LIFT

Low-Input Farming and Territories – Integrating knowledge for improving ecosystem based farming

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Synergies between farm level, farm-group and territorial sustainability of ecological farming

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About the LIFT research project

Ecological approaches to farming practices are gaining interest across Europe. As this interest grows there is a pressing need to assess the potential contributions these practices may make, the contexts in which they function and their attractiveness to farmers as potential adopters. In particular, ecological agriculture must be assessed against the aim of promoting the improved performance and sustainability of farms, rural environment, rural societies and economies, together.

The overall goal of LIFT is to identify the potential benefits of the adoption of ecological farming in the European Union (EU) and to understand how socio-economic and policy factors impact the adoption, performance and sustainability of ecological farming at various scales, from the level of the single farm to that of a territory.

To meet this goal, LIFT will assess the determinants of adoption of ecological approaches, and evaluate the performance and overall sustainability of these approaches in comparison to more conventional agriculture across a range of farming approaches and geographic scales. LIFT will also develop new private arrangements and policy instruments that could improve the adoption and subsequent performance and sustainability of the rural nexus. For this, LIFT will suggest an innovative framework for multi-scale sustainability assessment aimed at identifying critical paths toward the adoption of ecological approaches to enhance public goods and ecosystem services delivery. This will be achieved through the integration of transdisciplinary scientific knowledge and stakeholder expertise to co-develop innovative decision-support tools.

The project will inform and support EU priorities relating to agriculture and the environment in order to promote the performance and sustainability of the combined rural system. At least 30 case studies will be performed in order to reflect the enormous variety in the socio-economic and bio-physical conditions for agriculture across the EU.

Project consortium

No.	Participant organisation name	Country
1	**INRAE - Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement**	**FR**
2	VetAgro Sup – Institut d'enseignement supérieur et de recherche en alimentation, santé animale, sciences agronomiques et de l'environnement	FR
3	SRUC – Scotland's Rural College	UK
4	Teagasc – Agriculture and Food Development Authority	IE
5	KU Leuven – Katholieke Universiteit Leuven	BE
6	SLU – Sveriges Lantbruksuniversitet	SE
7	UNIBO – Alma Mater Studiorum – Universita di Bologna	IT
8	BOKU – Universitaet fuer Bodenkultur Wien	AT
9	UBO – Rheinische Friedrich-Wilhelms – Universitat Bonn	DE
10	JRC – Joint Research Centre – European Commission	BE
11	IAE-AR – Institute of Agricultural Economics	RO
12	KRTK – Közgazdaság- és Regionális Tudományi Kutatóközpont	HU
13	IRWiR PAN – Instytut Rozwoju Wsi i Rolnictwa Polskiej Akademii Nauk	PL
14	DEMETER – Hellinikos Georgikos Organismos – DIMITRA	GR
15	UNIKENT – University of Kent	UK
16	IT – INRAE Transfert S.A.	FR
17	ECOZEPT Deutschland	DE

Contents

List of acronyms and abbreviations

CAP – Common Agricultural Policy

ES – Ecosystem service

FADN – Farm Accountancy Data Network

NUTS – Nomenclature of Territorial Units of Statistics

USDA – United States' Department of Agriculture

1 Summary

In the present deliverable, D5.3 of the LIFT project we present a framework which evaluates the overall sustainability performance by incorporating farm and territorial level. The framework considers the sustainability along the economic, social and environmental dimensions. Matches and mismatches between the two spatial levels are considered by weighting farm level performance across said three dimensions. Weights are context-specific and reflect the importance of each dimension at the territorial level. Further, by evaluating sustainability performance across three different dimensions we are able to assess the synergies and trade-offs that exist between each and consider how these drive overall sustainability performance. The framework may also be used to inform policy decision-making by identifying which farming approaches are most sustainable within a particular case study area, and by identifying areas of focus to increase adoption rates of said systems.

The deliverable includes three components. First, we provide a brief overview of the literature on sustainability performance assessments and position the present framework within it. Following this we provide a detailed explanation of how the framework is constructed, highlighting the input data used. Second, we apply the framework to five LIFT case study areas, namely Flanders (Belgium), Austria, Romania, the United Kingdom and France. Here we detail the process of applying the data and discuss the results and how these can be interpreted. We also demonstrate how these results can be linked to drivers of change to help inform policy decision-making and identify target areas for increasing adoption of sustainable farming approaches. Finally, we provide insights into the assumptions that underpin the framework, highlighting the benefits and drawbacks of the proposed approach. We also provide insights and point of consideration for future application of the framework.

The framework incorporates stakeholder's sustainability objectives, multicriteria analysis, secondary data from the Farm Accountancy Data Network (FADN) database, and further descriptive analysis to present an innovative multi-dimensional and multi-scale approach to evaluating farming approach sustainability performance. Though the framework has been developed within the LIFT project, it is highly flexible and can easily be adopted by interested parties outside of the LIFT project.

2 Introduction

It is becoming increasingly evident that creating a more sustainable agricultural system is one of the core concerns of the 21st century. In Europe, this is perhaps best evidenced by the 10 key objectives of the new Common Agricultural Policy (CAP), which centres around achieving social, economic and environmental sustainability (European Commission, 2021). While many studies have evaluated the sustainability performance of farming approaches across these three sustainability dimensions (i.e., economic, social and environmental) (Janker and Mann, 2020; Rossing et al., 2007; Van Cauwenbergh et al., 2007; Van Passel et al., 2007), the integration of different spatial scales is not always considered in such analyses (Binder et al., 2010; de Olde et al., 2017). Nonetheless, consideration of spatial aspects when evaluating agricultural performance, particularly along the environmental dimension, has long been acknowledged (Binder et al., 2018; Lindborg et al., 2017; Van Cauwenbergh et al., 2007). Aside from this, assessments of sustainability in agriculture have also been criticised for lacking a clear delineation of what is sustainable (Janker and Mann, 2020), as well as for often being too much based on expert knowledge without adequate consultation of relevant stakeholders (Slätmo et al., 2017).

In this deliverable we propose a novel framework to evaluate the overall sustainability of farming approaches throughout case study areas in Europe, combining insights from across the LIFT project.

Specifically, we integrate the farm level sustainability assessment carried out in Niedermayr et al. (2022), in which farming approach performance was assessed along the economic, social and environmental dimensions, with the territorial level sustainability assessment results derived from Matthews et al. (2022). We use stakeholder's sustainability objectives, multicriteria analysis and further descriptive analysis to present an innovative multi-dimensional and multi-scale approach to evaluate the sustainability performance of farming approaches. By integrating both farm and territorial level assessments we are able to internalise the linkages and compromises between the levels into the assessment. Further, by evaluating sustainability performance across three different dimensions we are able to assess the synergies and trade-offs that exist between each, and consider how these drive overall sustainability performance. Though the framework has been developed within the LIFT project, it is highly flexible and can easily be adopted by interested parties outside of the LIFT project. Results from the implementation of the framework may be used to inform policy decision-making by identifying which farming approaches are most sustainable within a particular case study area, and by identifying areas of focus to increase adoption rates of said systems.

We address the critiques of sustainability assessments in agriculture that have been described above by explicitly integrating evidence from sustainability performances carried out at two spatial levels.

We use the definition of sustainability as defined by Agenda 21, which considers four dimensions: social, economic, environmental and institutional (United Nations Conference on Environment and Development, 1992). The environmental dimension is defined by the sum of all bio-geological processes and their elements, often referred to as "environmental capital", while the economic dimension concerns "man-made capital". The social dimension concerns individual human beings and their skills, dedication, experiences and behaviour. The institutional dimension include organisations and the system of rules governing the interaction of members of a society (United Nations Conference on Environment and Development, 1992). Finally, we engage with stakeholders across multiple steps of the framework composition to ensure the assessment is considerate local of knowledge and insights.

The deliverable is structured into 5 sections. Section 1 and the current section 2 provide a summary and an introduction to the deliverable, respectively. Section 3 introduces the framework and provides a detailed delineation of its methodology. In section 4 we illustrate the potential of the framework by applying it to four LIFT case study areas, namely Flanders (Belgium), France, Austria, Romania, and the United Kingdom. In this section we also highlight the benefits and drawbacks of the proposed framework. Finally, section 5 concludes by reflecting on the potential of the framework to inform policy decision-making as well as its wider future application.

3 Methodology

We propose a multi-scale sustainability assessment framework in which we combine findings from the LIFT project. Specifically, we incorporate a multicriteria analysis, stakeholders' sustainability objective, and descriptive analysis to reveal the linkages and compromises between farm and territorial level performance of farming approaches across the three dimensions of sustainability; economic, social and environmental. Furthermore, we link determinants of adoption to the sustainability of farming approaches to ensure a holistic overview of sustainability performance and to obtain policy-relevant recommendations.

The proposed framework adopts a five-step approach as illustrated visually in Figure 1, and as outlined in detail below.

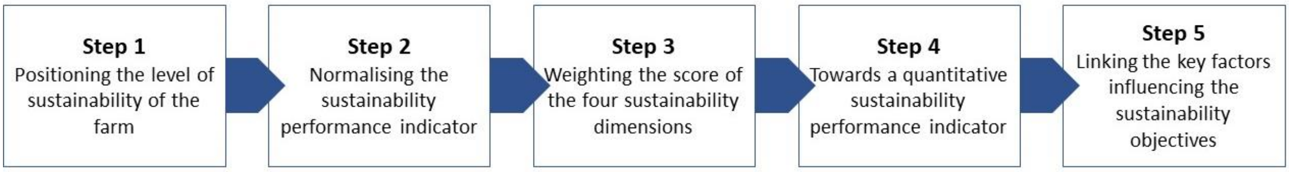


Figure 1. Visual representation of the five steps followed in the sustainability assessment framework.

Step 1: Positioning the level of sustainability of the farm. Previous LIFT project work (Niedermayr et al., 2022) uses Farm Accountancy Data Network (FADN) data to produce diagrams for each case study area in which the performance of farming approaches is measured across 12 indicators: five economic, three social, and four environmental. The indicators are aggregated per sustainability dimension for each farming approach (defined in Rega et al., 2021) to obtain an individual performance indicator for each dimension. As the four individual environmental indicators considered are composed based on farm input data (e.g., fertilisers, fuel,…) we supplement the output from step 1 (denoted 'environmental 1') with an additional environmental performance indicator quantifying the performance of farming approaches based on the potential supply of ecosystem services (ESs). The calculation of the secondary environmental performance indicator is described in detail in Van Ruymbeke et al. (2021a). In what follows, we will denote it 'environmental 2' indicator.

The number of farming approaches evaluated per case study area is determined by the analyses carried out in Niedermayr et al. (2022). Standard farming is used as a benchmark against which to compare the ecological farming approaches considered in LIFT (Rega et al., 2021). Therefore, standard farming is always considered in the analysis. Depending on the categorisation of the farms in the FADN data in the analysis in Niedermayr et al. (2022), each case study may incorporate one, a combination of multiple, or all of the following farming approaching: agroecological, low-input, integrated, organic, conservation. Allowing certain farming approaches to co-occur within a case study area poses a risk for double counting. This is particularly true for the second environmental indicator (quantifying the performance of farming approaches based on the potential supply of ESs) because this indicator is calculated based on the performance of underlying farm management practices (Van Ruymbeke et al., 2021b)[1]. Therefore, to avoid double counting, farm management practices that are included in both of the combined farming approaches are only considered once in the calculations of the second environmental indicator. That is to say, if two farming approaches are combined in which the same farm management practice is often applied, the performance of this practice on the second environmental indicator is only considered once. The number of farms considered in the sustainability assessment framework in this step is case study-dependent. The output from this step is a single, quantitative value whose scale is dimension-specific. In Figure 2 we demonstrate this step visually for Flanders, Belgium as an example.

[1] The list of farm management practices that are included in each of the five considered farming approaches is included in Appendix A.

Step 1
Positioning the level of sustainability of the farm

Step 2
Normalising the sustainability performance indicator

Step 3
Weighting the score of the four sustainability dimensions

Step 4
Towards a quantitative sustainability performance indicator

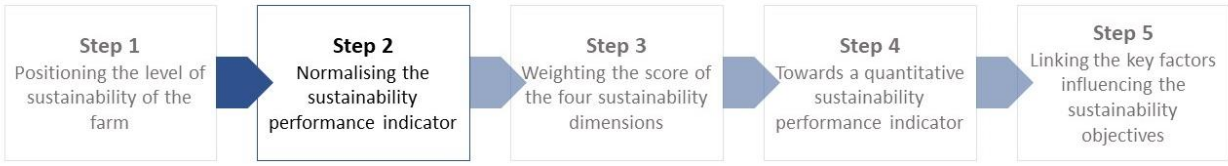
Step 5
Linking the key factors influencing the sustainability objectives

		Sustainability score		
	Sustainability dimension indicato	Standard	Integrated/ circular	Low-input AND integrated/ circular
Economic	Profitability incl. subsidies	0,00	0,27	1,72
	Profitability excl. subsidies	0,00	0,25	0,63
	Profitability excl. subsidies and incl. costs of own production factors	0,00	0,21	-0,13
	Cashflow / assets	0,00	-0,36	-0,03
	Net worth / assets	0,00	0,25	0,40
Social	Total labour	0,00	-0,30	-0,72
	Paid labour	0,00	0,11	-0,30
	Total labour / output	0,00	0,32	-0,33
Environmental	Fertilisation	0,00	1,38	1,82
	Plant protection	0,00	0,08	0,98
	Fuel	0,00	0,67	0,75
	Fallow land	0,00	0,02	2,06

	Average sustainability score		
Sustainability dimension	Standard	integrated/ circular	low-input AND integrated/ circular
Economic	0,00	0,61	2,58
Social	0,00	0,12	-1,34
Environmental 1	0,00	2,15	5,62
Environmental 2	0,17	0,80	0,78

Figure 2. Step 1 of the sustainability assessment framework: Positioning the level of sustainability of the farm. An average sustainability score per sustainability dimension for each farming approach is calculated. An example for Flanders, Belgium.

Step 2: **Normalising the sustainability performance indicator.** The output from step 1 is a single quantitative value whose scale is dimension-specific. In order to aggregate across the dimensions to obtain an overall sustainability assessment index of a farming approach per case study area, the sustainability performance indicator per dimension must be normalised such that each dimension is expressed along the same scale. To achieve this we perform a min-max normalisation in which the lowest and highest performing farming approaches within each sustainability dimension are rescaled to a scale from 0 to 1. All remaining farming approaches are rescaled respective to the highest and lowest performing systems. In this way, we are able to aggregate the performance across the various sustainability dimensions in step 3. This process of normalisation is illustrated visually for the example of Flanders, Belgium in Figure 3.

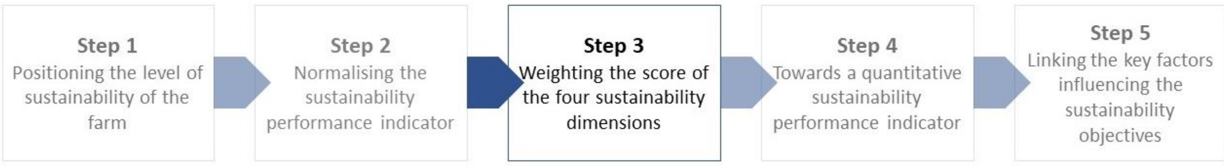


	Average sustainability score		
Sustainability dimension	Standard	integrated/ circular	low-input AND integrated/ circular
Economic	0,00	0,61	2,58
Social	0,00	0,12	-1,34
Environmental 1	0,00	2,15	5,62
Environmental 2	0,17	0,80	0,78

	Normalised sustainability score		
Performance dimension	Standard	Integrated/ circular	Low-input AND integrated/ circular
Economic	0,00	0,24	1,00
Social	0,92	1,00	0,00
Environmental 1	0,00	0,38	1,00
Environmental 2	0,00	1,00	0,97

Figure 3. Step 2 of the sustainability assessment framework: Normalising the sustainability performance. The average sustainability score is normalised per sustainability dimension to a scale of 0-1. An example for Flanders, Belgium.

Step 3: Weighting the score of the four sustainability dimensions. Prior to aggregating the three sustainability dimensions (economic, social, environmental 1, and environmental 2), a weight is attributed to each dimension based on its relative importance within a given case study area. Through weighting of the dimensions we are able to incorporate trade-offs between the sustainability dimensions on the one hand, and matches/mismatches between farm and territorial level performance on the other. By incorporating weights that reflect the relative importance of each dimension we allow for performance in more important dimensions to influence overall sustainability of farming approaches more strongly. Weights for each sustainability dimension are obtained from Matthews et al. (2022). There, case study-specific sustainability objectives were identified and scored by stakeholders for their relevance in improving farming approach sustainability at territorial level. Using these scores, an average score was calculated for each sustainability objective in each case study area. Sustainability objectives were then categorised into the three considered sustainability dimensions (economic, social and environmental), and an average score was then calculated for each dimension. The weight for the environmental sustainability objectives is equally distributed across the two environmental dimensions. In Figure 4 we illustrate this process visually for the example of Flanders, Belgium.

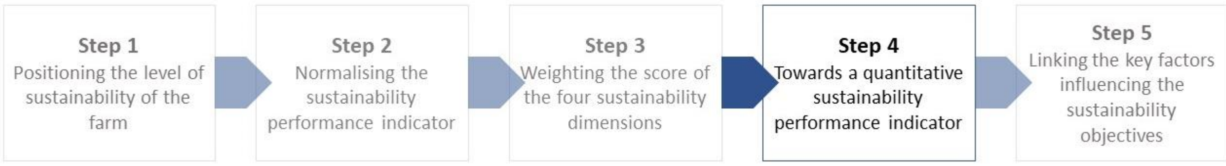


Sustainability dimension	Sustanability objective	Weight SH 1	SH 2	SH 3	SH 4	SH 5	SH 6	SH 7	SH 8	Average weight per sustainability objective	Average weight per sustainability dimension
Economic	SO1	2	2	1	2	2	2	2	2	1,88	1,81
Economic	SO2	2	1	2	1	2	1	2	2	1,63	
Economic	SO3	2	2	1	2	2	2	2	2	1,88	
Economic	SO4	2	2	2	2	1	2	2	2	1,88	
Social	SO11	2	.	2	2	2	2	1	1	1,71	1,61
Social	SO12	1	1	1	1	1	.	.	1	1,00	
Social	SO13	1	2	1	2	2	1	.	1	1,43	
Social	SO14	2	2	2	2	2	2	2	2	2,00	
Social	SO15	2	.	2	2	2	2	2	2	2,00	
Social	SO16	1	2	2	2	1	2	1	.	1,57	
Social	SO17	2	2	2	2	2	2	2	2	2,00	
Social	SO18	1	1	1	1	1	.	.	.	1,00	
Social	SO19	2	.	2	2	1	2	2	.	1,83	
Social	SO20	2	2	2	1	2	1	.	1	1,57	
Environmental	SO5	1	.	1	.	2	.	.	.	1,33	1,50
Environmental	SO6	2	.	1	1	2	1	2	2	1,57	
Environmental	SO7	1	.	1	1	2	.	1	1	1,17	
Environmental	SO8	2	1	1	1	2	.	1	1	1,29	
Environmental	SO9	2	2	1	1	2	2	2	2	1,75	
Environmental	SO10	2	1	2	2	2	2	2	2	1,88	

1 = partly significant, 2 = very significant, . = not isgnificant or unkown

Figure 4. Step 3 of the sustainability assessment framework: Weighting the score of the four sustainability dimensions. An average weight per sustainability dimension is calculated using sustainability objectives. An example for Flanders, Belgium.

Step 4: Towards a quantitative sustainability performance indicator. Through a weighted aggregation in which the dimension-specific sustainability performance indicators are weighted against the dimension-specific weights, we obtain an overall sustainability performance indicator for each farming approach, integrating trade-offs between both dimensions and spatial levels (see Figure 5). The final output is a quantitative sustainability performance indicator for each farming approach in each of the considered case study areas. This type of weighted aggregation is an often adopted approach in sustainability indicator calculations (see Singh et al., 2012 for examples).



Sustainability dimension	Normalised sustainability score Standard	Integrated /circular	Low-input AND integrated /circular	Average weight per sustainability dimension
Economic	0,00	0,24	1,00	1,81
Social	0,92	1,00	0,00	1,61
Environmental 1	0,00	0,38	1,00	0,75
Environmental 2	0,00	1,00	0,97	0,75

$$S_j = \frac{\sum_1^I x_{ij} w_i}{\sum_1^I w_i}$$

	Final sustainability performance Standard	Integrated /circular	Low-input AND integrated /circular
Weighted average	0,30	0,62	0,67

Figure 5. Step 4 in the sustainability assessment framework: Towards a quantitative sustainability performance indicator. A weighted aggregation is used to calculate the final sustainability performance for each farming approach based on the sustainability scores along the different sustainability dimensions. An example for Flanders, Belgium.

Step 5: Linking the key factors influencing the sustainability objectives. The output from step 4 identifies the relative sustainability performance of each of the considered farming approaches per case study area. Based on work done in Matthews et al. (2022), this performance can be linked to key factors influencing the sustainability objectives within a case study area to inform policy decisions. Matthews et al. (2022) had stakeholders in each case study area fill out an assessment matrix in which drivers of change were positively or negatively linked to sustainability objectives in high or low adoption scenarios. The relevant farm management practices and farming approaches were identified in each case study area during a Delphi exercise (Bailey et al., 2021). As such, the high and low adoption scenarios were defined for each case study area for a pre-determined farming approach(es). This information is consolidated with the results from step 4, and the relevant scenario for comparison is selected. If the results from step 4 indicate that low-input systems are the best performing systems in terms of overall sustainability in a given case study area, and the assessment matrix was filled out for low-input systems, then a high adoption scenario is selected for inclusion in the framework. Conversely, if low-input systems were found to be the worst performing farming approach, then the low adoption scenario is selected for analysis. This because the goal in the latter scenario will be to limit the adoption of low-input systems in the case study area.

Once the correct adoption scenario has been selected, sustainability objectives are once again categorised into the three sustainability dimensions (economic, social and environmental). Within each dimension, the various drivers of change are considered, and those with the strongest and most consistently positive impact across the objectives are identified (strongest and most consistent negative impact in a low adoption scenario). This is repeated for each of the three dimensions. The identified drivers of change can then be used to inform policy decisions as they highlight those drivers which may have the strongest positive impact on achieving sustainability objectives within a scenario where the best performing farming approach in terms of sustainability is highly adopted. Conversely, under a low adoption scenario the identified drivers provide insights into which should be avoided so as to ensure the least sustainable farming approaches are not over-invested in.

4 Results

4.1 Sustainability performance of farming approaches in selected case study areas

We demonstrate the application of the above-described sustainability assessment framework to assess sustainability of specialist field crop farming approaches in Flanders, Belgium. For this we use output derived from Niedermayr et al. (2022) on the farm level sustainability assessment of farming approaches in Flanders, combined with output from Matthews et al. (2022) on the link between drivers of change and sustainability objectives at territorial level. While the Flemish case study as defined within LIFT is made up of the Hageland-Haspengouw region (NUTS3: BE221, BE223, and BE242), the availability of observations in the FADN dataset for this area in Niedermayr et al. (2022) was too small. For this reason, this area was expanded in the present work to encompass all of Flanders (NUTS1: BE2). A total of 55 observations of specialist field crop farms were included in this assessment. Results of the sustainability assessment of farming approaches in Flanders at the farm level are illustrated in Figure 6.

Analysis carried out by Niedermayr et al. (2022) using FADN data categorised the specialist field crops farms in Flanders into three main farming approaches: standard farming, integrated/circular farming, and the combination of low-input AND integrated/circular farming. A total of 12 indicators are used to perform this farm level assessment; five indicators which can be categorised under the economic dimension of sustainability (profitability incl. subsidies, profitability excl. subsidies, profitability excl. subsidies and incl. costs of own production factors), three which can be categorised under the social dimension of sustainability (total labour, paid labour, total labour/output), and four which can be categorised under the environmental dimension of sustainability (fertilisation, plant protection, fuel, and fallow land). Figure 6 illustrates the sustainability performance of integrated/circular farming and of low-input AND integrated/circular farming in reference to standard farming in Flanders, Belgium.

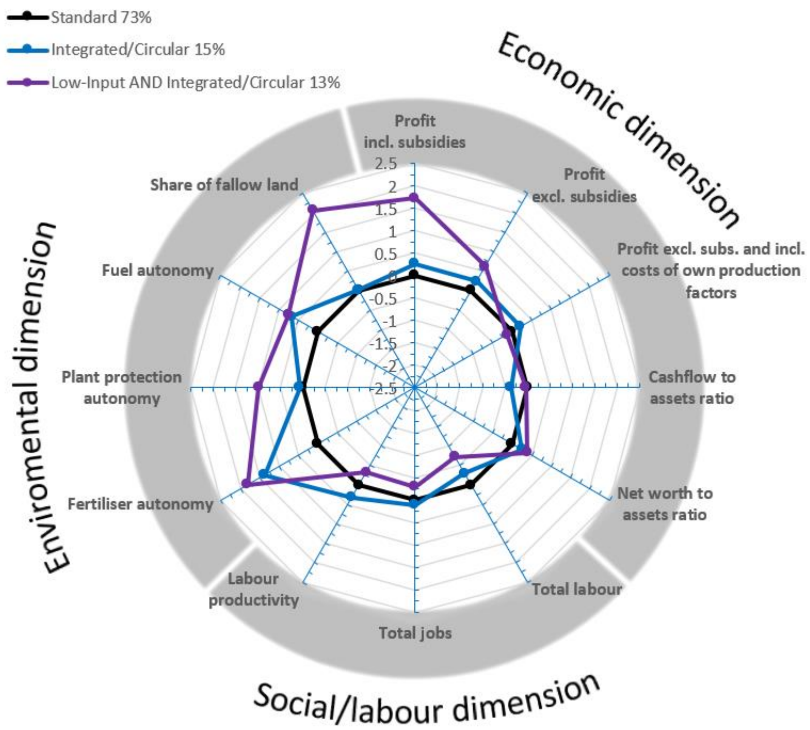


Figure 6. Farm level sustainability assessment for Flanders, Belgium according to the methodology described in Niedermayr et al. (2022), calculated using FADN data. Performance is measured for two ecological farming approaches (integrated/circular; and combination of low-input AND integrated/circular) compared against standard farming.

Following the procedure described in step 1: Positioning the level of sustainability of the farm, in the methodology above, the sustainability indicators derived from Niedermayr et al. (2022) are used to calculate the farm level performance of a farming approach along each of the sustainability dimensions (Table 1). As explained above, all environmental indicators used in Niedermayr et al. (2022) concern the use of external inputs. Therefore, we have supplemented the sustainability dimensions with a second environmental indicator. This second environmental indicator incorporates the results from Van Ruymbeke et al., 2021a, where a novel indicator framework is used which incorporates evidence from secondary literature to evaluate the environmental performance of a farming approach based on the supply of, and demand for, ESs. The composition of the second environmental indicator is described in more detail in section 5.2 in Niedermayr et al. (2022). Through this process of aggregation, we obtain a single indicator for the economic and social dimensions of sustainability, and two indicators for the environmental dimension for each of the three considered farming approaches in Flanders, Belgium (Table 1).

The indicators listed in Table 1 reflect the performance of each farming approach along each of the considered dimensions. Indicators have been normalised to a scale of 0 to 1 such that performance can be more readily compared between farming approaches and between dimensions (step 2: Normalising the sustainability performance indicator). As a result of the normalisation, the lowest performing farming approach in each dimension is attributed a score of 0, while the highest performing farming approach is attributed a score of 1. Every remaining farming approach is scored between 0 and 1 relative to the highest and lowest performing systems.

Table 1. Overall sustainability performance of farming approaches for Flanders, Belgium. Table lists the (normalised) sustainability performance per dimension, as well as the dimension weights and the overall sustainability performance.

	Sustainability performance			
Sustainability dimension	**Standard farming**	**Integrated/circular farming**	**Low-input AND integrated/circular farming**	**Dimension weight**
Economic	0	0.24	1	1.81
Social	0.92	1	0	1.61
Environmental 1	0	0.38	1	0.75
Environmental 2	0	1	0.97	0.75
Overall performance	0.30	0.62	0.67	

After normalisation, a weight is applied to each dimension based on the scoring of the case study-specific sustainability objectives by case study-specific stakeholders (Matthews et al., 2022; step 3: Weighting the score of the four sustainability objectives). The sustainability objectives for Flanders are listed in Table 5. During a scoring exercise, Flemish stakeholders were asked to provide a score (1, 2, N (not important), or U (unknown)) for each of the 20 considered sustainability objectives reflecting their importance within the case study area. The higher the attributed score, the more important the sustainability objective for the case study area. A total of nine stakeholders were consulted. Scores were then averaged to obtain a single value quantifying the importance of each sustainability objective. In a second step, sustainability objectives were categorised into the three sustainability dimensions (economic, social, and environmental) and within each of these dimensions an average was calculated. In this way we obtained a single weighting factor for each sustainability dimension, which reflects the relative importance of each dimension in a particular case study area. As we incorporated two environmental indicators in this framework, but only account for one environmental dimension in the sustainability objectives, we distributed the weight calculated for the environmental dimension equally across the two environmental indicators. The weights attributed to each dimension are listed in Table 1.

Finally, the overall sustainability performance of a farming approach is assessed through a weighted aggregation across the different sustainability dimensions, using dimension weights (step 4: Towards a quantitative sustainability performance indicator). The final sustainability performance of the three farming approaches considered for Flanders is listed in Table 2. Here we observe that overall, low-input AND integrated/circular farming has the highest sustainability performance. Conversely, we observe that standard farming has the overall lowest sustainability performance. Despite this, looking at the indicators along the individual sustainability dimensions we can observe that the best and worst performing farming approaches are not consistent across the dimensions. For example, low-input AND integrated/circular farming has the highest performance along the economic and environmental 1 indicator (calculated based on FADN), the second highest performance for the environmental 2 indicator (calculated based on potential ES supply), and the lowest performance for the social dimension. Comparatively, the highest performance along the social and environmental 1 indicators are observed for integrated/circular farming approach. Standard farming is the lowest or second lowest farming approach along all dimensions.

Due to the variation in performance along the different sustainability dimensions between integrated/circular, on the one hand, and low-input AND integrated/circular, on the other hand, the difference in the final sustainability assessment score between these farming approaches is small. This highlights the importance of the weights attributed to each dimension. By quantifying the relative importance of each dimension at the territorial level, the weights serve to integrate a measure of territorial-level trade-off. In Flanders, the higher weight attributed to the economic as opposed to the social and environmental dimensions is likely driving the overall higher sustainability score of low-input AND integrated/circular farming. While some sustainability performance assessments (and other multicriteria analyses) adopt an approach where the overall performance is only as good as the worst performing dimension, it was opted not to adopt this approach in this assessment. Specifically, the normalised nature of our output does not lend itself to this type of analysis. It would hypothetically be possible that each farming approach considered in a case study area obtained a normalised score of 0 along one of the three sustainability dimensions. A situation which, under the assumption that the overall performance is reflected by the worst performing dimension, would result in the overall performance of each farming approach being equal to 0. As such, none of the considered farming approaches would be considered better or worse than the others.

The same analysis was performed for four additional case study areas, namely France, Austria, Romania, and the United Kingdom using indicators calculated with FADN data from Niedermayr et al. (2022). While we will not provide a detailed description on the calculation process of the overall sustainability performance of the farming approaches for the remaining four case study areas in this section, the data used in steps 1 through 5 of these calculations can be found in Appendix B. In the remainder of this section we will present and describe the results of the overall sustainability performance of the farming approaches.

From Table 2 we can see that the FADN analysis in France results in a classification of farms into five separate farming approaches: standard, integrated/circular, low-input, organic, and integrated/circular AND organic. The results of the present framework applied to French data indicate that of these five farming approaches, the latter (i.e., integrated/circular AND organic) has the highest sustainability performance. Looking at the performance for each of the individual sustainability dimensions, we indeed see that this farming approach performs the best along the economic and social dimensions. Along the environmental dimension this is not the case. Here, integrated/circular AND low-input is the best performing farming approach along the environmental 1 indicator, while organic is the highest performing system along the environmental 2 indicator. Nonetheless, the relative performance of the integrated/circular AND organic farming approach is still high in both indicators.

The discrepancy observed in Table 2 between the performance of the farming approaches along the two environmental indicators highlights the importance of including additional environmental performance measures in sustainability assessments. By incorporating an indicator evaluating performance based on ESs (environmental 2 indicator) we can provide some additional relevant insights which may otherwise be missed if focussing only on external input data to evaluate environmental performance. Indeed, a similar observation was expressed by stakeholders in Belgium when presented with the framework. FADN data was not considered the most appropriate database to use when evaluating farming approach performance along both environmental and social dimensions. Thus, stakeholders considered the inclusion of environmental 2 indicator very important in the present framework, even indicating this should be given a larger share of the environmental dimension weight.

Table 2. Overall sustainability performance of farming approaches in France. Table lists the sustainability performance per dimension, as well as the dimension weights and the overall sustainability performance.

	Sustainability performance					
Sustainability dimension	**Standard farming**	**Integrated/ circular**	**Low-input farming**	**Organic farming**	**Integrated/ circular AND organic**	**Dimension weight**
Economic	0.00	0.01	0.73	0.01	1.00	1.55
Social	0.73	0.00	0.06	0.55	1.00	1.61
Environmental 1	0.00	1.00	1.00	0.33	0.49	0.87
Environmental 2	0.00	0.80	0.37	1.00	0.75	0.87
Overall performance	0.23	0.32	0.50	0.41	0.87	

Niedermayr et al. (2022) identified four farming approaches in Austria based on FADN data. The results of the sustainability assessment framework applied to these four systems are shown in Table 3. Here we can see that, similarly to the French case, integrated/circular AND organic farming approach has the highest sustainability performance. We can see that this system performs the best out of the four considered systems along the economic dimension as well and the environmental 1 indicator, but not along the social dimension and environmental 2 indicator. In Austria, standard farming approach seems to have the highest performance along the social dimension, while organic system has the highest performance along the environmental 2 indicator. It is this high performance of standard farming along the social dimension that is also driving the overall sustainability performance of this farming approach, which, unlike in Flanders and France, is not the lowest performing system. Instead, the framework indicates that integrated/circular system has the lowest sustainability performance in Austria; likely due to the low performance along the economic and social dimensions.

Table 3. Overall sustainability performance of farming approaches in Austria. Table lists the sustainability performance per dimension, as well as the dimension weights and the overall sustainability performance.

	Sustainability performance				
Sustainability dimension	**Standard farming**	**Integrated/ circular farming**	**Organic farming**	**Integrated/ circular AND organic farming**	**Dimension weight**
Economic	0.07	0.00	0.37	1.00	1.42
Social	1.00	0.00	0.56	0.31	1.43
Environmental 1	0.00	0.79	0.40	1.00	0.72
Environmental 2	0.00	0.76	1.00	0.72	0.72
Overall performance	0.36	0.26	0.54	0.72	

Similarly to the Austrian case, in Romania we can see that standard farming does not have the lowest sustainability performance of all considered farming approaches (Table 4). Instead, the worst performing approach is integrated/circular farming. The combination of low-input AND integrated/circular farming has the highest sustainability performance of the four systems considered. Looking at the performance of the farming approaches along the individual dimensions we observe that low-input AND integrated/circular farming is indeed the best performer along the social and economic dimension, and for environmental 1 indicator. While not the highest[2], low-input AND integrated/circular farming is still a strong-performing farming approach along the environmental 2 indicator. Noteworthy is that Romania is the only considered case study area in which the environmental dimension was not attributed the highest weight by stakeholders. Instead, the economic dimension is the highest weighted dimension.

[2] The highest performing farming approach along environmental 2 dimension is integrated/circular.

Table 4. Overall sustainability performance of farming approaches in Romania. Table lists the sustainability performance per dimension, as well as the dimension weights and the overall sustainability performance.

Sustainability performance					
Sustainability dimension	**Standard farming**	**Integrated/ circular farming**	**Low-input farming**	**Low-input AND integrated/ circular farming**	**Dimension weight**
Economic	0.34	0.00	0.99	1.00	1.16
Social	0.94	0.00	0.72	1.00	1.11
Environmental 1	0.00	0.26	0.31	1.00	0.56
Environmental 2	0.00	1.00	0.66	0.81	0.56
Overall performance	0.42	0.21	0.74	0.97	

Applying the framework to the three farming approaches considered in the United Kingdom we see that, unlike in all the previously considered countries, standard farming has a higher sustainability performance than the two ecological approaches. Indeed, we see that the combination of low-input AND organic farming has the lowest sustainability performance of the three considered approaches (Table 5). From the performance scores calculated for the farming approaches along each of the sustainability dimensions (Table 5) we see that standard farming has the highest performance along the economic and social dimensions, both of which are weighted higher than the environmental dimension. As a result, despite the two ecological approaches (and particularly the combination of low-input AND organic) performing the highest along the environmental dimension, standard farming is able to outperform the ecological approaches in terms of sustainability.

Table 5. Overall sustainability performance of farming approaches in the United Kingdom. Table lists the sustainability performance per dimension, as well as the dimension weights and the overall sustainability performance.

Sustainability performance				
Sustainability dimension	**Standard farming**	**Low-input farming**	**Low-input AND Organic farming**	**Dimension weight**
Economic	1.00	0.79	0.00	1.74
Social	1.00	0.00	0.19	1.47
Environmental 1	0.00	0.52	1.00	0.71
Environmental 2	0.00	0.89	1.00	0.71
Overall performance	0.69	0.51	0.37	

4.2 Linking sustainability performance to drivers of adoption

Aside from providing first insights into the sustainability performance of farming approaches in different regions, the present study also aims to help inform policy decision-making. This is achieved by evaluating the results of the framework against the drivers of change identified in the sustainability assessment matrix for each case study area developed in Matthews et al. (2022). As described in section 3, the assessment matrix was filled out by stakeholders in each case study area for the high and low adoption scenarios of a list of pre-defined case study area-specific farm management practices. In Flanders, these farm management practices matched those associated with integrated/circular and/or low-input systems – both of which are found to perform well based on the results of the present framework (Table 1). Therefore we consider the sustainability matrix of the high-adoption scenario, as this highlights the drivers of change most likely to have a positive impact on sustainability under a favourable, high-adoption rate of demonstrated sustainable farming approaches.

The approach taken to identify which drivers of change are key in achieving the sustainability objectives under the assumption of a high rate of adoption of integrated/circular and/or low-input systems is, first, to categorise the sustainability objectives into the three considered sustainability dimensions: economic, social and environmental. We demonstrate this process in Table 5 for Flanders. Once this has been done, we consider which drivers of change have the most consistently positive impact on the sustainability objectives within each dimension. For Flanders, four of the 20 sustainability indicators listed in Table 5 have been categorised as economic objectives. Across these four objectives, agricultural policy and technology are the two drivers of change which have the most consistent and strongest positive impact on the sustainability objectives. Note that the economic sustainability dimension was weighted most heavily in the previous section of the framework, implying that achieving the economic objectives is central in assuring sustainability in the Flemish region. Following this we can conclude that agricultural policy (e.g., farmer subsidies for the adoption of farm management practices related to integrated/circular and/or low-input farming approaches) and improved/more affordable technologies are key factors in attaining the economic sustainability objectives. Ten of the 20 sustainability objectives listed in Table 5 have been categorised as social objectives. Here, the most consistently positive driver(s) of change is less straightforward than for the economic dimension. Nonetheless, we can see that organisations and advisors seem to have the most consistent positive impact across the ten dimensions, and thus are considered as a key driver in achieving the sustainability objectives under a high adoption rate of integrated/circular and/or low-input farming approaches. The remaining six sustainability objectives in Table 5 have been categorised as environmental objectives. Here, agricultural policy and organisations and advisors have the most consistent and strongest positive impact on the objectives.

By linking the sustainability performance indicators with the sustainability assessment matrix, we are able to draw conclusion about which drivers of change are most important for policy decision-making process of a specific case study area. This allows us to not only inform how best to achieve the case study area-specific sustainability objectives, but also which drivers of change are most likely to positively influence the adoption rates of what are considered the most sustainable farming approaches. In the example of Flanders outlined above, we can see that agricultural policy, technology, and organisations and advisors are the key drivers of change most likely to have a positive influence on achieving the sustainability objectives. Likewise, these drivers of change are most likely to promote a high adoption rate of integrated/circular and/or low-input farming approaches in the area, which have been shown to be the most sustainable farming approaches.

Table 6. Sustainability assessment matrix assessed for a high-adoption scenario in the Flemish case study area of Hageland-Haspengouw, Belgium.

Sustainability dimension		Sustainability Objectives	Drivers of change						
			D_1	D_2	D_3	D_4	D_5	D_6	D_7
			Agricultural policy	Market conditions	Consumer demand	Technology	Organisations and advisors	Farmer demographics	Climate change
Social	1	To maintain and develop diverse, vibrant, creative, and locally distinctive communities, encouraging pride in the rural community and cohesion within it, recognising the needs and contributions of all individuals]	+	0	++	0	0	++	0
Environmental	2	To protect and restore natural carbon stores and increase carbon sequestration	++	+	+	++	++	+	++
Social	3	To minimise the fragmentation of residential areas by promoting the renovation of existing infrastructure as well as planning new infrastructure as compactly as possible	?	0	0	+	0	0	0
Environmental	4	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality (and the availability and continuity of the water supply)	++	+	0	++	++	0	+
Economic	5	To adapt to anticipated risks of shortages in the water supply for agriculture	++	-	0	++	++	0	++
Environmental	6	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity	++	+	+	++	++	+	+
Economic	7	To stimulate short-chain marketing of farming and food products	?	+	++	+	+	+	0
Social	8	To safely increase accessibility of services by foot and by bicycle	0	0	0	0	+	0	0
Social	9	To promote the development of (formal and / or informal) institutions or structures that allow members of the community to support each other, according to their own values and norms e.g. local associations and cooperatives	+	0	+	0	++	+	0
Social	10	To enable farmers to feel professional pride in their work, and reconcile the daily reality of being a farmer with their expectations / perceptions of their role / identity	+	++	++	+	++	+	0
Economic	11	To increase the potential for farming to be an economically viable option for making a living / managing land	++	++	++	++	++	++	-
Social	12	To sustainably maintain and restore hollow roads in consultation with farmers	++	0	0	0	++	0	0
Environmental	13	Targeted biodiversity initiatives which contribute to the experiencing of nature by those in the surrounding area	++	0	0	+	++	?	+
Social	14	To enable the agricultural sector, and wider society, to adapt to the effects of climate change which are already unavoidable	+	+	0	+	+	0	++
Social	15	To maintain / increase the quality of life, health, and well-being associated with the farming lifestyle and for the rural community, and minimise threats to public health	+	+	+	+	+	+	-
Social	16	To protect / improve the resilience of rural communities to change	-	0	0	+	+	0	?
Social	17	To ensure that landscape features of cultural heritage or aesthetic value are recognised, conserved, and enhanced	++	0	0	0	++	?	0
Environmental	18	To conserve and enhance natural biodiversity / protect endangered species	++	+	+	+	++	0	0

Environ-mental	**19**	To conserve, restore, and create semi-natural habitats and their connectivity (within and outside of protected sites), to establish and improve functional and resilient ecological networks	++	0	0	+	++	0	0
Economic	**20**	To reduce farm vulnerability to external events / increase the resilience of farm businesses	++	+	+	++	+	0	?

Note: ++ indicates a strong positive link between a driver of change and a sustainability objective, + indicates a positive link, 0 indicates no link, - indicates a negative link, -- indicates a strong negative link, and ? indicates an uncertain link between a driver of change and a sustainability objective.

4.3 Benefits and drawbacks of the proposed framework

The sustainability assessment framework presented here enables us to identify which farming approaches are most and least sustainable in a given region based on the definition of sustainability along three dimensions: economic, social, and environmental. By relying on a publicly available dataset (i.e., FADN) that is regularly updated, the framework is highly flexible and easy to adopt by interested parties outside of the LIFT project. By engaging local stakeholders in identifying the weights attributed to each of the considered sustainability dimensions, the framework not only benefits from incorporating insights from various actors with local expertise, but also from accounting for case study area-specific characteristics.

Upon presenting the framework to stakeholders in Belgium, Romania and the United Kingdom, a common point of feedback was the value of the framework for its ability to turn the complex web of dimensions underpinning sustainability into output that was simple enough to be useful for policy makers. The framework was seen as being straightforward, easy to use, and presentable to a non-technical audience, while also still acknowledging the multifaceted nature of agricultural sustainability. Amongst the English stakeholders consulted, farmers saw the framework as useful because they could envision it being used to help justify their personal farm management approaches in a regional context.

While incorporating weights for each sustainability dimension represents a strength of the framework, stakeholder consultation in Flanders and the United Kingdom raised some concerns on the distribution of these weights when multiple (averaged) indicators are used to evaluate a single dimension. Particularly, we use two indicators to evaluate the performance of farming approaches along the environmental dimension. While we initially distributed the weight for the environmental dimension equally between these two indicators, stakeholders raised some questions regarding this. Because the environmental 1 indicator is calculated based on FADN data, which relies on the use of external inputs to evaluate environmental performance, stakeholders suggested that this indicator should not be given an equal weight to the environmental 2 indicator. The latter evaluates environmental performance based on the potential supply of ESs. Stakeholders considered this a more appropriate approach to evaluate environmental performance. As such, they recommended a higher weight to be given to the environmental 2 indicator. However, stakeholder opinions on this seemed to differ depending on the case study area. Stakeholders consulted in Romania considered the equal distribution of the environmental dimension weight between the two indicators adequate as this way the dual nature of the inputs (FADN data and ESs) are equally captured. Other stakeholders in the United Kingdom said the distribution of weights should reflect the focus of the sustainability objectives. For example, if the sustainability objectives focussed more heavily on maintain ESs in an area, then more weight should be given to the ES-based environmental 2 indicator. As a result of these insights, we recommend that future applications of the framework are carried out through an iterative process, consulting with stakeholders at multiple stages along the assessment in order to reflect on the results. Particular attention should be paid to the distribution of the weights between the sustainability dimensions consisting of multiple indicators.

The stakeholders' concerns regarding the distribution of weights between the two environmental indicators arose from the consideration of FADN data as suboptimal for evaluating environmental performance. For example, stakeholders in the United Kingdom argued that the indicator 'fertiliser autonomy' (calculated based on fertiliser input data at the farm level) may not accurately reflect environmental performance as performance along this indicator may be poor not because farmers are applying high-input practices, but because they are taking advantage of low fertiliser prices.

Stakeholders expressed a similar opinion for the social dimension, questioning whether FADN data was the most appropriate to use in order to evaluate social performance. Some stakeholders stressed that they saw social sustainability performance mainly in terms of the health and well-being of farmers, rural communities, and the general public, and felt that these were overlooked in the current set of indicators. Despite these concerns, it was opted to use the FADN data in this analysis for two reasons. First, FADN data is very appropriate to evaluate economic performance. And while it is not preferred to evaluate environmental or social performance, we are able to demonstrate that supplementing the FADN-based indicators with indicators calculated from other, more appropriate data sources may provide an elegant way to account for this. One such alternative or supplementary data source to evaluate social performance of farming approaches may be primary data specifically collected from farmers, such as the LIFT large-scale farmer survey (Tzouramani et al., 2019) covering more than 1,600 farmers in 12 countries. Social performance may be more accurately evaluated due to specifically targeted questions answered by farmers directly. However, this dataset has a limited scope, it is a one-off and is not regularly updated. This highlights the second reason for which the FADN database was used in the framework. By employing a widely available database, we are able to expand the potential scope of the framework, gaining commensurable insights from across different case study areas.

A second concern regarding the dimension weights is their representativeness. As mentioned, weights were derived from the scoring of sustainability objectives by stakeholders in Matthews et al. (2022). However, this scoring exercise was not carried out with the idea of obtaining weights for this sustainability assessment framework in mind. As such, the approach adopted by the different partners may not have been ideal. For example, the number and type of stakeholders engaged in the exercise was not consistent across the case study areas, and the opportunity to jointly reflect on the weights was often not provided to the stakeholders. By engaging a large group of stakeholders, representative for the considered case study area, and by providing these stakeholders with the ability to jointly reflect on the weights attributed, the accuracy and representativeness of the dimension weights may be improved. As such, we once again highlight the need to engage stakeholders in reflecting on the different phases of the framework, paying particular attention to the dimension weights before any concrete conclusion are drawn.

As has been mentioned, the present framework is very flexible to different types of data inputs. We presented an example of the framework applied to the FADN data, however it should be noted that the framework can also be applied to other farm level data. The choice to demonstrate the capacity of the framework using the FADN data was made, as mentioned, because this dataset is widely available and was made specifically available to LIFT partners for their project research. However, it should be noted that the final step of the framework (step 5) – in which sustainability performance results of farming approaches are linked to the drivers of change – relies on results at the case study area level. In other words, the drivers of change have been linked to the sustainability objectives at the case study level, while the sustainability performance indicators were calculated at the larger region or country level (as allowed by the FADN data sample sizes). As such, care should be taken when interpreting the results of step 5. We neither recommend the use of the framework in its current state to draw concrete conclusions on the sustainability performance of farming approaches in Europe, nor do we advise its use, as it stands now, to inform policy decisions. Instead, the framework should be considered as one potential approach to homogenising the plethora of data and information that is available within and outside of the LIFT project. Before concrete application in the field of sustainability assessment and/or policy decision-making, the framework should be finetuned and the drawbacks highlighted above should be explored in more depth, preferably with the engagement of stakeholders.

5 Conclusion

In this deliverable we present a framework in which we incorporate output from farm and territorial level sustainability assessments to evaluate the overall sustainability performance of different farming approaches in Europe, considering economic, social and environmental performance dimensions. We consider the matches and mismatches between the two spatial levels by weighting the farm level performance of farming approaches across the three dimensions with weights reflecting the importance of each dimension at the territorial level. Weights are derived subjectively through stakeholder consultation, allowing a great deal of flexibility in the framework while ensuring results remain considerate of the case study area context.

While the framework's flexibility, along with its ability to capture a wide variety of complex underlying data in easily-interpreted output, is arguably one of its main benefits, there are a number of drawbacks that must be acknowledged. The use of FADN data to evaluate performance of farming approaches along social and environmental dimensions is perhaps the largest of these drawbacks. While we are able to partly compensate for this in the environmental sustainability dimension by supplementing the dimension with a second indicator evaluating environmental performance using ecosystem services, we have not done the same for the social dimension. As such, caution must be exercised when interpreting the sustainability performance results along the social dimension. The framework can be used to gain first insights on case study area-specific farming approach sustainability performance, but still requires considerable work before these results can be taken as fact and used in aiding policy decision-making. Nonetheless, consultation with stakeholders in three different LIFT case study areas indicated that there is potential, and interest, in the framework's capacity to aid in policy-making decisions. Stakeholders across all case study areas suggested that the framework may provide a useful starting point for initiating sensible debate between different perspectives of sustainability.

The framework is able to make a two-fold contribution to policy decision-making. First, it can be used to identify those farming approaches which are likely to have the best overall sustainability impact in an area. Second, the framework can be used to identify which key drivers of change should be targeted to increase adoption rates of the most sustainable farming approaches and ensure the sustainability objectives specific to a region are achieved.

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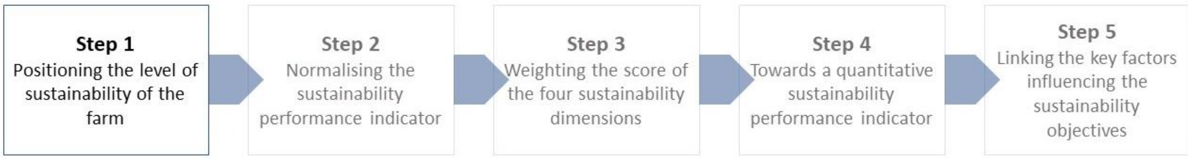
Appendix A

Table A1. Categorisation of farm management practices into farming approaches. X indicates practice is often associated with, but does not form a defining part of, the farming approach. XX indicates practice forms a defining part of the farming approach.

Farm management practice	Agroecological	Organic	Low-input	Integrated	Conservation	Standard
Agri-environmental schemes	X	XX	X	X		
Agroforestry	XX		X	X		
Alternative weed management	XX	XX	X	X		
Biological N fixation	XX	XX	X	XX		
Biological pest control	XX	XX	X	X		
Conservation tillage	X	X	X	X	X	
Cover crops	XX	XX	X	X	X	
Crop livestock integration	XX			X		
Crop residue management	XX	X	X	XX	XX	
Crop rotation	XX	XX	X	X	X	XX
Extensive livestock systems	XX	XX	XX			
Intercropping	XX	X				
Low agrochemical pesticide input			XX			
Low fertiliser input	X	X	XX	X		
Low mechanisation	X	X	X	X	XX	
Mulching	XX	XX	X	X	X	
Precision farming				X		XX
Selection of breeds	XX	X	X	X		
Semi-natural habitats	XX	X	X	X		
Spatial heterogeneity	XX	X	X	X		
Sustainable grazing	XX	X	X	X		
Sustainable water management	XX	X	X			
Use of chemical fertiliser inputs					XX	X
Use of chemical pesticide inputs					XX	X
Use of organic fertilisers	XX	XX		X		
Use of organic pesticides	XX	XX		X		

Appendix B

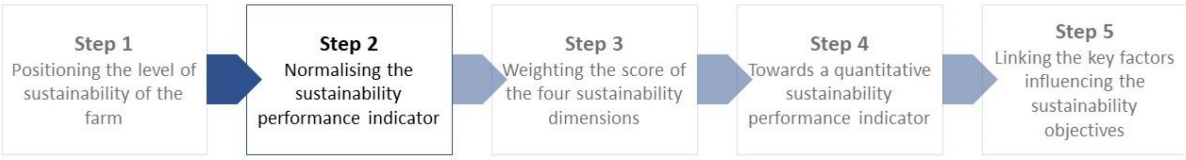
France



	Sustainabilit dimension indicators	Sustainability score				
		Standard	Integrated /circular	Low-input	Organic	Integrated/ circular AND organic
Economic	Profit incl. subsidies	0,00	0,40	11,65	0,25	14,86
	Profit excl. subsidies	0,00	-0,16	0,37	-0,14	0,86
	Profit excl. subs. and incl. costs of own production factors	0,00	-0,60	-0,18	-0,29	0,38
	Cashflow to assets ratio	0,00	0,06	0,51	0,46	0,75
	Net worth to assets ratio	0,00	0,48	0,31	-0,08	0,40
Social	Total labour	0,00	-0,48	-0,44	0,05	0,26
	Paid jobs	0,00	0,01	-0,02	0,09	0,65
	Labour productivity	0,00	-0,95	-0,84	-0,50	-0,38
Environmental	Feed autonomy (own feed)	0,00	0,91	0,50	0,55	0,85
	Feed autonomy (grass)	0,00	0,81	10,06	10,75	0,78
	Feed autonomy (concentrate)	0,00	13,86	11,00	0,24	15,51
	Fuel autonomy	0,00	-0,05	14,09	0,07	0,14
	Veterinary autonomy	0,00	0,30	0,85	0,50	0,75

Sustainability dimension	Standard	Integrate d/circular	Low-input	Organic	Integrate d/circular AND organic
Economic	0,00	0,04	2,53	0,04	3,45
Social	0,00	-0,48	-0,43	-0,12	0,18
Environmental 1	0,00	7,30	7,30	2,42	3,61
Environmental 2	0,27	0,89	0,56	1,05	0,86

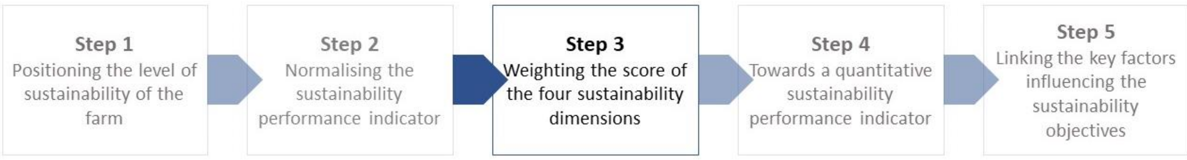
Figure B1. Step 1 of the sustainability assessment framework: Positioning the level of sustainability of the farm, as calculated for the French case study area. An average sustainability score per sustainability dimension for each farming approach is calculated.



Sustainability dimension	Standard	Integrate d/circular	Low-input	Organic	Integrate d/circular AND organic
Economic	0,00	0,04	2,53	0,04	3,45
Social	0,00	-0,48	-0,43	-0,12	0,18
Environmental 1	0,00	7,30	7,30	2,42	3,61
Environmental 2	0,27	0,89	0,56	1,05	0,86

Sustainability dimension	Standard	Integrated /circular	Low-input	Organic	Integrated /circular AND organic
Economic	0,73	0,00	0,06	0,55	1,00
Social	0,00	0,01	0,73	0,01	1,00
Environmental 1	0,00	1,00	1,00	0,33	0,49
Environmental 2	0,00	0,80	0,37	1,00	0,75

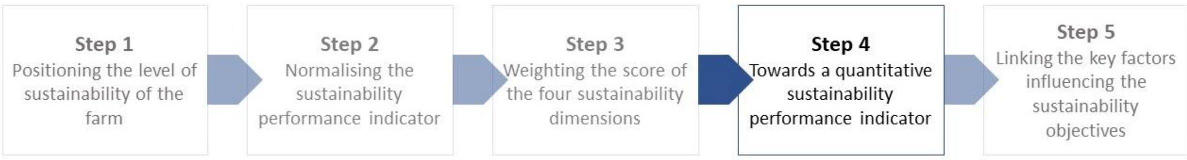
Figure B2. Step 2 of the sustainability assessment framework: Normalising the sustainability performance, as calculated for the French case study area. The average sustainability score is normalised per sustainability dimension to a scale of 0-1.



Sustainability dimension	Sustainability objective	Average weight per sustainability objective
Economic	36	1,50
Economic	37	1,80
Economic	38	1,71
Economic	39	1,67
...		
Social	18	1,78
Social	19	1,70
Social	20	1,71
Social	21	1,83
Social	22	1,43
...		
Environmental	1	1,60
Environmental	2	1,80
Environmental	3	1,60
Environmental	4	1,44
Environmental	5	1,50
...		

Average weight per sustainability dimension
1,61
1,55
1,73

Figure B3. Step 3 of the sustainability assessment framework: Weighting the score of the four sustainability dimensions, as calculated for the French case study area. An average weight per sustainability dimension is calculated using sustainability objectives.



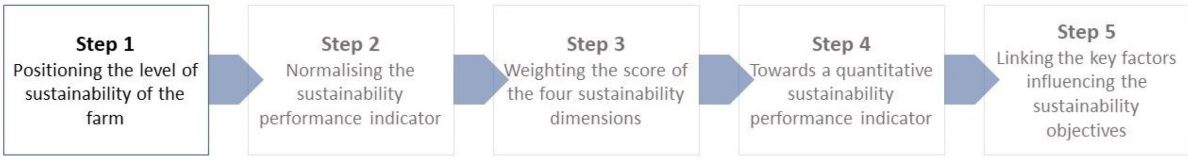
	Normalised sustainability score					
Sustainability dimension	Standard	Integrated /circular	Low-input	Organic	Integrated /circular AND organic	Average weight per sustainability dimension
Economic	0,73	0,00	0,06	0,55	1,00	1,55
Social	0,00	0,01	0,73	0,01	1,00	1,61
Environmental 1	0,00	1,00	1,00	0,33	0,49	0,87
Environmental 2	0,00	0,80	0,37	1,00	0,75	0,87

$$S_j = \frac{\sum_1^I x_{ij} w_i}{\sum_1^I w_i}$$

	final sustainability performance				
	Standard	Integrated/ circular	Low-input	Organic	Integrated /circular AND organic
Weighted average	0,23	0,32	0,50	0,41	0,87

Figure B4. Step 4 in the sustainability assessment framework: Towards a quantitative sustainability performance indicator, as calculated for the French case study area. A weighted aggregation is used to calculate the final sustainability performance for each farming approach based on the sustainability scores along the different sustainability dimensions.

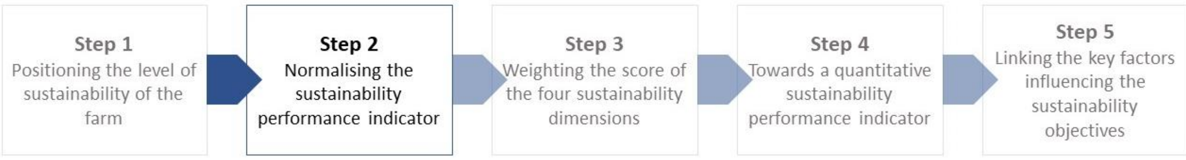
Austria



		Sustainability score			
	Sustainability dimension indicator	Standard	Integrated /circular	Organic	Integrated /circular AND organic
Economic	Profitability incl. subsidie:	0,00	0,38	0,48	1,18
	Profitability excl. subsidie	0,00	-0,04	0,03	0,40
	Profitability excl. subsidie	0,00	-0,73	-0,16	-0,30
	Cashflow / assets	0,00	-0,02	0,14	0,08
	Net worth / assets	0,00	0,28	0,04	0,27
Social	Total labour	0,00	-0,50	-0,26	-0,21
	Paid labour	0,00	-0,27	-0,04	-0,17
	Total labour / output	0,00	-0,79	-0,40	-0,70
Fertilisation	UAA for livestock	0,00	0,80	0,70	1,37
	Grassland share	0,00	0,22	0,72	0,49
	Concentrate feed	0,00	1,39	-0,18	1,34
	Fuel	0,00	0,09	0,07	-0,07
	Veterinary	0,00	0,46	0,20	0,65

	Average sustainability score			
Sustainability dimension	Standard	Integrated /circular	Organic	Integrated /circular AND organic
Economic	0,00	-0,03	0,11	0,33
Social	0,00	-0,52	-0,23	-0,36
Environmental 1	0,00	0,59	0,30	0,75
Environmental 2	0,33	1,08	1,32	1,04

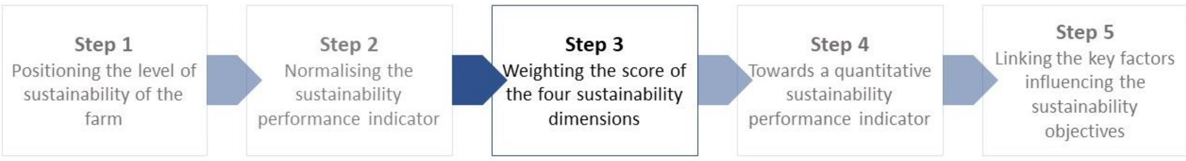
Figure B5. Step 1 of the sustainability assessment framework: Positioning the level of sustainability of the farm, as calculated for the Austrian case study area. An average sustainability score per sustainability dimension for each farming approach is calculated.



	Average sustainability score			
Sustainability dimension	Standard	Integrated /circular	Organic	Integrated /circular AND organic
Economic	0,00	-0,03	0,11	0,33
Social	0,00	-0,52	-0,23	-0,36
Environmental 1	0,00	0,59	0,30	0,75
Environmental 2	0,33	1,08	1,32	1,04

	Normalised sustainability score			
Sustainability dimension	Standard	Integrated /circular	Organic	Integrated /circular AND organic
Economic	0,07	0,00	0,37	1,00
Social	1,00	0,00	0,56	0,31
Environmental 1	0,00	0,79	0,40	1,00
Environmental 2	0,00	0,76	1,00	0,72

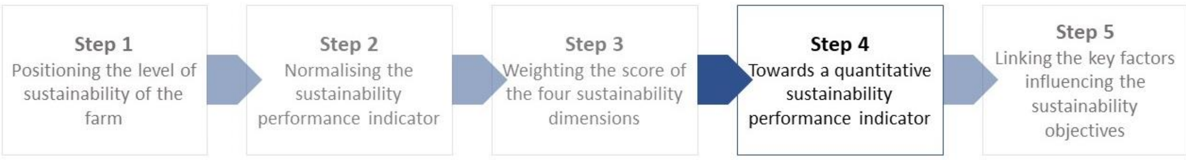
Figure B6. Step 2 of the sustainability assessment framework: Normalising the sustainability performance, as calculated for the Austrian case study area. The average sustainability score is normalised per sustainability dimension to a scale of 0-1.



Sustainability dimension	Sustainability objective	Average weight per sustainability objective
Economic	O_3	1,29
Economic	O_5	1,43
Economic	O_{10}	1,47
Economic	O_{15}	1,50
Social	O_1	1,21
Social	O_6	1,43
Social	O_8	1,47
Social	O_9	1,47
Social	O_{13}	1,50
Social	O_{16}	1,53
Environmental	O_2	1,29
Environmental	O_4	1,40
Environmental	O_7	1,46
Environmental	O_{11}	1,47
Environmental	O_{12}	1,50
Environmental	O_{14}	1,50

Average weight per sustainability dimension
1,42
1,44
1,43

Figure B7. Step 3 of the sustainability assessment framework: Weighting the score of the four sustainability dimensions, as calculated for the Austrian case study area. An average weight per sustainability dimension is calculated using sustainability objectives.



	Average sustainability score				
Sustainability dimension	Standard	Integrated /circular	Organic	Integrated /circular AND organic	Average weight per sustainability dimension
Economic	0,00	-0,03	0,11	0,33	1,42
Social	0,00	-0,52	-0,23	-0,36	1,43
Environmental 1	0,00	0,59	0,30	0,75	0,72
Environmental 2	0,33	1,08	1,32	1,04	0,72

$$S_j = \frac{\sum_1^I x_{ij} w_i}{\sum_1^I w_i}$$

	Final sustainability performance			
	Standard	Integrated /circular	Organic	Integrated /circular AND organic
Weighted average	0,36	0,26	0,54	0,72

Figure B8. Step 4 in the sustainability assessment framework: Towards a quantitative sustainability performance indicator, as calculated for the Austrian case study area. A weighted aggregation is used to calculate the final sustainability performance for each farming approach based on the sustainability scores along the different sustainability dimensions.

Romania

Step 1	Step 2	Step 3	Step 4	Step 5
Positioning the level of sustainability of the farm	Normalising the sustainability performance indicator	Weighting the score of the four sustainability dimensions	Towards a quantitative sustainability performance indicator	Linking the key factors influencing the sustainability objectives

	Sustainability dimension indicators	Sustainability score			
		Standard	Integrated /circular	Low-input	Low-input AND integrated/circular
Economic	Profitability incl. subsidies	0,00	-0,48	1,22	1,13
	Profitability excl. subsidies	0,00	-0,54	1,23	0,94
	Profitability excl. subsidies and incl. costs of own production factors	0,00	-0,86	0,82	0,69
	Cashflow / assets	0,00	-0,48	0,87	1,35
	Net worth / assets	0,00	0,12	0,12	0,19
Social	Total labour (AWU)	0,00	-0,25	0,01	0,00
	Paid labour (persons)	0,00	-0,21	-0,08	0,02
	Total labour / output	0,00	-0,61	-0,18	0,05
Environmental	UAA for livestock	0,00	0,67	-0,21	0,67
	Grassland share	0,00	1,08	0,05	1,19
	Concentrate feed	0,00	0,30	0,02	0,43
	Fuel	0,00	-0,76	0,75	0,59
	Veterinary	0,00	-0,47	0,34	0,18

Sustainability dimension	Average sustainability score			
	Standard	Integrated /circular	Low-input	Low-input AND integrated/circular
Economic	0,00	-0,45	0,85	0,86
Social	0,00	-0,36	-0,08	0,02
Environmental 1	0,00	0,16	0,19	0,61
Environmental 2	0,19	0,77	0,57	0,66

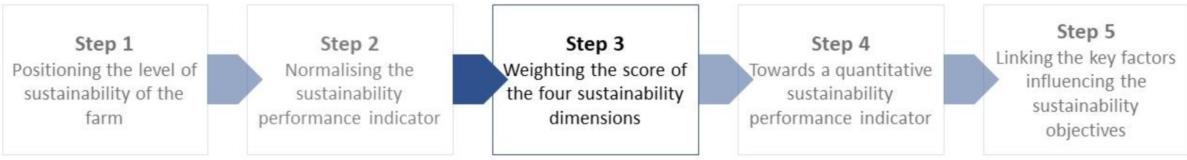
Figure B9. Step 1 of the sustainability assessment framework: Positioning the level of sustainability of the farm, as calculated for the Romanian case study area. An average sustainability score per sustainability dimension for each farming approach is calculated.

Step 1	Step 2	Step 3	Step 4	Step 5
Positioning the level of sustainability of the farm	Normalising the sustainability performance indicator	Weighting the score of the four sustainability dimensions	Towards a quantitative sustainability performance indicator	Linking the key factors influencing the sustainability objectives

Sustainability dimension	Average sustainability score			
	Standard	Integrated /circular	Low-input	Low-input AND integrated/circular
Economic	0,00	-0,45	0,85	0,86
Social	0,00	-0,36	-0,08	0,02
Environmental 1	0,00	0,16	0,19	0,61
Environmental 2	0,19	0,77	0,57	0,66

Sustainability dimension	Normalised sustainability score			
	Standard	Integrated /circular	Low-input	Low-input AND integrated/circular
Economic	0,34	0,00	0,99	1,00
Social	0,94	0,00	0,72	1,00
Environmental 1	0,00	0,26	0,31	1,00
Environmental 2	0,00	1,00	0,66	0,81

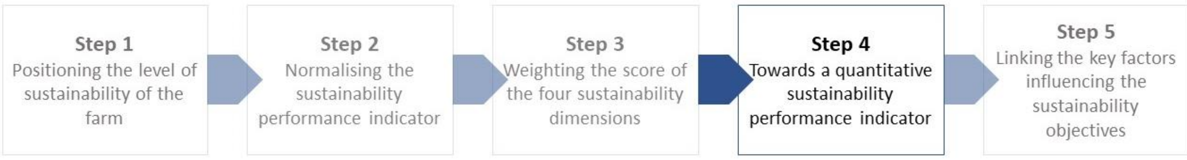
Figure B10. Step 2 of the sustainability assessment framework: Normalising the sustainability performance, as calculated for the Romanian case study area. The average sustainability score is normalised per sustainability dimension to a scale of 0-1.



Sustainability dimension	Sustainability objective	Average weight per sustainability objective
Economic	4	1,05
Economic	18	1,19
Economic	19	1,24
Social	1	1,00
Social	7	1,09
Social	8	1,13
Social	9	1,13
Social	11	1,09
Social	20	1,24
Environmental	2	1,00
Environmental	3	1,04
Environmental	5	1,09
Environmental	6	1,09
Environmental	10	1,14
Environmental	12	1,09
Environmental	13	1,18
Environmental	14	1,18
Environmental	15	1,22
Environmental	16	1,14
Environmental	17	1,10

Average weight per sustainability dimension
1,16
1,11
1,12

Figure B11. Step 3 of the sustainability assessment framework: Weighting the score of the four sustainability dimensions, as calculated for the Romanian case study area. An average weight per sustainability dimension is calculated using sustainability objectives.



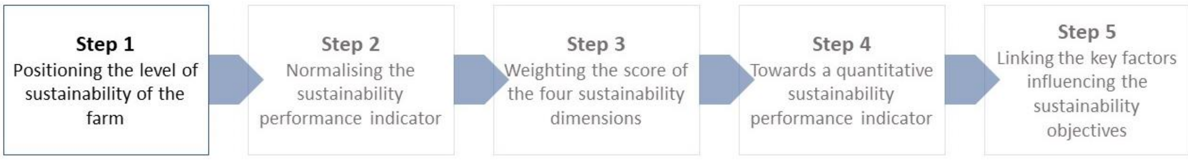
	Normalised sustainability score				
Sustainability dimension	Standard	Integrated /circular	Low-input	Low-input AND integrated/circular	Average weight per sustainability dimension
Economic	0,34	0,00	0,99	1,00	1,16
Social	0,94	0,00	0,72	1,00	1,11
Environmental 1	0,00	0,26	0,31	1,00	0,56
Environmental 2	0,00	1,00	0,66	0,81	0,56

$$S_j = \frac{\sum_1^I x_{ij} w_i}{\sum_1^I w_i}$$

	final sustainability performance			
	Standard	Integrated /circular	Low-input	Low-input AND integrated/circular
Weighted average	0,42	0,21	0,74	0,97

Figure B12. Step 4 in the sustainability assessment framework: Towards a quantitative sustainability performance indicator, as calculated for the Romanian case study area. A weighted aggregation is used to calculate the final sustainability performance for each farming approach based on the sustainability scores along the different sustainability dimensions.

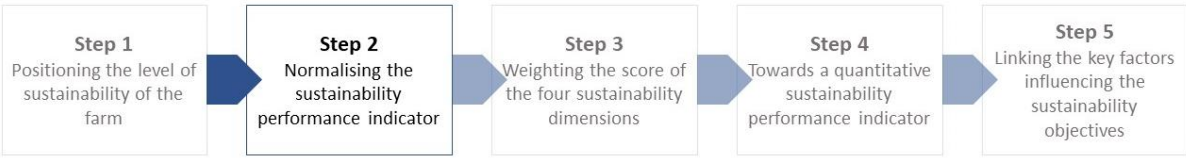
United Kingdom



		Sustainability score		
	Sustainability dimension indicators	Standard	Low-input	Low-input AND organic
Economic	Profitability incl. subsidies	0,00	0,05	0,05
	Profitability excl. subsidies	0,00	-0,32	-0,92
	Profitability excl. subsidies and incl. costs of own production factors	0,00	-0,22	-0,07
	Cashflow / assets	0,00	0,09	-0,18
	Net worth / assets	0,00	0,18	0,03
Social	Total labour	0,00	-0,24	-0,02
	Paid labour	0,00	-0,27	-0,05
	Total labour / output	0,00	0,13	-0,24
Environmental	Fertilisation	0,00	0,81	1,87
	Plant protection	0,00	0,73	1,35
	Fuel	0,00	0,86	1,13
	Fallow land	0,00	0,50	1,18

	Average sustainability score		
Sustainability dimension	Standard	Low-input	Low-input AND organic
Economic	0,00	-0,05	-0,22
Social	0,00	-0,13	-0,10
Environmental 1	0,00	0,73	1,38
Environmental 2	0,30	0,84	0,91

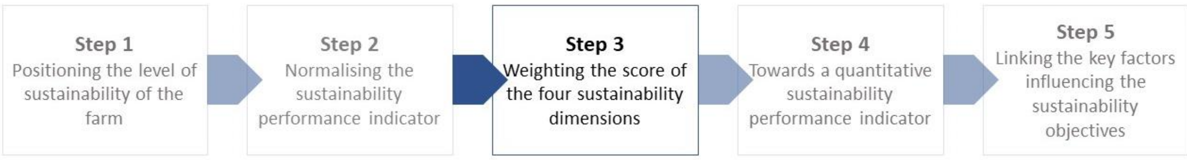
Figure B13. Step 1 of the sustainability assessment framework: Positioning the level of sustainability of the farm, as calculated for the United Kingdom case study area. An average sustainability score per sustainability dimension for each farming approach is calculated.



	Average sustainability score		
Sustainability dimension	Standard	Low-input	Low-input AND organic
Economic	0,00	-0,05	-0,22
Social	0,00	-0,13	-0,10
Environmental 1	0,00	0,73	1,38
Environmental 2	0,30	0,84	0,91

	Normalised sustainability score		
Sustainability dimension	Standard	Low-input	Low-input AND organic
Economic	1,00	0,79	0,00
Social	1,00	0,00	0,19
Environmental 1	0,00	0,52	1,00
Environmental 2	0,00	0,89	1,00

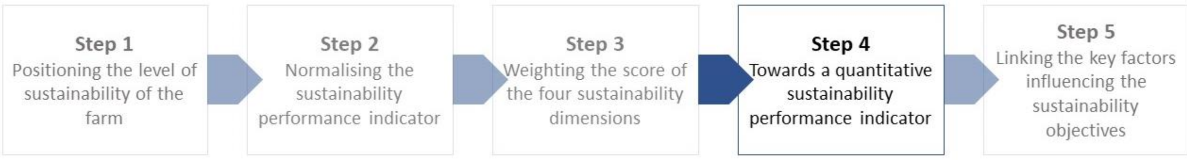
Figure B14. Step 2 of the sustainability assessment framework: Normalising the sustainability performance, as calculated for the United Kingdom case study area. The average sustainability score is normalised per sustainability dimension to a scale of 0-1.



Sustainability dimension	Sustainability objective	Average weight per sustainability objective
Economic	12	1,86
Economic	13	2,00
Economic	15	1,77
Economic	2	1,67
Economic	18	1,53
Social	2	1,82
Social	3	1,86
Social	7	1,58
Social	8	1,33
Social	9	1,55
Social	14	1,25
Social	16	1,45
Social	17	1,26
Social	18	1,15
Environmental	1	1,38
Environmental	4	1,95
Environmental	5	1,43
Environmental	6	1,22
Environmental	10	1,42
Environmental	11	1,53
Environmental	1	1,50

Average weight per sustainability dimension
1,74
1,47
1,42

Figure B15. Step 3 of the sustainability assessment framework: Weighting the score of the four sustainability dimensions, as calculated for the United Kingdom case study area. An average weight per sustainability dimension is calculated using sustainability objectives.



	Normalised sustainability score			Average weight per sustainability dimension
Sustainability dimension	Standard	Low-input	Low-input AND organic	
Economic	1,00	0,79	0,00	1,74
Social	1,00	0,00	0,19	1,47
Environmental 1	0,00	0,52	1,00	0,71
Environmental 2	0,00	0,89	1,00	0,71

$$S_j = \frac{\sum_1^I x_{ij} w_i}{\sum_1^I w_i}$$

	Final sustainability performance		
	Standard	Low-input	Low-input AND organic
Weighted average	0,69	0,51	0,37

Figure B16. Step 4 in the sustainability assessment framework: Towards a quantitative sustainability performance indicator, as calculated for the United Kingdom case study area. A weighted aggregation is used to calculate the final sustainability performance for each farming approach based on the sustainability scores along the different sustainability dimensions.