indicator Animal health

Theme: Materials use & environmental protection
- Indicator Material flows

Theme: Energy & climate
- Indicator Energy intensity of agricultural production
- Indicator Greenhouse gas balance

Theme: Biodiversity
- Indicator Ecological infrastructures
- Indicator Distribution of ecological infrastructures

The farm data, which were used for the computation of the indicator, were increased or decreased by 10%. If the data showed good or favourable results for the score (> 67 points) they were lowered, if they showed problematic or critical scores (< 67 points) they were raised by 10%. This was done for all produce on a farm (crop and livestock categories) for the indicators crop productivity, livestock productivity and animal health. For indicators on material use, energy and climate, as well as biodiversity, the parameters entered were on farm level. All changes were made separately, and results shown as scenarios (1-9) for the indicators, computing the changes in scores which could be registered. In the RISE tool, a change of one indicator can affect the score of another. This direct effect was also registered.

The score of an indicator can unintentionally be influenced directly by parameters which are used for computation of several sub-indicators, or indirectly by other parameters than the main data input. The indirect influence (correlated) cannot be tested by altering parameter input. The indicators scores were already tested in a previous study on dairy farms, using data from 17 organic dairy farms (Lehman and Dalgaard, 2017).

Table 1. Correlation matrix for theme scores.

	Soil	Animal husbandry	Materials use & environment	Water use	Energy & Climate	Biodiversity	Working conditions	Quality of life	Economic viability	Farm management
Soil	1	0.03	0.50	0.28	0.20	-0.08	-0.11	0.34	0.01	-0.02
Animal husbandry	0.03	1	0.44	-0.16	-0.23	-0.31	0.06	0.29	-0.11	-0.01
Materials use & environment	0.50	0.44	1	0.34	0.02	-0.45	0.31	0.64	0.16	-0.22
Water use	0.28	-0.16	0.34	1	-0.37	-0.4	0.08	0.47	-0.21	-0.41
Energy & climate	0.20	-0.23	0.02	-0.37	1	0.23	0.49	0.01	0.73	0.37
Biodiversity	-0.08	-0.31	-0.45	-0.4	0.23	1	-0.21	-0.32	0.15	0.43
Working conditions	-0.11	0.06	0.31	0.08	0.49	-0.21	1	0.36	0.64	0.14
Quality of life	0.34	0.29	0.64	0.47	0.01	-0.32	0.36	1	0.10	-0.19
Economic viability	0.01	-0.11	0.16	-0.21	0.73	0.15	0.64	0.10	1	0.48
Farm management	-0.02	-0.01	-0.22	-0.41	0.37	0.43	0.14	-0.19	0.48	1

Table 2. Most positive correlations between indicator results

Variable 1	**Variable 2**	**Correlation**
Other areas of life	Stability	0.91
Other areas of life	Social relations	0.83
Indebtedness	Profitability	0.77
Soil reaction	Soil management	0.73
Other areas of life	Animal welfare	0.73
Air pollution	Soil organic matter	0.72
Stability	Safety at work	0.71
Fertilisation	Livestock productivity	0.70

The sensitivity of indicators and theme scores related to data input changes, were registered using data from five real farms; all organic dairy. This was done as farms are never similar, they are managed differently, have different field distribution, yield level, feeding management, size and more, and therefore it was chosen to use five real life farms , which it is assumed will give a relatively good estimation of the tested hypothesis for case farm studies. Among other characteristics, they were selected to be different in terms of management, size, cow breed, feeding regime and choice of crops.

In RISE, the individual theme scores are computed as an average of the indicator scores for each theme. There is a different number of indicators in each theme, thereby diluting the effect of a change of score for the theme. The number of indicators used for computation of the theme are mentioned in the results (Table 3). In addition, the scores of the indicators are often the result of different average computations of sub indicators and incidental bonus point (extra points) given for a score.

1.4 The nine scenarios

1. **Crop productivity**. The RISE score was tested in this scenario by making yield changes of 10% for all crops, except those without the purpose of yielding (set aside, nature, biodiversity).
2. **Soil reaction**. The RISE score was tested in this scenario by changing 10%. This changed the category distribution of the farm area. The reaction of the soil is grouped in three categories pH 5-5,5; pH 5,5-7; pH 7-8 and the farm area is divided by percentage in these categories.
3. **Livestock productivity**. The RISE score was tested in this scenario by changing the yield of all categories by 10%.
4. **Animal health**. The RISE score was tested in this scenario by raising the proportion of animal deaths by 10% in all categories.
5. **Material flows**. The RISE score was tested in this scenario by changing the import of fertiliser and animal feed by 10%.
6. **Energy intensity of agricultural production**. The RISE score was tested in this scenario by raising the energy consumption of electricity by 10% and the consumption of diesel by 10%.
7. **Greenhouse gas balance**. The RISE score was tested in this scenario by changing the Nitrogen application by 10%, and the fodder fed to ruminants by 10%.
8. **Ecological infrastructures**. The RISE score was tested in this scenario by changing the proportion of areas with a high environmental quality on agricultural area by 10%. There is a regional target in the reference rules for Denmark saying 17% = 100 points.
9. **Distribution of ecological infrastructures**. The RISE score for this scenario was tested by changing the proportion of agricultural area in the vicinity of ecological elements by 10%.

1.5 Results

Table 3. Baseline and scenario scores of selected themes and indicators of five organic dairy farms. The scenarios are defined in the methodology text. Five organic dairy farms are shown

Farm 1.

Theme	Indicator	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Soil use	*6 indicators*	81	80	80	81	81	81	81	81	81	81
	Crop productivity	78	72	78	78	78	78	78	78	78	78
	Soil reaction	97	97	93	97	97	97	97	97	97	97
Animal husbandry	*5 indicators*	92	92	92	86	90	92	92	92	92	92
	Livestock productivity	84	84	84	57	84	84	84	84	84	84
	Animal health	75	75	75	75	67	75	75	75	75	75
Materials use & environmental protection	*5 indicators*	80	81	80	80	80	80	80	80	80	80
	Material flows	78	78	78	78	78	78	78	78	78	78
	Fertilization	78	80	78	78	78	78	78	77	78	78
Energy & Climate	*3 indicators*	58	58	58	58	58	58	56	58	58	58
	Energy intensity of agricultural production	97	97	97	97	97	97	91	97	97	97
	Greenhouse gas balance	0	0	0	0	0	0	0	0	0	0
Biodiversity	*5 indicators*	71	71	71	71	71	71	71	71	71	69
	Ecological infrastructures	100	100	100	100	100	100	100	100	100	100
	Distribution of ecological infrastructures	75	75	75	75	75	75	75	75	75	68
	Intensity of agricultural production	59	59	59	59	59	59	59	59	60	59
	Average of 5 theme scores	76,4	76,4	76,2	75,2	76	76,4	76	76,4	76,4	76
	% change of average of themes		0	0,3	1,6	0,5	0,0	0,5	0,0	0,0	0,5
	% change on the theme		1,2	1,2	6,5	2,2	0,0	3,4	0,0	0,0	2,8
	% change on indicator		7,7	4,1	32,1	10,7	0,0	6,2	0,0	0,0	9,3

Farm 2.

Theme	Indicator	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Soil use	*6 indicators*	78	79	77	78	78	78	78	78	78	78
	Crop productivity	52	59	52	52	52	52	52	52	52	52
	Soil reaction	100	100	95	100	100	100	100	100	100	100
Animal husbandry	*5 indicators*	88	88	88	93	88	88	88	88	88	88
	Livestock productivity	64	64	64	87	64	64	64	64	64	64
	Animal health	77	77	77	77	76	77	77	77	77	77
Materials use & environmental protection	*5 indicators*	80	80	80	80	80	80	80	80	80	80
	Material flows	64	65	64	64	64	64	64	64	64	64
	Fertilization	98	97	98	98	98	98	98	97	98	98
Energy & Climate	*3 indicators*	62	62	62	62	63	62	60	65	62	62
	Energy intensity of agricultural production	82	82	82	82	82	82	78	82	82	82
	Greenhouse gas balance	23	23	23	23	23	23	22	31	23	23
Biodiversity	*5 indicators*	76	76	76	76	76	76	76	76	76	75
	Ecological infrastructures	100	100	100	100	100	100	100	100	100	100
	Distribution of ecological infrastructures	95	95	95	95	95	95	95	95	95	88
	Intensity of agricultural production	65	65	65	65	65	65	65	67	66	65
	Average of 5 theme scores	76,8	77	76,6	77,8	77	76,8	76,4	77,4	76,8	76,6
	% change of average of themes		0,3	0,3	1,3	0,3	0,0	0,5	0,8	0,0	0,3
	% change on the theme		1,3	1,3	5,7	0,0	0,0	3,2	4,8	0,0	1,3
	% change on indicator		13,5	5,0	35,9	1,3	0,0	4,9	34,8	0,0	7,4

Farm 3.

Theme	Indicator	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Soil use	*6 indicators*	81	80	80	81	81	81	81	81	81	81
	Crop productivity	78	72	78	78	78	78	78	78	78	78
	Soil reaction	97	97	93	97	97	97	97	97	97	97
Animal husbandry	*5 indicators*	92	92	92	86	90	92	92	92	92	92
	Livestock productivity	84	84	84	57	84	84	84	84	84	84
	Animal health	75	75	75	75	67	75	75	75	75	75
Materials use & environmental protection	*5 indicators*	80	81	80	80	80	80	80	80	80	80
	Material flows	78	78	78	78	78	78	78	78	78	78
	Fertilization	78	80	78	78	78	78	78	77	78	78
Energy & Climate	*3 indicators*	58	58	58	58	58	58	56	58	58	58
	Energy intensity of agricultural production	97	97	97	97	97	97	91	97	97	97
	Greenhouse gas balance	0	0	0	0	0	0	0	0	0	0
Biodiversity	*5 indicators*	71	71	71	71	71	71	71	71	71	69
	Ecological infrastructures	100	100	100	100	100	100	100	100	100	100
	Distribution of ecological infrastructures	75	75	75	75	75	75	75	75	75	68
	Intensity of agricultural production	59	59	59	59	59	59	59	59	60	59
	Average of 5 theme scores	76,4	76,4	76,2	75,2	76	76,4	76	76,4	76,4	76
	% change of average of themes		0	0,3	1,6	0,5	0,0	0,5	0,0	0,0	0,5
	% change on the theme		1,2	1,2	6,5	2,2	0,0	3,4	0,0	0,0	2,8
	% change on indicator		7,7	4,1	32,1	10,7	0,0	6,2	0,0	0,0	9,3

Table 3 continued

Farm 4.

Theme	Indicator	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Soil use	*6 indicators*	75	76	74	75	75	75	75	75	75	75
	Crop productivity	61	67	61	61	61	61	61	61	61	61
	Soil reaction	96	96	91	96	96	96	96	96	96	96
Animal husbandry	*5 indicators*	86	86	86	82	86	86	86	86	86	86
	Livestock productivity	75	75	75	54	75	75	75	75	75	75
	Animal health	54	54	54	54	55	54	54	54	54	54
Materials use & environmental protection	*5 indicators*	77	79	77	77	77	78	77	79	77	77
	Material flows	66	67	66	66	66	67	66	66	66	66
	Fertilization	52	60	52	52	52	56	52	62	52	52
Energy & Climate	*3 indicators*	74	74	74	74	74	74	73	76	74	74
	Energy intensity of agricultural production	97	97	97	97	97	97	97	97	97	97
	Greenhouse gas balance	48	48	48	48	48	48	47	55	48	48
Biodiversity	*5 indicators*	85	85	85	85	85	85	85	85	84	85
	Ecological infrastructures	97	97	97	97	97	97	97	97	90	97
	Distribution of ecological infrastructures	100	100	100	100	100	100	100	100	100	97
	Intensity of agricultural production	79	79	79	79	79	79	79	80	79	79
	Average of 5 theme scores	79,4	80	79,2	78,6	79,4	79,6	79,2	80,2	79,2	79,4
	% change of average of themes		0,8	0,3	1,0	0,0	0,3	0,3	1,0	0,3	0,0
	% change on the theme		1,3	1,3	4,7	0,0	1,3	1,4	2,7	1,2	0,0
	% change on indicator		9,8	5,2	28,0	1,9	1,5	0,0	14,6	7,2	3,0

Farm 5.

Theme	Indicator	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Soil use	*6 indicators*	68	69	67	68	68	68	68	68	68	68
	Crop productivity	51	58	51	51	51	51	51	51	51	51
	Soil reaction	98	98	93	98	98	98	98	98	98	98
Animal husbandry	*5 indicators*	87	87	87	83	88	87	87	87	87	87
	Livestock productivity	73	73	73	51	73	73	73	73	73	73
	Animal health	64	64	64	64	65	64	64	64	64	64
Materials use & environmental protection	*5 indicators*	83	85	85	83	83	83	83	82	83	83
	Material flows	74	74	74	74	74	73	74	73	74	74
	Fertilization	77	84	77	77	77	75	77	70	77	77
Energy & Climate	*3 indicators*	86	86	86	86	86	86	86	84	86	86
	Energy intensity of agricultural production	97	97	97	97	97	97	97	97	97	97
	Greenhouse gas balance	77	77	77	77	77	77	76	70	77	77
Biodiversity	*5 indicators*	76	76	76	76	76	76	76	76	74	77
	Ecological infrastructures	97	97	97	97	97	97	97	97	89	97
	Distribution of ecological infrastructures	48	48	48	48	48	48	48	48	48	51
	Intensity of agricultural production	85	85	85	85	85	84	85	83	85	85
	Average of 5 theme scores	80	80,6	80,2	79,2	80,2	80	80	79,4	79,6	80,2
	% change of average of themes		0,7	0,3	1,0	0,3	0,0	0,0	0,8	0,5	0,3
	% change on the theme		1,5	1,5	4,6	1,1	0,0	0,0	2,3	2,6	1,3
	% change on indicator		13,7	5,1	30,1	1,6	1,4	0,0	9,1	8,2	6,3

Table 4. Average changes for five organic dairy farms, caused by the scenario calculation of a 10% increase of annotated indicator. Data for nine scenarios are shown.

Average of 5 farms	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
% change of average of all 5 themes	0,41	0,26	1,24	0,36	0,05	0,26	0,72	0,15	0,21
% change on the theme	1,29	1,29	5,39	1,32	0,26	1,61	3,20	0,76	1,09
% change on indicator	10,02	4,94	31,42	6,41	0,85	2,42	23,12	3,09	5,79

Table 5. Scenario, Theme and Indicator

Scenario	Theme	Indicator
1	Soil use	Crop productivity
2	Soil use	Soil reaction
3	Animal husbandry	Livestock production
4	Animal husbandry	Animal health
5	Material use & environment	Material flows
6	Energy & climate	Energy intensity
7	Energy & climate	Greenhouse gas emissions
8	Biodiversity	Ecological infrastructures
9	Biodiversity	Distribution of ecological infrastructures

The effect of a substantial change of input data (10%) for crucial drivers of sustainability (Table 3), changed the scores (Table 4) for the themes between 0 and 7%. The increase of 10% of input for parameters used for the calculation of the annotated indicators, changed individual indicator scores between 0 and 36 %.
For the theme scores, which are presented in the report for farmers, and in the pedagogic colours used in the RISE polygon, the score changes were not large enough to change the colour, which is defined green, yellow and red, within the respective intervals 0-34, 35-67, and 68-100.
For the indicators, the 10% change in input data changed a few (9 out of 450) of the score's colours: livestock productivity score (5 times), animal health (1 time), crop productivity (1 time), material flows (2 times).

The size of the change in scores expressed as percentage of the baseline score, was substantial, although very different from indicator to indicator. Especially the livestock production (scenario 3) and the greenhouse gas emissions (scenario 7) increased the score more than 10%, due to the increase in the data input. This is not quite clear enough and can be potentially confusing.
Scenarios 5 (material flow), 6 (energy intensity) and 8 (ecological infra structure) changed only a little. It was substantially less than 10%.

1.6 Discussion

The RISE tool is designed as an advisory decision support, to be used to identify critical issues on a farm, in relation to sustainability and to set in action, possible incentives for improvement. The tool should therefore have the possibility to show which parameters the farmer needs to pay attention to. In addition, the tool should be able to show a change in score when improvements have been made in the years thereafter.
The scores that are used in the RISE tool are visible for the farmer at theme level and at indicator level. For the advisor, more detailed information can be extracted from the tool (at parameter level).

In the annex of this deliverable, it can be seen in more detail, how the change of input data in detail was inserted into the software. Due to different algorithms for the calculations of the scores, a 10% change can result in different percentages for the end score. However, the change should reflect the importance. It can, therefore give misinformation when a 10% input change results in >30% change of an indicator, such as for livestock production. The scores for livestock production are calculated relative to the high and low levels inserted as reference values per country. Hereby, a 10% change may increase the vicinity to maximum or minimum values, thereby changing the score more than the 10%. Also, questions on yield or production trends in the last 5 years, as well as quality aspects are included in the score. The same computation method is used for crop yields, but here the change of scores is not unintentionally high.

Another distortion of scores arises when a farm input data computes to a value much higher than the reference value for 100%, which occurred in three farms for the indicator "ecological infrastructure" score. This explains the zero percentage change for farms 1,2 and 3.

The indicator for material flow is computed using both fertilisation and animal feed data, both for Nitrogen and Phosphorous. In the test for sensitivity, both fertiliser and feed import were changed by 10%. Dependent on crop nutrition and yield level, as well as livestock production levels, this extra import affects the score, as it also affects the self-sufficiency score. In the RISE computation these calculations counteract the score, which erases the effect.

Communication value and complexity.

For some indicators, the results of the RISE computation, based on several parameter inputs, only reacts slightly on a large change, which can be an improvement or a deterioration. Especially for the indicator material flow (indicator 5) and energy intensity (indicator 6), the impact of the 10% change was small, which given the importance of these indicators for climate change and eutrophication, can be critiqued.
On the other hand, for the indicators livestock production (indicator 3) and GHG emissions, the impact of the change in score was large, which could imply a higher focus than actually intended.

Reasons for the different impact on scores can be found in the computation algorithms, which due to scoring thresholds, and arbitrary extra points or deductions, can have different effects. In addition, the averaging of sub-parameters or giving intermediate scores with their respective calculations, before letting them contribute to the final impact scoring, can lead to large differences in impact. By using many parameters in the computation of indicator scores and indicators for the theme score, the complexity erases the impact on the visible score, and a deeper insight in the calculations and algorithms is necessary to interpret the score.

The RISE tool is based on a complex set of algorithms, which are based on farm data, either from databases or farmers themselves when they use management tools. The data input is therefore very precise and both farmers and advisors can in fairness claim, that changes should be visible in the score. The score might in some cases even be used as an external communication, to justify work done to improve sustainability.

1.7 Conclusions

The RISE tool has a great level of detail in the computation of the sustainability scores, based on farm data input. Changing the farm data input for some parameters used in the computation of the indicators by as much as 10%, affected the score of different indicators in distinct ways.
For some indicators, the scores were in line with the data input change; soil productivity (indicator 1 of the 6 soil use theme indicators), animal health (indicator 4 of the 5 animal husbandry theme indicators), and distribution of ecological infrastructures (indicator 9 of the 5 biodiversity theme indicators).
For other indicators the scores were too low compared to the data input change; soil reaction (indicator 2 of the 6 soil use theme indicators), indicator material flow (indicator 5 of the 5 material use and environmental protection theme indicators), energy intensity (indicator 6 of the 3 energy and climate theme indicators), ecological infrastructures (indicator 8 of the 5 biodiversity theme indicators).
For some indicators, the scores were too high compared to the data input change; livestock production (indicator 3 of the 5 animal husbandry the indicators), greenhouse gas emissions (indicator 7 of the 3 energy and climate theme indicators).
The differences make it difficult to check if the farm improvements actually have improved the sustainability of the farm when relying on the scores.

2 Validity of sustainability assessment report – Part B: LCA, Uncertainty and sensitivity assessments

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2.1 Abstract

A revision of the main causes of uncertainty in the Life Cycle Assessments (LCA), conducted in the frame of Organic-PLUS, has been performed. Due to the ambition of the LCA studies, and the fact that the whole production chain is included, and a high number of impact categories are reported, a large amount of data is needed. Especially for organic production systems, this data was not always available or even possible to collect.

This Part B section covers how we have addressed this lack of information. First, the introduction and methodological sections present how variability and uncertainty is addressed in LCA studies. Second, some examples from the different case studies are provided to underline potential sources of uncertainty and how to deal with it.

Between the different sources of uncertainty encountered we highlight those in relation to: i) estimating emissions instead of measuring; ii) Tier level used and iii) allocation criteria. To deal with them we have used sensitivity assessments and Monte Carlo uncertainty assessment.

Inclusion of uncertainty values is the first stage in conducting corresponding uncertainty assessments, where we can differentiate between basic uncertainty typical of the process' variability, and that in relation to data quality of datasets used to prepare inventories.

As a result of the assessment conducted, we could conclude that major efforts are needed to improve quality of datasets to be used and improvement on methods on uncertainty values for inputs and outputs in organic production systems. Advice for further research is included.

2.2 Introduction

Uncertainty refers to situations in which something is not known with certainty. Uncertainty and variability are often mentioned as factors complicating the interpretation of outcomes of LCAs making it difficult to draw conclusions about impact results, especially when comparing different options (Huijbregts et al., 2001). In fact, uncertainty is frequently perceived as potentially discrediting LCAs. However, similar to all models that can simulate results, there are always uncertainties related to models since they do not measure the actual outcome but are used to get a general picture of the outcome, though in a more simplified form. This section aims to highlight the types of uncertainty in LCA and how we have managed it in Organic-PLUS. Because of the ambition of LCA studies, the whole production chain and the high number of impact categories, a large amount of data is needed, but not only data about resource use and emissions, which are needed to prepare life cycle inventories, but also the corresponding characterisation factors in impact assessment. In general, the more (good quality) data we have, the better the LCA, as is the case for all models. Therefore, it is important to know to what extent the outcome of an LCA is affected by data uncertainty in the inventory and in the impact assessment stage, as it may be helpful for decision makers in judging the significance of the differences in product comparisons, options for product improvements or the assignment of ecolabels (Huijbregts et al., 2001).

First of all, it is important to differentiate between variability and uncertainty. Variability is understood as stemming from inherent variations in the real world, particularly in the agricultural sector we are faced with high variability due to spatial or temporal conditions (climate, soil, pests, etc). Uncertainty comes from inaccurate measurements, lack of data, model assumptions, etc, that are used to "convert" the real world into LCA outcomes (Huijbregts, 1998).

When it comes to organic production systems, these are issues that acquire major importance, first because of a higher inherent variability, starting with yield productions, following with inputs used (for instance comparing organic fertilisers, which show higher variability than mineral ones) and lack of representativeness and incompleteness of the models applied in both emission estimation and impact characterisation. In addition, we could add the common LCA uncertainties due to different methodological choices (functional unit, multi-functionality, allocation criteria, impact assessment methods, normalisation, weighting, etc).

In the frame of th Organic-PLUS project we have conducted a review of these uncertainty sources and evaluate how they may affect our studies; some examples are provided.

2.3 Methodology

Variation in the data can be described by a distribution, expressed as a range or standard deviation. That requires to have a sample size large enough to establish such distribution. However, actual monitoring of resource use and emissions is not common practice and requires major temporal and economic efforts not generally feasible, so we can revert to basic uncertainty by default values, which are variation and stochastic error of the values, due to lack of sufficient information Basic uncertainty describes notions due to e.g., measurement uncertainties and inherent variability of the activity assessed. As we have stated this could/should be partially corrected with more measurements and a correct probability distribution if feasible. Without this information, the lognormal distribution is the default distribution used. This is due to the fact that the lognormal distribution is frequently observed in real life populations because many real-life effects are multiplicative rather than additive. In addition, most parameters for real life populations are always positive, which result in a skewed distribution with a longer tail towards the higher values. Weidema et al. (2013) in the data quality guidelines for the Ecoinvent database (one of the most popular LCA database) provide default values for assessing the basic uncertainty due to this variation, from which we have selected those in relation to agricultural sector (Table 1). This will affect mainly the primary data used. Primary data corresponds to those of the company/farm assessed. Secondary data corresponds to those we apply coming from databases, usually upstream or downstream of the production chain. Hence, we need to add an uncertainty value due to the quality of the secondary data used. Uncertainty in this case can be due to use of estimates and extrapolation from temporally, spatially and/or technological representivity. Weidema et al. (2013) established the pedigree matrix with corresponding uncertainty values to judge quality of the data. This matrix listed five indicators: reliability, completeness, temporal correlation, geographical correlation, and further technological correlation. Similarly, the European Commission’s Environmental Footprint programme (EC-JRC, 2018) has established the data quality ratio (DQR) based on four data quality criteria: technological, geographical, time representativeness, and precision/uncertainty. The latter of which could be equivalent to the reliability from the previous one. In the current deliverable, we have combined coefficient of variance from Ecoinvent with DQR of EC (Table 2). Major discrepancies come from temporal criteria, for which the number of years considered as representative differs considerably. Preliminarily, we follow the Ecoinvent criteria (just to keep coherence because most of the datasets we use come from this database), but we would advise to adjust temporal representativeness as a function of datasets, for instance taking into consideration life span of the item itself.

Once we have defined uncertainty values, we can apply statistical methods, such as Monte Carlo techniques, to handle these types of uncertainties, and calculate the data uncertainty in the LCA results.

Table 1. Default basic uncertainty applied to agricultural intermediate and elementary exchanges (adapted for Weidema et al 2013).

Flow exchange	Coefficient of variance
Inputs	
Land use, occupation	1.10
Primary energy carriers, metals, salts	1.05
Fertilisers	1.05
Infrastructures	3.00
Transport	2.00
Energy	1.05
Intermediate products	1.05
Outputs	
Air emissions	
NH_3	1.20
N_2O	1.40
NO_x	1.40
CH_4	1.20
Water emissions	
NO_3	1.50
PO_4	1.50
Pesticides	1.50
Heavy metals	1.80
Soil emissions	
Pesticides	1.20
Heavy metals	1.50

Table 2. Combination of Pedigree matrix with Data quality criteria defined by Ecoinvent guidelines (Weidema et al 2013) and EF (in italics) (EC 2018) including Coefficient of variance (Ciroth et al 2016).

DQR	1	CV	2	CV	3	CV	4	CV	5	CV
Temporal	Less than 3 years of difference to the time period of the dataset	1.00	Less than 6 years of difference of the time period of the dataset	1.03	Less than 10 years of difference to the time period of the dataset	1.10	Less than 15 years of difference to the time period of the dataset	1.19	Unknown or more than 15 years of difference to the time period of the dataset	1.29
	The EF report publication date happens within the time validity of the dataset		*The EF report publication date happens not later than 2 years beyond the time validity of the dataset*		*The EF report publication date happens not later than 4 years beyond the time validity of the dataset*		*Less than 6 years beyond the time validity of the dataset*		*More than 6 years after the time validity of the dataset*	
Geographical	Data from area under study	1.00	Average data from larger area in which the area under study is included	1.04	Data from area with similar production conditions	1.08	Data from area with slightly similar production conditions	1.11	Data from unknown or distinctly different area	n.a.
	The process modelled in the EF study takes place in the country the dataset is valid for		*Process takes place in the geographical region (e.g. Europe) the dataset is valid for*		*Process modelled takes place in one of the geographical regions the dataset is valid for*		*Process modelled takes place in a country that is not included in the geographical region(s) but sufficient similarities are estimated*		*Process modelled takes place in a different country than the one the dataset is valid for*	
Technology	Data from enterprises. processes and materials under study	1.00	Data from processes and materials under study (i.e. identical technology) but from different enterprises	1.18	Data from processes and materials under study from different technology	1.65	Data on related processes or materials	2.08	Data on related processes on laboratory scale or from different technology	2.80
	Idem		*The technologies used in the EF study is included in the mix of technologies in scope of the dataset*		*The technologies used in the EF study are only partly included in the scope of the dataset*		*The technologies used in the EF study are similar to those included in the scope of the dataset*		*The technologies used in the EF study are different from those included in the scope of the dataset*	
Precision*	Measured/calculated and externally verified	1.00	Measured/calculated and internally verified, plausibility checked by reviewer	1.54	Measured/calculated/literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	1.61	Qualified estimate (e.g. by industrial expert)	1.69	Non-qualified estimate	n.a.

*Precision is a criteria established by EF (CE 2018), definition and CV correspond to Ecoinvent Reliability criteria (Weidema 2013)

2.4 Dealing with uncertainties in Organic-PLUS LCAs

We have performed a revision of potential causes of uncertainty in the LCA's conducted in Organic-PLUS, and we have dealt with them using sensitivity assessments or Monte Carlo uncertainty assessment. This section presents the main aspects that have been considered.

2.4.1 Emission measured or estimated

In the case of the LCA conducted to compare alternatives to contentious peat inputs, there is a composting process for which we have used default emission factors (see deliverable 6.3). As we have pointed out in the corresponding deliverable composting is a biological process with high variability in emissions, influenced by the applied substrates, physical infrastructure and management method, weather conditions etc. Measurements were not planned; therefore, this is a critical aspect in the uncertainty in this particular assessment. To deal with this lack of knowledge, a sensitivity assessment for composting emissions was provided. Results demonstrated the importance of choosing the tier for emission modelling more appropriately (see deliverable 6.3).

2.4.2 Selection of Tier level for emission modelling

Since none of the contentious inputs have a direct relation with livestock emission accounting, enteric fermentation, or manure management, we have applied Tier I in LCA case studies conducted. Emission factors for the Tier I method are not based on country-specific data; they may not accurately represent a country's livestock characteristics, and may be highly uncertain as a result. Therefore, we have conducted a sensitivity assessment for the N_2O emissions from manure management for the pig case study applying Tier II. When using the Tier I method, for swine production in Denmark, a default value of 0.65 kg nitrogen excreted (N_{ex}) per 1 tonne live weight and 76 kg per head in West Europe is provided. That results in a value of 0.05 kg N_{ex} per animal. The calculation of N_{ex} according to Tier II method was conducted according to the balance between N_{intake} and $N_{retention\text{-}fraction}$ following equation 1.

$$\boldsymbol{N_{ex} = N_{intake} \cdot (1 - N_{retention-frac})} \qquad 1$$

Being and N_{intake}

$$\boldsymbol{N_{intake} = DMI \cdot \% \frac{CP}{6.25}} \qquad 2$$

Applying equation 2, the N_{intake} for a growing pig between 76 to 100 kg of body weight with a daily dry matter intake (DMI) of 2.1 kg and a diet containing 14.5 percent of crude protein (CP) would be equivalent to 0.049 kg N/day. Using equation 1, Nex=0.034 kg N/day with a $N_{retention\text{-}frac}$ = 0.30 kg $N_{retained}$/kg N_{intake} for swine, which could be considered an important adjustment in relation to Tier I. However, due to the mostly higher relevance of N_2O emissions when this manure is applied on-field, this correction of manure management emissions on farm is relatively small. A default N_2O emission factor IPCC (2019) of 1% of the N applied to N fertiliser application in soils. However, given the growing number of studies highlighting the role of climate and fertiliser type in determining emission factors, the IPCC (2019) provide alternative emission factors that are disaggregated by climatic zone and fertiliser type. In wet climates, the default value has been set at 0.6 % of organic N inputs (uncertainty range 0.1% to 1.1%), which means an important reduction of N_2O emissions due to field application of slurry. Therefore, the final result is not affected by the correction of manure management showing that Tier I selection is appropriate despite the wide uncertainty range, otherwise, more detailed Tier levels for fertiliser application are advisable.

2.4.3 Allocation criteria for multifunctional processes

When we deal with multifunctional products, the inputs and outputs shall be allocated to the different products according to clearly stated procedures that shall be documented and explained together with the allocation procedure. According to ISO 14040 when allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships. Where physical relationships alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products. In addition, some outputs may be partly co-products and partly waste. In such cases, it is necessary to identify the ratio between co-products and waste since the inputs and outputs shall be allocated to the co-products part only.

Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach.

The sheep production case study is a clear example to deal with allocation. These productions systems commonly produce both wool and meat, with different proportions and quality of the wool product. Sheep production systems also commonly produce two meat products (lamb and mutton) of different food quality grades. Therefore, we face a challenge for assessing the inputs for and impacts of the product in question.

In the first instance, the PEFCR (EU-JRC 2018) suggests the use of a biophysical approach based on energy requirements for the allocation of upstream burdens to the different co-products for sheep farms, they provide a default % allocation factor based on energy requirements for wool (23.6%), milk (73.8%) and meat (2.5%) at farm stage. On the other hand, economic allocation is advised at slaughterhouse stage for sheep. Allocation on a physical basis between meat, hides and wool was excluded due to the very different characteristics of these products. Depending on the farm activity, it could be concluded that milk or wool have very low or no economic value and be considered as waste, and then no allocation assigned. In fact, while for some sheep flocks, sheep milk is economically and nutritionally important, it is relatively unimportant for most other temperate regions where meat and wool are the main products. In the case study conducted for the organic production of sheep, we have a farm with co-production of meat and wool. As a sensitivity assessment we have tried different allocation methods: i) we conducted a biophysical allocation approach based on energy requirements, but recalculating the % for meat and wool, because no milk was produced in the farm studied, we followed IPCC 2019 guidelines to calculate energy requirements; ii) we conducted an economic allocation, but knowing that prices are a variable parameter, we tested two different years 2014 and 2017, consulting FAOSTAT data, just to reflect how changes in prices could affect the corresponding impact, iii) finally we have conducted the assessment adjudicating all the impact to the meat. Table 3 shows the assumptions used in calculating factors for the different allocation criteria.

Table 3. Allocation percentages for meat and wool following different criteria scenarios.

	Biophysical, Energy	Economic, 2014	Economic, 2017	Inputs to meat
Meat	59%	95 %	90%	100%
Wool	41%	5%	10%	0%

We present the results for climate change impact category showing the results for lamb meat per ‘one kilogram of live weight (LW) at the farm gate’ and for wool, per ‘one kilogram of greasy wool at the farm gate (Table 4). Results show how impacts may change according to the different criteria, especially for the wool. We compare our results with references from the review conducted by Poore and Nemecek (2019), which provide an average value of 12.3 Kg CO_2 eq/kg LW (7.4-18.7) and the study of Wiedemann et al (2015), which provides values between 7-35 Kg CO_2 eq/kg greasy wool for economic allocation. We may conclude that the biophysical energy criteria does not seem to be the most appropriate, at least for a farm in which milk is not a co-product. Therefore, we must be extremely cautious when comparing and choosing an appropriate allocation method. Although in the current case study we conclude that energy allocation is inappropriate, we advise to use different types of allocations for comparison prior to providing final values. In addition, we would rather provide a range of values than one absolute value. For the case study conducted, those would be 10-11.5 kg CO_2 eq/kg LW lamb meat and 7-15 kg CO_2 eq/kg greasy wool.

Table 4. Results for climate change impact category according to the different allocation scenarios.

		Biophysical, Energy	Economic, 2014	Economic, 2017	Inputs to meat
Meat	**kg CO_2 eq/kg LW**	**6.65**	**10.70**	**10.16**	**11.27**
Wool	**kg CO_2 eq/kg greasy wool**	**60.15**	**7.49**	**14.47**	**0.00**

2.4.4 Data Quality Ratio (DQR) and Uncertainty

One of the main problems we face when conducting an LCA is the need of secondary data and lack thereof. This is especially serious in the case of organic production system datasets (Montemayor et al., 2022) for more traditional inputs but especially for alternatives. Table 5. Quality scores and corresponding uncertainty factors for the different contentious and alternative inputs addressed at ORG+ LCA case studies. The indicators used for data quality assessment include representativeness of time (Ti), geographical location (G), technology (Te), and precision (P), and their corresponding uncertainty factors (U), where U_B corresponds to a basic factor that can be used as a default.
shows data quality indicators applied and the corresponding scores for each dataset, the mean of these scores resulting in the mean data quality rating (DQR), corresponding uncertainty factors (contributing to the square of the geometric standard deviation), and the standard deviation (SD) for the most relevant inputs assessed. Please refer to Table 2 in Part B of this report for further information regarding these quality indicators.
According to the overall quality level (Table 6), it can be seen that the DQR could be attributed as "Good quality" for most of the inputs involved. Clear exception are those products such as essential oils, antibiotics, antifungal and anthelmintics, for which no information is available and on the other side potassium hydrogen carbonate, fossil plastics with excellent quality and bioplastics very good quality.
Looking at the different criteria, it is worth mentioning that the worst score was for technology representativeness, which shows us that the secondary datasets used do not corresponds to the exact technology required. Also, it is important to remark in relation to geographical representativeness, that most of the datasets used corresponds to average data from a larger area than the area under study (i.e. European average).

Table 5. Quality scores and corresponding uncertainty factors for the different contentious and alternative inputs addressed at ORG+ LCA case studies. The indicators used for data quality assessment include representativeness of time (Ti), geographical location (G), technology (Te), and precision (P), and their corresponding uncertainty factors (U), where U_B corresponds to a basic factor that can be used as a default.

	Quality Indicators				Mean DQR	Uncertainty factors					
Contentious input dataset	Ti	G	Te	P		U_B	U_{Ti}	U_G	U_{Te}	U_P	SD
Copper oxychloride fungicide	2	2	3	2	2.3	1.05	1.03	1.04	1.65	1.54	1.94
Potassium hydrogen carbonate	1	2	1	2	1.5	1.05	1.0	1.04	1.0	1.54	1.55
Low copper fertiliser (Vitibiosap)	2	2	4	2	2.5	1.05	1.03	1.04	2.08	1.54	2.35
Low copper fertiliser (Dentamet)	2	2	4	2	2.5	1.05	1.03	1.04	2.08	1.54	2.35
Mineral oil manufacture	2	2	3	2	2.3	1.05	1.03	1.04	1.65	1.54	1.94
Essential oil (Thymol)	n.a	n.a	n.a	n.a	-	-	-	-	-	-	-
Synthetic vitamins	1	3	2	2	2.0	1.1	1.0	1.1	1.2	1.5	1.6
Fossil plastic manufacture	1	2	1	2	1.5	1.1	1.0	1.0	1.0	1.5	1.5
Peat	2	2	2	2	2.0	1.1	1.0	1.0	1.2	1.5	1.6
Biopolymers PLA	1	2	2	2	1.8	1.1	1.0	1.0	1.2	1.5	1.6
Composting	1	3	3	2	2.3	1.1	1.0	1.1	1.7	1.5	1.9
Manure pellets	1	3	4	2	2.5	1.1	1.0	1.1	2.1	1.5	2.4
Antibiotics, Antifungal & Anthelmintics	n.a	n.a	n.a	n.a	-	-	-	-	-	-	-
AVERAGE	1.5	2.3	2.6	2.0							

Table 6. DQR and corresponding overall quality level.

DQR	Overall data quality level
≤ 1.6	“Excellent quality”
1.6 to 2.0	"Very good quality"
>2.0 to 3.0	“Good quality”
>3 to 4.0	"Fair quality"
> 4	“Poor quality”

2.5 Case studies for contentious inputs

2.5.1 Plastic mulching contentious inputs

According to Deliverable 6.3, there were two main hotspots contributing to the environmental impact of bioplastic mulching, 1) thickness of the film and 2) potato cultivation. In D6.3 we tested mulching thickness of 0.04 mm and 0.025 mm, which showed a 37.5% reduction in environmental impact. According to more current knowledge from the partners at Polytechnic Czestochowa University, some bioplastic films can be produced at thicknesses similar to fossil-based film, for example, 0.015 mm. This can result in a 40% reduction in environmental impacts (Table 7).

Potato cultivation was also found to be an important hotspot in bioplastic film production since it was assumed that potatoes were cultivated strictly for producing bioplastic film and thus included in the analysed system. This is a parameter only valid from an experimental trial, and it is not foreseen to supplant food production. Taking a default value of 13% starch content in potato tubers, 3738 kg of potatoes would be needed to produce enough starch to make a bioplastic film of 0.04 mm thickness to cover 1 ha of land. Often, agricultural production is an important hotspot in the production of agriculturally-based products (Poore et al, 2018) due to the many diverse inputs and emissions included, thus, coincides with the results in this report. Considering the quantity of potatoes needed, it is clear that potato cultivation would be an environmentally relevant stage in bioplastic production. The idea would be to produce starch-based bioplastics based on starch from residual processing waste, such as wastewater from potato processing. Since this starch is considered a waste from potato processing, the further recycling to make bioplastics would not carry any upstream burden related to potato production or processing; it would come “burden-free” from processing, often called the “cut-off” approach for recycled products in LCA. This is so that the producer of the waste does not receive any “credit” (or reduction in impact) from the recycling of starch. Thus, another LCA was done where the potato cultivation was excluded from the system and only the transport of starch from the potato processing plant was included in the feedstock manufacturing stage (all other stages remained the same). This can result in reductions in environmental impact between 21 – 99% across all categories (Table 7).

One of the most important benefits to using biodegradable plastics over fossil-based plastics is its end of life. It can be tilled into the soil after use, eliminating waste and disposal challenges, and can be cheaper when considering end-of-season removal and disposal of fossil fuel-based mulch (see deliverables from WP5). It also did not have short-term effects on soil health, but long-term studies are still needed (also see deliverables from WP5). Other treatment options also exist for biodegradable plastic films, such as anaerobic digestion and composting, yielding more valuable products. Fossil fuel-based plastic often ends up in landfills in Spain and in most eastern and south-eastern European countries, whilst in Central Europe and Scandinavia (except Finland), less than 10% of agricultural plastic waste is disposed of in landfills or landfill bans are implemented (Plastics Europe, 2015). Recycling or reuse of fossil-based plastic mulch is also very difficult seeing as they are often contaminated with soil and agrochemicals, where contaminants must be <5% if it were to be recycled, but more often than not contaminants make up between 40-50% of the overall mass of the mulch (Steinmetz et al., 2016).

Fossil-based plastic pollution is becoming a very pertinent problem, especially in terrestrial habitats, where parts of the plastic mulch is often left in the soil, leading to accumulation of micro- and macro-plastics in the environment (Meng et al., 2020). It must be kept in mind that LCA does not take into account macro- and micro-plastic pollution to the surrounding soil, plants, animals, or water, due to lack of information on this topic in general. Only recently has attention been paid to this topic, and much more research is needed into how plastic pollution can affect biogeochemical soil processes (Steinmetz et al., 2016). Some studies have found that micro- and macro-plastic pollution can reduce water mass and distribution in soils as well as bulk density of soils (Jiang et al 2017). The soil enzyme activity and fertility can also be significantly reduced (Zhang et al., 2017). Moreover, plastic pollution from mulching may act as potential pesticide vehicles in soil, leading to unpredictable migration of pesticides (Ramos et al., 2015; Teuten et al., 2009). Furthermore, the most obvious problem with plastic debris is the ingestion of micro-plastics by soil meso- and micro-fauna (Rillig, 2012) which could negatively affect growth and survival (Huerta Lwanga et al., 2016). There are advancements in the development of LCA indicators for micro- and macro-plastic pollution in oceans and seas (MarLCA, https://marilca.org/), but currently none exist for soil pollution. Since organic agriculture prides itself on promoting healthy soils, this would be an important and critical aspect to consider when comparing fossil-based plastics to bioplastics.

Table 7. Sensitivity analysis of different bioplastic thicknesses and their environmental impact, and the sensitivity of obtaining potato starch from processing wastewater.

Impact category	Bioplastic width 0.04 mm	Bioplastic width 0.025 mm	Bioplastic width 0.015 mm	Bioplastic width 0.015 mm, starch from residual processing wastewater
Climate change	1.17E+03	7.31E+02	4.39E+02	3.05E+02
Ozone depletion	1.18E-04	7.37E-05	4.42E-05	3.03E-05
Ionising radiation	1.02E+02	6.35E+01	3.81E+01	3.01E+01
Photochemical ozone formation	5.89E+00	3.68E+00	2.21E+00	1.41E+00
Particulate matter	3.06E-04	1.91E-04	1.15E-04	1.29E-05
Human toxicity, non-cancer	1.59E-04	9.94E-05	5.96E-05	5.49E-06
Human toxicity, cancer	1.98E-06	1.24E-06	7.42E-07	1.91E-07
Acidification	4.56E+01	2.85E+01	1.71E+01	2.21E+00
Eutrophication, freshwater	6.53E-01	4.08E-01	2.45E-01	1.92E-01
Eutrophication, marine	8.51E+00	5.32E+00	3.19E+00	4.87E-01
Eutrophication, terrestrial	1.89E+02	1.18E+02	7.09E+01	5.10E+00
Ecotoxicity, freshwater	3.04E+04	1.90E+04	1.14E+04	5.89E+03
Land use	8.62E+04	5.39E+04	3.23E+04	3.39E+03
Water use	6.17E+03	3.86E+03	2.32E+03	2.83E+01
Resource use, energy carriers	1.34E+04	8.35E+03	5.01E+03	3.97E+03
Resource use, minerals and metals	3.52E-02	2.20E-02	1.32E-02	8.48E-03

2.5.2 Copper contentious input

In deliverable 6.3 (D6.3), an assessment was carried out comparing copper alternatives to highly concentrated copper sulphate and copper oxide baselines. Alternatives included potassium hydrogen carbonate which is effective against *Botrytis cinerea* in tomato, and low-copper fertilisers Vitibiosap and Dentamet, which have been found to be effective against fungi (i.e. *C. gloeosporioides*, *A. alternata*, *P. digitatum*) and bacteria (i.e. *P. syringae* and *X. euvesicatoria* pv. *perforans*) in in vitro tests. Since Vitibiosap and Dentament are similar to copper fungicides, just at lower copper concentrations (but higher pH solution), this analysis also serves as a sensitivity assessment. The copper dose was reduced by 92% in the alternative scenario compared to the baseline scenario, resulting in less copper emitted to air, water and soil than in the baseline scenario. The assessment of baseline scenarios showed that copper and mineral oil emissions may have major importance in the freshwater ecotoxicity impact category, while for the rest of the impact categories other inputs are more relevant. Therefore, we provided results in relation to freshwater ecotoxicity. Using the Italian lemon case study, reducing copper dosage by 92%, can result in a 95% reduction in ecotoxicity, when taking into account the life cycle of lemons from cradle-to-farm gate (Figure 1).

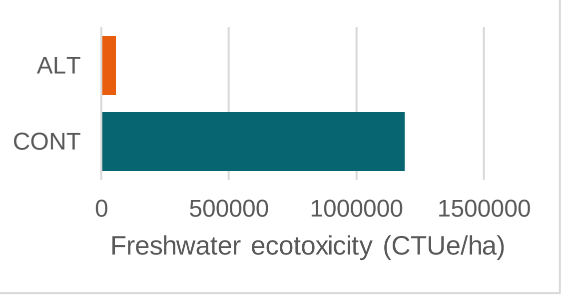

Figure 1. Comparing the impact of lemon cultivation on freshwater ecotoxicity in an alternative scenario with reduced copper dosage (ALT) and contentious baseline scenario with business-as-usual copper dosage (CONT).

To check the certainty of these results, a Monte Carlos analysis was conducted to compare the ALT and CONT scenarios, resulting in 100% probability that the ALT had lower impacts in freshwater ecotoxicity than the CONT scenario.

The data quality of copper manufacturing background datasets was also analysed since it was an important hotspot for resource use, and other categories related to energy consumption like ozone depletion, particulate matter, photochemical ozone formation. In order to do this, a weighted average data quality rating (W-DQR) was used (Montemayor et al., 2022). The indicators used to calculate the DQR were reliability, completeness, temporal and geographical correlation, and further technological correlation using the pedigree matrix approach from Weidema (1998), and modified in Weidema et al. (2013, refer to pg. 76 for explanation) and the Product Environment Footprint, PEF (European Commission, 2017). A score of 1 means excellent data quality, 2 good quality, 3 fair quality and 4-5 poor quality. The initial scores for each LCI dataset were provided by the LCA database providers. Using these scores, a W-DQR was calculated in the present study by first averaging the initial DQR of each input/output within a dataset (e.g., electricity in the Copper LCI, $DQR_{electricity}$ = 2.2), then weighted each of these DQRs by its contribution to the total impact for each category (e.g., 4% in climate change), then averaged across all categories to get a final W-DQR (e.g., 4.67, poor). According to the PEF data quality requirements (European Commission, 2017), 90% of environmentally relevant data within an LCI shall be at least of fair quality, hence the importance of using a W-DQR average. Details on the information used to calculate the average W-DQR can be found in the Annex.

Copper oxide had poor W-DQR (4.8, i.e., poor) mainly due to the market for copper metal production; this process contributes to >90% of the total impact of copper oxide, hence demonstrating its relevance and importance (Table A1). Specifically, the completeness, temporal and geographical correlation, and further technological correlation, had poor quality ratings that should be improved. Copper sulphate had fair W-DQR due to the poor quality of the copper oxide manufacturing dataset nested within that dataset, accounting for 64 – 99% of the total impact across all categories (Table A2). Therefore, the aforementioned datasets do not comply with the PEF data quality requirements (European Commission, 2017) where 90% of environmentally relevant data within an LCI shall be at least of fair quality.

In regard to more specific organic pest management techniques, OA focuses mainly on preventative measures that relies on maintaining a healthy soil biology and overall biodiversity. This may include providing a habitat for beneficial organisms, diverse rotations, using resistant varieties, intercrops, proper soil and nutrient monitoring and management, among others. When such preventative measures are insufficient to prevent or control pests, diseases and weeds, the addition of permitted PPPs would normally be the last resort. Such preventative techniques are difficult to account for in LCA and are not included in Ecoinvent organic crop datasets. The other preventative measures that require diverse ecological structures to increase biodiversity and habitats for beneficial organisms, which may also be referred to as ecosystem services, are difficult to account for in LCA as they are difficult to quantify and/or reach a consensus as to how to measure it. However, some studies aim to, for example, estimate the vascular plant biodiversity in organic and conventional cropland in Europe (Knudsen et al., 2017; Koellner and Scholz, 2008; Mueller et al., 2014; Schryver and Goedkoop, 2010), which may be a good start.

2.5.3 Mineral oil Contentious inputs

A for copper fungicide effects, the mineral oil proxy “insecticides, unspecified” (a common proxy dataset representing a European average of all insecticides), can have a major impact on the freshwater ecotoxicity category. Comparing the freshwater ecotoxicity impact of the alternative scenario (thyme oil) and the contentious baseline scenario (mineral oil) in the Italian lemon case study, the alternative scenario had 96% lower impact than the contentious (Figure 2) when considering their emissions to the environment.

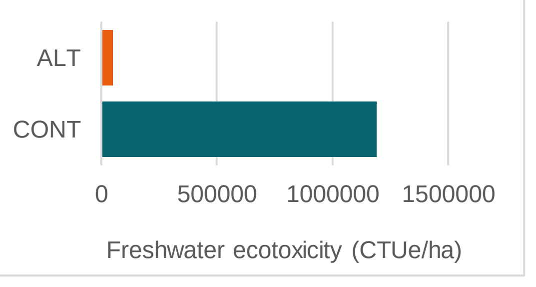

Figure 2. Comparing the impact of lemon cultivation on freshwater ecotoxicity in an alternative scenario with thyme oil (ALT) and contentious baseline scenario with mineral oil (CONT).

To see how certain these results were, a Monte Carlos analysis was done comparing the same life cycle from cradle-to-farm gate for the Italian lemons case study. It was found that in 100% of the iterations, the alternative scenario had lower impacts than the contentious scenario, thus, we can be sure of our conclusions.

In regard to the data quality of the manufacturing dataset for paraffin oil (a proxy/precursor of mineral oil), it had poor W-DQR (3.6) due to the poor quality of the chemical factory data (4.8) and fair quality of the heat data from sources other than natural gas (3.2) (Table A3). Specifically, the chemical factory data had poor reliability, completeness, temporal and geographical correlation and further technological correlation, whereas the heat data had poor ratings only for the first three indicators. Therefore, this dataset does not comply with the PEF data quality requirements (European Commission, 2018) where 90% of environmentally relevant data within an LCI shall be at least of fair quality.

2.5.4 Peat contentious inputs

For the case study Peat vs. Compost substrate, one major hotspot that was found across most of the categories in the compost scenario was the transport of biomass residues from the forest (See D6.3 for more information). Therefore, a sensitivity analysis was done to see how susceptible the results are to a change in transport distance. In Figure 3 below, the distance used in the real case study was 35 km, but reducing the distance to 20 km or 10 km can reduce the overall impact by 16% or 26%. Thus, finding sources closer to the compost plant would be beneficial to the overall impact of this compost substitute.

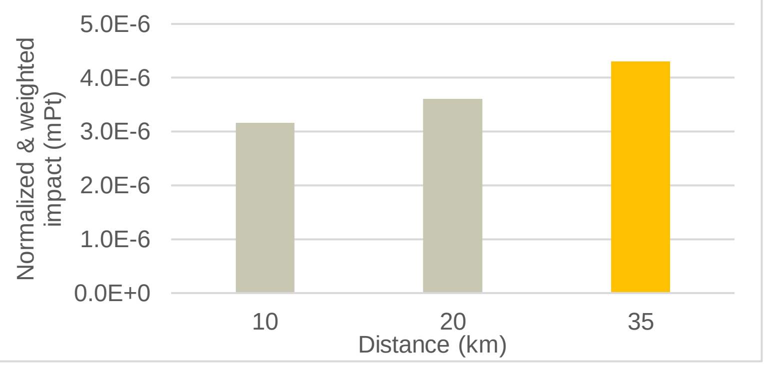

Figure 3. Sensitivity analysis of the normalised and weighted impact of compost substrate, differing only by the transport distance of the forest residues to the compost plant.

2.6 Further research

The work presented has highlighted potential areas for future work, with regards to managing and reducing variability and uncertainty. Potential developments are listed below:

- Increase data collection to better define activities, inputs and corresponding statistical distribution
- Improvement and development of emission models, through measurements preferably, and provide clear guidelines in terms of which of the different Tier levels should be applied
- Improvement through empirical data and more detailed classification of inputs and outputs of basic uncertainty
- A more specific criteria definition for pedigree matrix, differentiating between the different inputs (i.e. fertilisers, plant protection products, fossil-based materials, biomaterials, etc) and corresponding uncertainty values
- Prioritisation of results as ranges, rather than absolute values, but in any case, standard deviation should be accounted for
- Development of characterisation factors or integrate effects of terrestrial micro- and macro-plastic pollution into existing toxicity and soil quality impact categories
- Include different end of life scenarios for bioplastic mulching (e.g., anaerobic digestion, composting, etc) within the system boundaries of the LCA in order to account for these effects and their beneficial co-products (e.g., biogas and fertiliser)

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4 Annex

4.1 Annex Part A: - Nine scenario details for five farms

4.1.1 Farm 1

__Scenario 1:__

Crop productivity – baseline score 78 points

10% reduction in yield for crops in rotation.

Barley and pea mix (for silage)

- Current yield: 9.2 t/ha (regional average 9 t/ha)
- 10% reduction in yield --> 8.28 t/ha

Clover grass in rotation

- Current yield: 10 t/ha (regional average 9 t/ha)
- 10% reduction in yield --> 9 t/ha

Corn silage

- Current yield: 7.2 t/ha (regional average 10 t/ha)
- 10% reduction --> 6.48 t/ha

Winter rye

- Current yield: 4 t/ha (regional average 6 t/ha)
- 10% reduction: 3.6 t/ha

Pea, fodder (whole-crop)

- Current yield: 7 t/ha (regional average 7 t/ha)
- 10% reduction: 6.3 t/ha

In this scenario, for this farm, the decreased yields give a better N and P balance, thus increasing the score for fertilisation (and thereby also the score for materials use & environmental protection).

__Scenario 2:__

Soil reaction – current score 97 points

- Current: 6% pH 5-5.5 and 94% pH 5.5-7
- 10% increase: 5.4% pH 5-5.5. 85.2% pH 5.5-7 and 9.4 % pH 7-8

No effects on other indicators.

__Scenario 3:__

Livestock productivity – current score 84 points

Dairy cow, heavy breed, 10000 kg ECM (DK data)

- Yield per unit: 10.554 l milk
- Average: 9.874 l milk
- 10% reduction --> 9.498 l milk

No effects on other indicators.

<u>Scenario 4:</u>

Animal health – current score 75 points

Dairy cow, heavy breed, 10000 kg ECM (DK data)

- 22.6 dead animals (322.7 animals in this category)
- 10% increase --> 24.9 dead animals

Bull calf, heavy breed, 0-6 months (DK data)

- 26.8 dead animals (184 animals in this category)
- 10% increase --> 29.5 dead animals

Heifer, heavy breed, 0-6 months (DK data)

- 10 dead animals (68.4 animals in this category)
- 10% increase --> 11 animals

Heifer, heavy breed, 6 months to calving (DK data)

- 0 dead animals (247.4 animals in this category)
- 10% of animals in category --> 24.7 dead animals

No effects on other indicators.

<u>Scenario 5:</u>

Material flows – current score 78 points

Self-sufficiency of nutrients for animals and crops, calculated based on imported fertilisers and imported feed. Scenario 5 includes the calculation of five indicators simultaneously, as they all include the 10% reduction of fertiliser.

Current N self-sufficiency, fertiliser = 94.7 %
Current N self-sufficiency, animal feed = 78.6 %
Current P self-sufficiency, fertiliser = 93.6 %
Current P self-sufficiency, animal feed = 69.9%

Fertilisation – current score 78 points

Current N balance = 62.7%
Current P balance = 36.1%

Intensity of agricultural production – current score 59 points

50.1.1.b Organic fertilizers and litter: used imported and own exported organic fertizlizers.

	Use of imported organic fertilizers	Export of own organic fertilizers		
other organic fertilizers: Liquid from agricultu	880	0	m3	
manure: Pigs, slurry (DK data)	1,130	0	m3	
manure: Cattle, slurry (DK data)	0	920	m3	

50.1.1.c Imported feedstuff

		Used Amount	Unit	Amount fed to own ruminants	
legume: Soy shred, 42% protein, 88% DM	t	200	t	200	
legume: Faba bean (Vicia faba), 25% protein	t	30	t	25	
straw: Wheat straw, 88% DM	t	225	t	225	
cereal: Fodder barley (Hordeum vulgare), 12	t	150	t	150	
supplement: Mineral supplement for cattle, 4	t	35	t	35	
concentrate: Milk substitute, 22% crude prot	t	2.4	t	2.4	
concentrate: Starter ration, 18% crude prote	t	5	t	5	

10% increase in import of fertiliser and feed.

- Other organic fertiliser --> 968 m3
- Pigs, slurry --> 1243 m3
- Soy shred --> 220 t
- Faba bean --> 33 t
- Wheat straw --> 247.5 t
- Fodder barley --> 165 t
- Mineral supplement --> 38.5 t
- Milk substitute --> 2.64 t
- Starter ration --> 5.5 t

In the scenario, N balance increased to 63.2 % and P balance increased to 36.8 %. The N self-sufficiency, fertiliser decreased to 94.1%, the N self-sufficiency, animal feed decreased to 76.5%, the P self-sufficiency, fertiliser decreased to 93% and the P self-sufficiency, animal feed decreased to 66.8%.
This did not change the scores for the material flows and fertiliser indicators.
No effects on other indicators.

<u>Scenario 6:</u>

Energy intensity of agricultural production – current score 97 points

60.e Energy carriers

Energy carriers	Quantity	Unit	Proportion from renewable sources		Suggestion from master data		
Electricity: Electricity mix Denmark (44% rer	341,339	kWh	100	%	44	%	
liquid: Diesel	25,755	l	0	%	0	%	

Current energy consumption: 6.805 MJ/ha
National average: 11.000 MJ/ha

Increase use of each energy carrier by 10%

- Electricity --> 375472.9 kWh
- Diesel --> 28330.5 l

Energy consumption increased to 8193 MJ/ha
No effects on other indicators.

Scenario 7:

Greenhouse gas balance – current score 0 points

Decrease N input by 10% and decrease fodder fed to ruminants by 10% (for both imported feed. and feed produced on the farm).

- Exported cattle slurry increased to 1830 m3

Fodder fed to animals reduced to:

- Soy shred --> 180 t
- Faba bean --> 22.5 t
- Wheat straw --> 202.5 t
- Fodder barley --> 135 t
- Mineral supplement --> 31.5 t
- Milk substitute --> 2.16 t
- Starter ration --> 4.5 t
- Barley and pea mix (for silage) --> 849.69 t
- Clover grass in rotation --> 1662.3 t
- Corn silage --> 338.58 t
- Winter rye --> 43.85 t
- Pea, fodder (whole-crop) --> 27.66 t
- Permanent grass --> 22.59 t

The fertilisation score decreases slightly due to an increase in export of manure. Material flows (self-sufficiency of nutrients) is also affected, but not enough to change the score.

Scenario 8:

Ecological infrastructures – current score 100 points

30.4.5.g Proportion of areas with a high environmental quality on agricultural area

40.00 %

Regional target = 17%

Decrease by 10% --> 36% = still 100%

Intensity of agricultural production increases to 60 points.

Scenario 9:

Distribution of ecological infrastructures – current score 75 points

30.4.5.h Proportion of agricultural area in the vicinity of ecological elements

75.00 %

Regional target = 100%
Decrease by 10% --> 67.5%

No effects on other indicators.

4.1.2 Farm 2:

<u>Scenario 1:</u>

Crop productivity – current score 52 points

10% increase in yield for crops in rotation.

Clover grass in rotation:

- Current yield: 7.14 t/ha (regional standard: 9 t/ha)
- 10% increase --> 7.85 t/ha

Corn silage:

- Current yield: 9.5 t/ha (regional standard: 10 t/ha)
- 10% increase --> 10.45 t/ha

Mixture: pea and barley or pea and wheat

- Current yield: 4.2 t/ha (regional standard: 5 t/ha)
- 10% increase --> 4.62 t/ha

Winter rye

- Current yield: 5 t/ha (regional standard: 6 t/ha)
- 10% increase --> 5.5 t/ha

Barley, whole plant cut green

- Current yield: 2.5 t/ha (regional standard: 3.4 t/ha)
- 10% increase --> 2.75 t/ha

The increased yields give a slightly better score on material flows. For the fertilisation, the score decreases slightly, because the yields affect the N and P balances.

<u>Scenario 2:</u>

Soil reaction – current score 100 points

10% decrease in pH.

- Current: 100% pH 5.5-7
- Scenario: 10% pH 5-5.5 and 90% 5.5-7

No effect on other indicators.

<u>Scenario 3:</u>

Livestock productivity – current score 64 points

Dairy cow, heavy breed, 10.000 kg ECM (DK data)

- Yield per unit: 9453 l milk
- Average: 9874 l milk

10% increase --> 10398.3 l milk

No effect on other indicators.

<u>Scenario 4:</u>

Animal health – current score 77 points

10% increase:

Cow --> 4 dead animals

Heifer, 0-6 months --> 2.2 dead animals

Heifer, 6 months to calving --> 1.1 dead animals
Bull calf --> 13.2 dead animals

No effect on other indicators.

<u>Scenario 5:</u>
Material flows – current score 64 points

50.1.1.b Organic fertilizers and litter: used imported and own exported organic fertizlizers.

	Use of imported organic fertilizers	Export of own organic fertilizers		
manure: Pig slurry diluted (1:2), average P c	2,279	0	m3	
manure: Cattle, slurry (DK data)	0	639	m3	

50.1.1.c Imported feedstuff

		Used Amount	Unit	Amount fed to own ruminants	
straw: Wheat straw, 88% DM	t	90	t	90	
concentrate: Concentrate for dairy cows, 18°	t	169.25	t	169.25	

Fertilisation – current score 98 points

Intensity of agricultural production – current score 65 points

Increase imported feed and imported fertiliser by 10%

- Pig slurry --> 2506.9 m3
- Wheat straw --> 99 t
- Concentrate --> 186.18 t

Import is not increased enough to have any effects on the scores.

<u>Scenario 6:</u>
Energy intensity of agricultural production – current score 82 points

60.e Energy carriers

Energy carriers	Quantity	Unit	Proportion from renewable sources		Suggestion from master data		
Electricity: Electricity mix Denmark (44% rer	81,464	kWh	44	%	44	%	
liquid: Diesel	16,621	l	0	%	0	%	

Increase use of each energy carrier by 10%

- Current: 6.998 MJ/ha
- Scenario: 7.529 MJ/ha

There is a slight decrease in greenhouse gas balance score, due to higher emissions from energy.

<u>Scenario 7:</u>
Greenhouse gas balance – current score 23 points

Decrease N input by 10% and decrease fodder fed to ruminants by 10% (for both imported feed, and feed produced on the farm).

- Exported cattle slurry increased to

Fodder fed to animals reduced to:

- Wheat straw --> 81 t

- Concentrate --> 152.33 t
- Clover grass --> 621.07 t
- Corn silage --> 206.66 t
- Mixture: pea and barley or pea and wheat --> 65.09 t
- Winter rye --> 44.6 t
- Barley, whole plant cut green --> 12.72 t
- Permanent grass --> 30.32 t

Fertilisation decreases slightly. Intensity of agricultural production increases, due to lower N input.

Scenario 8:

Ecological infrastructures – current score 100 points

30.4.5.g Proportion of areas with a high environmental quality on agricultural area

30.00 %

Decrease by 10% --> 27%

Intensity of agricultural production increases to 66 points.

Scenario 9:

Distribution of ecological infrastructures – current score 95 points

30.4.5.h Proportion of agricultural area in the vicinity of ecological elements

75.00 %

Decrease by 10% --> 67.5%

4.1.3 Farm 3:

<u>Scenario 1:</u>

Crop productivity – current score 93 points

10% decrease in yield for crops in rotation.

Corn silage

- Current yield: 9.58 t/ha (regional: 10 t/ha)
- 10% decrease: 8.62 t/ha

Clover grass in rotation

- Current yield: 8.88 t/ha (regional: 9 t/ha)
- 10% decrease: 7.92 t/ha

Wheat

- Current yield: 5.4 t/ha (regional: 5 t/ha)
- 10% decrease: 4.86 t/ha

Material flows, fertilisation and greenhouse gas balance are affected. Material flows decreases slightly due to less self-sufficiency in feed. Fertilisation increases due to more balanced N and P balances. GHG balance increases due to less N input from N fixation in clover grass, and therefore less N2O emission from N input.

<u>Scenario 2:</u>

Soil reaction – current score 95 points

10% decrease in pH.

- Current: 10% pH 5-5.5 and 90% 5.5-7
- 10% decrease: 1% pH < 5, 18% pH 5-5.5 and 81% pH 5.5-7

<u>Scenario 3:</u>

Livestock productivity – current score 81 points

Dairy cow, jersey, 8000kg ECM (DK data)

- Yield per unit: 6217.4 l milk
- Regional average: 6197 l milk

10% decrease ---> 5595.66 l milk

<u>Scenario 4:</u>

Animal health – current score 72 points

10% increase in dead animals.

- Dairy cow: current 1 dead animal --> 1.1 dead animal
- Heifer, 6 months – calving: current 0 dead animals --> 5.51 dead animals (10% of animals in category)
- Heifer, 0-6 months: current 11 dead animals --> 12.1 dead animals
- Young bull: current 4 dead animals --> 4.4 dead animals

<u>Scenario 5:</u>

Material flows – current score 72 points

Fertilisation – current score 86 points

Intensity of agricultural production – current score 72 points

50.1.1.b Organic fertilizers and litter: used imported and own exported organic fertizlizers.

	Use of imported organic fertilizers	Export of own organic fertilizers		
manure: Mink, slurry (DK data)	137	0	m3	
manure: Cattle, slurry (DK data)	0	329	m3	
manure: P adjustment	262	-57	kg	

50.1.1.c Imported feedstuff

		Used Amount	Unit	Amount fed to own ruminants	
concentrate: Concentrate for dairy cows, 18%	t	156.34	t	156.34	
concentrate: Concentrate for dairy cows, 18%	t	4	t	4	

Increase imported feed and imported fertiliser by 10%
Mink, slurry --> 150.7 m3
P adjustment --> 288.2 kg
Concentrate --> 176.37 t

Scenario 6:

Energy intensity of agricultural production – current score 97 points

60.e Energy carriers

Energy carriers	Quantity	Unit	Proportion from renewable sources		Suggestion from master da
Electricity: Electricity mix Denmark (44% rer	84,552	kWh	100	%	44
liquid: Diesel	5,080	l	0	%	0

Increase use of each energy carrier by 10%

- Electricity --> 93007.2 kWh
- Diesel --> 5588 l

Slight decrease in GHG balance score, due to higher emissions from energy.

Scenario 7:

Greenhouse gas balance – current score 14 points

Decrease N input by 10% and decrease fodder fed to ruminants by 10% (for both imported feed, and feed produced on the farm).

Exported cattle slurry increased to 474 m3
Fodder fed to animals reduced to:

- Concentrate --> 144.31 t
- Corn silage --> 25.88 t (current: 28.75 t)
- Clover grass --> 505.92 t (current: 562.13 t)
- Permanent grass --> 21.15 t (current: 23.5 t)

Fertilisation decreases slightly. Intensity of agricultural production increases, due to lower N input.

Scenario 8:

Ecological infrastructures – current score XX points

30.4.5.g Proportion of areas with a high environmental quality on agricultural area

22.00 %

Decrease by 10% --> 19.8 %

Scenario 9:

Distribution of ecological infrastructures – current score XX points

30.4.5.h Proportion of agricultural area in the vicinity of ecological elements

85.00 %

Decrease by 10% --> 76.5 %

4.1.4 Farm 4:

Scenario 1:

Crop productivity – current score 61 points

10% increase in yield for crops in rotation.

Barley

- Current: 4 t/ha (region: 5 t/ha)
- 10% increase: 4.4 t/ha

Rye

- Current: 3.1 t/ha (region: 5 t/ha)
- 10% increase: 3.41 t/ha

Oats

- Current: 4.8 t/ha (region: 5 t/ha)
- 10% increase: 5.28 t/ha

Clover grass

- Current: 7.25 t/ha (region: 9 t/ha)
- 10% increase: 7.98 t/ha

Corn silage

- Current: 5.01 t/ha (region: 10 t/ha)
- 10% increase: 5.51 t/ha

Faba bean

- Current: 2.8 t/ha (region: 4.5 t/ha)
- 10% increase: 3.08 t/ha

Lupin

- Current: 3 t/ha (region: 3 t/ha)
- 10% increase: 3.3 t/ha

The increased yields give a slightly better score on material flows. For the fertilisation, the score increases slightly, because the yields affect the N and P balances.

Scenario 2:

Soil reaction – current score 96 points

10% decrease in pH.

- Current: 7.7% pH 5-5.5 and 92.3% 5.5-7
- 10% decrease: 0.77% pH < 5, 16.16% pH 5-5.5 and 83.07% pH 5.5-7

Scenario 3:

Livestock productivity – current score 75 points

Dairy cow, heavy breed, 9000 kg ECM (DK data)

- Yield per unit: 8745 l milk (regional: 8886 l milk)
- 10% decrease: 7870.5 l milk

Scenario 4:

Animal health – current score 54 points

10% decrease in dead animals.

Dairy cow: 4 dead animals --> 3.6

Heifer, 6 months to calving: 11 dead animals --> 9.9

Heifer, 0-6 months: 43 dead animals --> 38.7
Steer: 3 dead animals --> 2.7

Scenario 5:

Material flows – current score 66 points

Fertilisation – current score 52 points

Intensity of agricultural production – current score 79 points

50.1.1.b Organic fertilizers and litter: used imported and own exported organic fertizlizers.

	Use of imported organic fertilizers	Export of own organic fertilizers	
manure: Cattle, slurry (DK data)	0	308	m3
manure: Cattle, slurry (DK data)	0	673	m3
manure: Cattle, slurry (DK data)	0	301	m3
manure: Cattle, slurry (DK data)	0	32	m3
manure: Mink, slurry (DK data)	3,000	0	m3
manure: Cattle, slurry (DK data)	353	0	m3

50.1.1.c Imported feedstuff

		Used Amount	Unit	Amount fed to own ruminants
cereal: Fodder barley (Hordeum vulgare), 12	t	128	t	128
concentrate: Concentrate for dairy cows, 11%	t	272.2	t	272.2
concentrate: Concentrate (for dairy cows, 34	t	12.5	t	12.5
legume: Soy shred, 42% protein, 88% DM	t	45.5	t	45.5

Decrease imported feed and imported fertiliser by 10%

- Mink slurry --> 2700 m3
- Cattle slurry --> 317.7 m3
- Fodder barley --> 115.2 t
- Concentrate, 11% protein --> 244.98 t
- Concentrate, 34% protein --> 11.25 t
- Soy shred --> 40.95 t

Scenario 6:

Energy intensity of agricultural production – current score 97 points

60.e Energy carriers

Energy carriers	Quantity	Unit	Proportion from renewable sources		Suggestior
Electricity: Electricity mix Denmark (44% rer	176,500	kWh	100	%	44
liquid: Diesel	22,800	l	0	%	0

Increase use of each energy carrier by 10%

- Electricity: 194150 kWh
- Diesel: 25080 l

Slight decrease in GHG balance score, due to higher emissions from energy.

<u>Scenario 7:</u>

Greenhouse gas balance – current score 48 points

Decrease N input by 10% and decrease fodder fed to ruminants by 10% (for both imported feed, and feed produced on the farm).

Exported cattle slurry increased to 2113.46 m3

Fodder fed to animals reduced to:

- Fodder barley --> 115.2 t
- Concentrate, 11% protein --> 244.98 t
- Concentrate, 34% protein --> 11.25 t
- Soy shred --> 40.95 t
- Barley --> 27 t (current 30 t)
- Rye --> 45 t (current 50 t)
- Clover grass --> 1039.32 t (current: 1154.8 t)
- Corn silage --> 136.44 t (current: 151.6 t)
- Faba bean --> 18.72 t (current: 20.8 t)
- Permanent grass --> 58.23 t (current: 64.7 t)
- Lupin --> 27 t (current: 30 t)

The fertilisation score decreases due to an increase in export of manure. Material flows (self-sufficiency of nutrients) is also affected, but not enough to change the score. Intensity of agricultural production increases slightly, due to lower N input.

<u>Scenario 8:</u>

Ecological infrastructures – current score 97 points

30.4.5.g Proportion of areas with a high environmental quality on agricultural area

12.80 %

Decrease by 10% --> 11.52 %

<u>Scenario 9:</u>

Distribution of ecological infrastructures – current score 100 points

30.4.5.h Proportion of agricultural area in the vicinity of ecological elements

85.00 %

Decrease by 10% --> 76.5 %

4.1.5 Farm 5:

Scenario 1:

Crop productivity – current score XX points

10% increase in yield for crops in rotation.

Clover grass
- Current: 7 t/ha (regional: 9 t/ha)
- 10% increase: 7.7 t/ha

Lucerne
- Current: 9 t/ha (regional: 15 t/ha)
- 10% increase: 9.9 t/ha

Corn silage
- Current: 9 t/ha (regional: 10 t/ha)
- 10% increase: 9.9 t/ha

Rye
- Current: 6 t/ha (regional: 6 t/ha)
- 10% increase: 6.6 t/ha

Barley
- Current: 4.5 t/ha (regional: 5 t/ha)
- 10% increase: 4.95 t/ha

Mixture: pea & barley or pea & wheat
- Current: 5 t/ha (regional: 5 t/ha)
- 10% increase: 5.5 t/ha

Barley, whole plant cut green
- Current: 5.1 t/ha (regional: 3.4 t/ha)
- 10% increase: 5.61 t/ha

Grass
- Current: 10 t/ha (regional: 10.5 t/ha)
- 10% increase: 11 t/ha

Peas
- Current: 4.5 t/ha (regional: 6 t/ha)
- 10% increase: 4.95 t/ha

Scenario 2:

Soil reaction – current score 98 points

10% decrease in pH
- Current: 5% pH 5-5.5 and 95% pH 5.5-7
- 10% decrease: 0.5% pH <5, 14% pH 5-5.5 and 85.5% pH 5.5-7

Scenario 3:

Livestock productivity – current score 73 points

Dairy cow, heavy breed, 9000 kg ECM (DK data)
- Yield per unit: 8800 l milk (regional: 8886 l milk)
- 10% decrease: 7920 l milk

Scenario 4:

Animal health – current score 64 points

10% decrease in dead animals

Bull calf: current 5 --> 4.5

Steer: current 1 --> 0.9

Heifer, 6 months to calving: current 1 --> 0.9

Heifer, 0-6 months: current 12 --> 10.8

Dairy cow: current 11 --> 9.9

Scenario 5:

Material flows – current score 74 points

Fertilisation – current score 77 points

Intensity of agricultural production – current score 85 points

50.1.1.b Organic fertilizers and litter: used imported and own exported organic fertizlizers.

	Use of imported organic fertilizers	Export of own organic fertilizers	
manure: N adjustment	6,985	0	kg
manure: P adjustment	4,393	0	kg

50.1.1.c Imported feedstuff

		Used Amount	Unit	Amount fed to own ruminants
concentrate: Concentrate (for dairy cows, 24	t	120	t	90
straw: Wheat straw, 88% DM	t	280	t	270
cereal: Fodder barley (Hordeum vulgare), 12	t	40	t	40

Increase imported feed and imported fertiliser by 10%

- Manure N --> 7683.5 kg
- Manure P --> 4832.3 kg
- Concentrate --> 132 t
- Wheat straw --> 308 t
- Fodder barley --> 44 t

Scenario 6:

Energy intensity of agricultural production – current score 97 points

60.e Energy carriers

Energy carriers	Quantity	Unit	Proportion from renewable sources		Suggestion from master da
liquid: Diesel	21,057	l	0	%	0
Electricity: Electricity mix Denmark (44% rer	114,964	kWh	100	%	44

Increase use of each energy carrier by 10%

- Diesel: 23162.7 l
- Electricity: 126460.4 kWh

Scenario 7:

Greenhouse gas balance – current score 77 points

Increase N input by 10% and increase fodder fed to ruminants by 10% (for both imported feed. and feed produced on the farm).

Imported manure N increases to 9826.41 kg

Fodder fed to ruminants is increased to:

- Concentrate --> 99 t (current 90 t)
- Wheat straw --> 297 t (current 270 t)
- Fodder barley --> 44 t (current 40 t)
- Clover grass --> 816.66 t (current 742.42 t)
- Corn silage --> 313.04 t (current 284.58 t)
- Rye --> 77 t (current 70 t)
- Barley --> 36.3 t (current 33 t)
- Mixture: pea & barley or pea & wheat --> 85.91 t (current 78.1 t)
- Barley, whole plant cut green --> 91.1 t (current 82.82 t)
- Permanent grass --> 1.1 t (current 1 t)

Scenario 8:

Ecological infrastructures – current score 97 points

30.4.5.g Proportion of areas with a high environmental quality on agricultural area

15.00 %

Decrease by 10% --> 13.5%

Scenario 9:

Distribution of ecological infrastructures – current score 48 points

30.4.5.h Proportion of agricultural area in the vicinity of ecological elements

28.00 %

Increase by 10% --> 30.8%

4.2 Annex Part B: - Calculation of weighted DQR average

Table A1. Calculation of weighted DQR average for "Copper oxide {RER}| production | Cut-off, U" in ecoinvent. Percentages show contribution of corresponding datasets to the total impact for each category. The average DQR was provided by the database providers for each dataset, derived from pedigree ratings (unweighted). This average DQR for each dataset was weighted by their contribution to each impact category, then a final average was taken among all categories. (Source: Montemayor et al., 2022)

Impact category	Inputs from nature and output emissions	Ammonia, liquid {RER}| market for | Cut-off, U	Ammonium carbonate {RER}| market for ammonium	Chemical factory, organics {RER}| construction | Cut-off, U	Copper {GLO}| market for | Cut-off, U	Nitrogen, liquid {RER}| market for | Cut-off, U	Tap water {RER}| market group for | Cut-off, U	Electricity, medium voltage {RER}| market group for | Cut-	Heat, district or industrial, natural gas {RER}| market group for	Heat, from steam, in chemical industry {RER}| market for	Wastewater, average {CH}| market for wastewater,	Wastewater, average {Europe without Switzerland}|	***Weighted DQR***
Average DQR from pedigree ratings provided by database provider for each dataset (unweighted)	***2.9***	***(4,3,5,4,) 4.8***	***4.8***	***2.2***	***4.8***	***2.2***	***2.2***	***2.2***	***2.2***	***2.2***	***2.2***	***2.2***	
Climate change	0%	0%	0%	1%	91%	0%	0%	4%	3%	0%	0%	0%	***4.58***
Ozone depletion	0%	0%	0%	1%	85%	0%	0%	5%	6%	1%	0%	0%	***4.43***
Ionising radiation	0%	0%	0%	3%	70%	1%	0%	26%	0%	0%	0%	0%	***4.02***
Photochemical ozone formation	0%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%	***4.78***
Particulate matter	1%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%	***4.77***
Human toxicity, non-cancer	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	***4.80***
Human toxicity, cancer	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	***4.79***
Acidification	0%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%	***4.78***
Eutrophication, freshwater	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	***4.79***
Eutrophication, marine	0%	0%	0%	0%	98%	0%	0%	1%	0%	0%	0%	0%	***4.76***
Eutrophication, terrestrial	2%	0%	0%	0%	97%	0%	0%	0%	0%	0%	0%	0%	***4.74***
Ecotoxicity, freshwater	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	***4.80***
Land use	0%	0%	0%	2%	97%	0%	0%	1%	0%	0%	0%	0%	***4.72***
Water use	2%	0%	0%	0%	96%	0%	0%	1%	0%	0%	0%	0%	***4.72***
Resource use, fossils	0%	0%	0%	1%	86%	0%	0%	8%	4%	1%	0%	0%	***4.45***
Resource use, minerals and metals	0%	0%	0%	1%	99%	0%	0%	0%	0%	0%	0%	0%	***4.78***
												Average	***4.67***

Table A2. Calculation of weighted DQR average for "Copper sulphate {GLO}| production | Cut-off, U" in ecoinvent. Percentages show contribution of corresponding datasets to the total impact for each category. The average DQR was provided by the database providers for each dataset, derived from pedigree ratings (unweighted). This average DQR for each dataset was weighted by their contribution to each impact category, then a final average was taken among all categories. (Source: Montemayor et al., 2022)

Impact category	Inputs from nature and output emissions	Chemical factory, organics {GLO}| market for | Cut-off, U	Copper oxide {GLO}| market for | Cut-off, U	Sulfuric acid {RER}| market for sulfuric acid | Cut-off, U	Sulfuric acid {RoW}| market for sulfuric acid | Cut-off, U	Electricity, medium voltage {GLO}| market group for | Cut-off, U	Heat, from steam, in chemical industry {RER}| market for heat, from steam, in chemical industry | Cut-off, U	Heat, from steam, in chemical industry {RoW}| market for heat, from steam, in chemical industry | Cut-off, U	***Weighted DQR***
Average DQR from pedigree ratings provided by database provider for each dataset (unweighted)	***2.84***	***4.2***	***3.2***	***3.2***	***3.2***	***4.2***	***4.2***	***4.2***	
Climate change	0%	2%	79%	0%	3%	8%	1%	7%	***3.38***
Ozone depletion	0%	2%	74%	1%	5%	5%	2%	11%	***3.41***
Ionising radiation	0%	3%	74%	1%	3%	16%	1%	2%	***3.42***
Photochemical ozone formation	0%	1%	95%	0%	2%	1%	0%	1%	***3.23***
Particulate matter	0%	1%	90%	1%	5%	2%	0%	2%	***3.24***
Human toxicity, non-cancer	0%	0%	99%	0%	0%	0%	0%	0%	***3.20***
Human toxicity, cancer	0%	1%	98%	0%	0%	0%	0%	0%	***3.21***
Acidification	0%	0%	96%	0%	2%	0%	0%	0%	***3.21***
Eutrophication, freshwater	0%	0%	99%	0%	0%	0%	0%	0%	***3.21***
Eutrophication, marine	0%	1%	94%	0%	2%	2%	0%	1%	***3.23***
Eutrophication, terrestrial	0%	1%	96%	0%	1%	1%	0%	1%	***3.23***
Ecotoxicity, freshwater	7%	0%	92%	0%	0%	0%	0%	0%	***3.18***
Land use	0%	3%	92%	0%	2%	1%	0%	1%	***3.25***
Water use	14%	1%	64%	4%	16%	1%	0%	0%	***3.17***
Resource use, fossils	0%	2%	73%	1%	6%	9%	1%	7%	***3.40***
Resource use, minerals and metals	0%	1%	84%	0%	14%	0%	0%	0%	***3.21***
								Average	***3.26***

Table A3. Calculation of weighted DQR average for "Paraffin {RER}| production | Cut-off, U" in ecoinvent. Percentages show contribution of corresponding datasets to the total impact for each category. The average DQR was provided by the database providers for each dataset, derived from pedigree ratings (unweighted). This average DQR for each dataset was weighted by their contribution to each impact category, then a final average was taken among all categories. (Source: Montemayor et al., 2022)

	Inputs from nature and output emissions	Chemical factory, organics {RER}| construction | Cut-off, U	Electricity, medium voltage {RER}| market group for | Cut-off, U	Heat, district or industrial, natural gas {RER}| market group for | Cut-off, U	Heat, district or industrial, other than natural gas {RER}| market group for | Cut-off, U	Municipal solid waste {RER}| market group for municipal solid waste | Cut-off, U	***Weighted DQR***
Average DQR from pedigree ratings provided by database provider for each dataset (unweighted)	***2.8***	***4.8***	***3.2***	***3.2***	***3.2***	***2.8***	
Climate change	47%	8%	2%	22%	21%	1%	***3.14***
Ozone depletion	0%	12%	3%	63%	23%	0%	***3.39***
Ionising radiation	0%	47%	30%	7%	16%	0%	***3.96***
Photochemical ozone formation	76%	7%	1%	4%	12%	0%	***3.01***
Particulate matter	65%	9%	0%	1%	24%	0%	***3.09***
Human toxicity, non-cancer	2%	78%	1%	2%	17%	0%	***4.44***
Human toxicity, cancer	8%	73%	1%	4%	13%	1%	***4.33***
Acidification	62%	13%	1%	2%	22%	0%	***3.16***
Eutrophication, freshwater	0%	58%	8%	1%	33%	0%	***4.12***
Eutrophication, marine	71%	8%	1%	4%	15%	0%	***3.04***
Eutrophication, terrestrial	71%	9%	1%	4%	15%	0%	***3.06***
Ecotoxicity, freshwater	1%	58%	1%	2%	35%	3%	***4.11***
Land use	0%	32%	2%	1%	65%	0%	***3.71***
Water use	94%	3%	0%	1%	2%	0%	***2.88***
Resource use, fossils	91%	1%	0%	5%	3%	0%	***2.86***
Resource use, minerals and metals	0%	99%	0%	0%	1%	0%	***4.78***
						Average	***3.57***