LIFT

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

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Farm level 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 farm systems 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, Department für Wirtschafts- und Sozialwissenschaften, Institut fuer Agrar- und Forstoekonomie	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

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List of acronyms and abbreviations

AEP:	Agri-environmental performance
AWU:	Annual working units
ESs:	Ecosystem Services
EU:	European Union
FADN:	Farm accountancy data network
FMPs:	Farm management practices
FP:	Factorial plan
FSDN:	Farm sustainability data network
GWP:	Global warming potential
LFA:	Less-favoured area
LSU:	Livestock unit
NUTS:	Nomenclature of territorial units for statistics
NRW:	North Rhine-Westphalia
PI:	Performance indicator
PCA:	Principal component analysis
RCR:	Revenue cost ratio
REA:	Rapid evidence assessment
SD:	Standard Deviation
SMA:	Societal metabolism accounting
TF:	Type of farming
TSG:	Traditional speciality guaranteed
UAA:	Utilised agricultural area
UK:	United Kingdom
WP:	Workpackage

1 Summary

In light of the ambitions of the European Union (EU) to achieve an ecological transition of its agricultural sector it is crucial to assess and continuously monitor (i) the uptake of main ecological approaches by farms and (ii) associated effects on farm performance, considering all sustainability dimensions (economic, environmental, social) jointly. Given these needs, in the present deliverable D5.1 of the LIFT project, we develop a novel indicator system, which combines the LIFT farm typology and farm performance data, covering all sustainability dimensions. The approach compares performance of farms in five ecological groups (referred to as ecological farming approaches or ecological farming systems) from the LIFT farm typology (Conservation Agriculture, Low-Input farming, Integrated/Circular farming, Organic farming, Agroecology) as well as possible combinations of these groups with a less ecological group, referred to as Standard farming. This allows us to depict whether ecological farms perform differently or have different trade-offs and synergies than standard farms. Based on this system, we carry out a farm sustainability performance assessment with the two main data sources in the LIFT project, namely Farm Accountancy Data Network (FADN) data and data from the LIFT large-scale farmer survey, covering main farm types present in the European Union (EU) in several case study regions/countries. Additionally, we present in-depth analyses of further specific aspects, namely (i) the extension of the developed indicator framework to bio-economic models, (ii) the integration of the consumption and provision of ecosystem services into the developed indicator system through composite agri-environmental performance (AEP) indicators, derived from the body of secondary literature and region-specific stakeholder input, and (iii) working conditions and employment on farms in the context of an ecological transition.

Overall, our results show the importance of considering trade-offs and synergies both within and between farm sustainability dimensions, in the assessment of farm level sustainability performance of ecological farming approaches. Our results also highlight that in many cases the effects of an increasing uptake of ecological approaches are heterogenous and need to be investigated further. We clearly point out the assumptions associated with our approach as well as its limitations. Given these limitations, the LIFT farm sustainability performance assessment developed here is nevertheless well suited for large-scale and long-term monitoring. This is based on readily available FADN data and, in the near future, could be based on Farm Sustainability Data Network (FSDN) data, providing an in-depth exploratory view for policy makers and researchers regarding farm level sustainability performance of ecological approaches in the EU farming sector. We outline several possible avenues for further research, namely (i) the inclusion of other data sources, (ii) the usage of econometric methods to facilitate causal inference, (iii) the broader usage of the developed composite AEP indicators, and (iv) further in-depth studies regarding the social sustainability dimension. Finally, in terms of policy recommendations we point out the importance of (i) flexible policy measures, able to properly address region-specific needs of farms, (ii) sound data as a basis for evidence-based policy, and (iii) investigating the ecological transition of the EU farming sector in more detail also at regional level, e.g. via living labs.

2 Introduction

This document presents results of Task 5.1 (Assessment of farm level sustainability of ecological farming) in workpackage (WP) 5 (Integrative analysis: trade-offs and synergies) of the LIFT project, and has been edited by Andreas Niedermayr, Marie Kohrs, Lena Schaller and Jochen Kantelhardt (all BOKU, Austria) who have also written chapters 1-3, sections 4.1.1, 4.2.1 and chapter 6. The authors of other chapters/sections are named at the beginning of the respective chapter/section.

The European Green Deal[1] sets out ambitious goals of the European Union (EU) with respect to tackling pressing problems like climate change and biodiversity loss. For the agricultural sector, the Farm to Fork strategy[2] addresses these issues. It aims at an ecological transition of food systems, which should, inter alia, reduce the environmental and climate impact of agricultural production, while at the same time ensuring fair economic returns for farms. In order to achieve these goals, the broad adoption of farming practices associated with positive environmental impacts by farms plays a key role. However, it is crucial to assess and continuously monitor this aspired transition of the agricultural sector and its effects on farms, not only from an environmental perspective, but also considering economic and social implications.

A major data base, which allows to assess the impact of European policies related to agriculture and which is also used in task 5.1, is the European Farm Accountancy Data Network (FADN)[3]. FADN consists of an annual survey of a sample of farms, representative of commercial farms in the EU. However, as FADN provides primarily economic data it is planned to convert FADN into a Farm Sustainability Network (FSDN)[4], expanding its scope in terms of environmental and social information. This should improve possibilities to analyse for example the uptake of ecological farming practices by farmers and its economic, environmental and social effects at the farm level.

In this context, the overall aim of Task 5.1 of the LIFT project is to assess farm level sustainability of ecological farming, considering different degrees of uptake of ecological practices. Specifically, this entails

(a) the development of an indicator system at the farm level, integrating all performance dimensions (technical-economic, environmental, private-social as well as employment effects) jointly,

(b) the application of this indicator system to farm level data, for an integrative assessment of farm performance, in order to uncover potential trade-offs and synergies associated with an increasing uptake of ecological practices,

(c) the consideration of farmers' private social sustainability (e.g. stress, working conditions, quality of life) and employment in this context, and

(d) the development of a system able to integrate indicators describing the demand (consumption) and supply (provision) of ecosystem services (including ones with public good characteristics) in the measurement of farm performance and combining it with the indicator system from (a) for an extended assessment of overall farm performance.

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[2] https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_de
[3] https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/farms-farming-and-innovation/structures-and-economics/economics/fadn_en
[4] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12951-Conversion-to-a-Farm-Sustainability-Data-Network-FSDN-_en

Such an integrative analysis of farm performance, considering all performance dimensions jointly, generates valuable insights regarding farm level sustainability performance of ecological agriculture in the EU.

The present deliverable breaks this task down as follows: chapter 3 presents the developed indicator system from point (a) above. The system is based on input from **scientific literature, various stakeholders** as well as from LIFT **WPs 1-3** and the **data used in these WPs**. Regarding this last aspect, the system provides a flexible framework which is on the one hand directly applicable to incorporate the **LIFT farm typology protocols** from LIFT WP1 (Rega et al., 2021), **LIFT large-scale farmer survey data** from LIFT WP2 (Tzouramani et al., 2019) and **FADN data** used in LIFT WP3, but can on the other hand be also extended to incorporate other data sources (e.g. extending it to include further/different performance indicators). This is of particular relevance in the context of the conversion of FADN to FSDN. In general, the framework is based on two steps: In the first step, farms are classified according to the farming approaches (farming systems)[5] from the LIFT farm typology and/or combinations thereof, reflecting **different degrees of uptake of ecological practices**. This provides a first valuable overview regarding the absence or presence and share of various farming approaches in the analysed data. In the second step, **sustainability performance** of these resulting groups is assessed with the indicator system and a **comparison between the identified farming approaches** is carried out, depicted with spider web diagrams, using the Standard farming approach as a benchmark for the other farming approaches. This allows to gain first exploratory insights, regarding relative changes in farm sustainability performance, associated with an increasing uptake of ecological approaches by farms.

Chapter 4 comprises point (b) from above. Here, the developed indicator system from chapter 3 is applied to empirical data, covering the **major farm types** present in the EU in **several case study regions/countries**. The chapter is divided into two sections, where the first one covers **analyses based on FADN data** and the second one **analyses based on LIFT large-scale farmer survey data**. In terms of farm types, the analyses cover different types of arable farms (e.g. cereal, oil and protein crops, other field crops), livestock farms (dairy, beef, sheep, other cattle and granivores), as well as permanent crop farms (olive, fruit).

Chapter 5 deals with further specific aspects, presented in three sections, namely (i) the extension of the developed indicator framework to **bio-economic models**, (ii) the integration of the **consumption and provision of ecosystem services** into the developed indicator system and finally (iii) **working conditions and employment on farms** in the context of an ecological transition.

The first section 5.1 presents an overall assessment of farm performance similar to that from chapter 4, but based on **bio-economic modelling**. In contrast to the analyses in chapter 4, which are all based on an ex-post comparison of farms, adopting different ecological approaches, bio-economic modelling is able to ex-ante simulate a **stepwise increasing degree of uptake of ecological approaches** by farms and the resulting **causal effects** on different aspects of **farm level sustainability**. Additionally, this modelling approach allows to include more detailed farm-level performance indicators, compared to those in chapter 4, particularly in the environmental- and labour-related performance dimensions and thus shows, how the developed framework from chapter 3 can be extended to different data sources. Empirically, the analysis investigates a stepwise conversion to conservation agriculture for eight typical case study farms in North Rhine-Westphalia, Germany.

[5] We want to highlight that we use the terms 'farming approach' and 'farming system' interchangeably. Both terms refer to combinations of individual farming practices, according to certain ecological criteria. See Rega et al. (2021) for more information.

The second section 5.2 presents the integration of **supply of and demand for ecosystem services** (point (d) from above). Specifically, a system is developed, where the spider webs from chapter 3 are supplemented with further **composite environmental indicators**, reflecting overall supply and region-specific demand of ecosystem services, associated with the different farming approaches.

The third section 5.3 shows a detailed analysis of farmer's private social sustainability (point (c) from above), applied to specialist dairy farms or dairy and cattle farms in a few European case studies. This analysis presents firstly an **assessment of working conditions and employment on farms** for French dairy and cattle farms. Then, the section investigates how **specific aspects of working conditions** are related to the **uptake of ecological approaches**, based on an analysis of dairy farms from four case study regions in Austria and France.

In the final chapter of the deliverable, we summarise and critically discuss the overall results and provide concluding remarks and policy recommendations.

3 Performance indicator system, reflecting all performance dimensions jointly

In this chapter we develop an indicator system which considers all performance dimensions jointly. In the first section, we provide a concise overview of already existing sustainability assessment approaches, indicators and data sources used in an agricultural context, based on scientific literature. The second section first presents our developed system (LIFT farm sustainability performance assessment), describing first our overall methodological approach before outlining two distinct sets of indicators, one used for FADN data and one used for LIFT large-scale farmer survey data.

3.1 Overview of existing approaches

The assessment of farm level sustainability has gained immense interest in the scientific literature in recent years, which has led to a "flood" of indicators and indicator systems and tools. Despite this, there is no universal definition of farm level sustainability and sustainability dimensions. However, more recently, several contributions have provided overviews of the current state of the sustainability discussion (see e.g. Binder et al., 2010; Lebacq et al., 2013; Latruffe et al., 2016; Olde et al., 2016; van der Linden et al., 2020; Chopin et al., 2021).

Chopin et al. (2021) provide a particularly broad and very recent meta-analysis, covering more than 100 papers, where they use a classification framework from Binder et al. (2010) to characterise the analysed approaches according to three overarching dimensions (normative, procedural and systemic). An overview of these dimensions and associated criteria is given in Table 1, which is taken from Chopin et al. (2021) and slightly modified for usage in this deliverable:

- The normative dimension refers to characteristics such as the view on sustainability or the assessment type. The view on sustainability is related to the conceptualisation or sustainability, where the authors differentiate between a view that is either goal orientated (i.e. a farm has to achieve some objective or result to be considered as sustainable) or means orientated (i.e. it is assumed that there are certain relations between what a farm does and some desired impact) (see e.g. Lampridi et al. (2019) for more information on this topic). The assessment type ranges from life cycle assessment, bio-economic farm models (van der Linden et al., 2020) or indicator-based approaches (Gómez-Limón and Sanchez-Fernandez, 2010; Ssebunya et al., 2019) to efficiency-based approaches (Ait Sidhoum et al., 2019), e.g. using data envelopment analysis (Cherchye et al., 2007; Zhou et al., 2018).
- The procedural dimension is related to aspects such as the overall tool function, the type of data used and mode of data collection, indicator complexity or time for data collection.
- Finally, the systemic dimension describes, how indicators are connected to each other (e.g. via aggregation and weighting).

Based on these characteristics of the investigated studies in Table 1, Chopin et al. (2021) group together studies with similar combinations of characteristics through statistical approaches and identify 5 different types of sustainability assessment approaches at farm level.

The first group (12 studies) is referred to as long-term monitoring of farm activities and mostly encompasses approaches which collect detailed farm data via surveys and field measurements over a longer time span. While such approaches allow for very detailed analyses, they are also very resource demanding in terms of data collection, limiting the number of farms which can be analysed.

The second group is made up of 10 studies and summarises studies carrying out ex-ante assessments of farm sustainability with bio-economic models (see also van der Linden et al. (2020) for a recent overview of such models). Bio-economic models allow a very detailed bottom-up modelling of farms and are often used for policy advice. Similar to the first group this results however in an overall higher resource demand in terms of data collection and such models are usually relatively complex.

The third and largest group (43 studies) consists of survey- and indicator-based assessment tools, which are mostly collecting data either through surveys or directly from already existing data sources. This data is then used to calculate various indicators, which are less complex and the overall time requirement for data collection is also lower.

Table 1: Description of farm sustainability assessments from Chopin et al. (2021)

Dimension	Variable name	Levels (number of studies with respective level)
Normative	View on sustainability	Goal-oriented (58); means-oriented (22); both (26)
	Orientation of the tool	Top-down (83); bottom-up (12); both (11)
	Assessment type	Efficiency (10); Analytic hierarchy process (5); Bio-economic farm model (6); Energy and Life cycle assessment (6); expertise (6); indicator-based (68); simulation (5)
	System existence	Ex-ante (5); ex-post (85); both (16)
Procedural	Tool function	Strengths and weaknesses (46); Research (6); Policy advice (11); Strengths and weaknesses and Research (7); Strengths and weaknesses and Policy advice (19); Policy advice and Research (7); Multi-purpose (10)
	Stakeholder involvement	No involvement (66); consultation (23); active (17)
	Indicator selection	Literature (77); expert consultation (11); participatory (18)
	Type of data	Quantitative (61); qualitative (10); both (35)
	Data collection	Database (14); self-recording (10); collective definition (11); farm surveys (51); farm surveys and field measurements (17)
	Complexity of indicator	Low (56); medium (38); high (12)
	Time for data collection	Low (50); medium (33); high (23)
Systemic	Indicator interaction	Yes (32); no (74)
	Aggregation	Yes (45); no (61)
	Weighing	Yes (39); no (67)

Source: table taken from Chopin et al. (2021), modified.

The fourth group (26 studies) is called consultation-based assessment and is also mostly based on indicators, but relies more on stakeholder consultations for indicator selection and sustainability framing. The data used is quantitative as well as qualitative and often also comes directly from experts. Some approaches also combine different sustainability assessment tools (see e.g. Landert et al. (2020)). An overview of such approaches, as well as approaches from the third group for some part, is also provided by Olde et al. (2016). In general, such tools can have a different thematic focus, leading also to potentially differing outcomes in sustainability assessments of identical farms (Olde et al., 2017).

The fifth and final group (15 studies) is named active engagement of stakeholder-based assessment. As the name suggests these studies rely even more on stakeholders than in group 4 in a participatory approach at various stages throughout the sustainability assessment. The data used is often more qualitative (e.g. subjective ratings of farm performance on an ordinal scale). The advantage of such approaches is that they can be very fine-tailored to region-specific problems due to stakeholder knowledge. At the same time, it becomes more difficult to ensure comparability of such an assessment over different case study regions.

As can be seen from this overview of studies, in terms of assessment type, indicator-based approaches are dominating in the literature. In the context of LIFT and the main data sources used in the project, such approaches seem most promising. In what follows, we thus provide an overview regarding sustainability indicators at the farm level, based on the very comprehensive reviews of Lebacq et al. (2013) and Latruffe et al. (2016) as well as an overview regarding the usage of FADN data for calculation of such indicators. In general, such indicators can be categorised according to the three classical sustainability dimensions: economic sustainability, environmental sustainability and social sustainability (Latruffe et al., 2016):

- Economic sustainability indicators

  These indicators refer to the long-term viability of farms, which is in general assessed via profitability, liquidity, stability and productivity (Latruffe et al., 2016). Profitability indicators refer to profit and farm income (e.g. net farm income, gross margin, etc.). Given detailed economic data, such indicators can be adjusted to reflect various nuances contributing to profitability, e.g. including or excluding public payments, costs of own production factors, variable costs or fixed costs. Additionally, indicators can be expressed in absolute terms (e.g. farm income in respective currency) or as ratios (e.g. revenues divided by costs). Liquidity refers to the availability of liquid assets (cash) and is also an important aspect with respect to the economic sustainability dimension, in particular concerning investments, repayments of debts and short-term payment of current bills. Stability indicators relate to the ownership structure of farm capital and are often expressed as ratios (e.g. equity to assets ratio or debt to assets ratio). Finally, productivity indicators mostly relate to either partial productivity indicators (e.g. output per unit of land, labour, capital) or productivity/efficiency indicators such as total factor productivity or technical efficiency.

- Environmental sustainability indicators

  These indicators can be categorised into different groups according to what is measured. Lebacq et al. (2013) differentiate between means-based indicators, which relate to technical means and input use on farms (e.g. stocking density, fertiliser use per unit of agricultural land, etc.), effect-based indicators, which reflect the actual environmental outcomes, related to farming (e.g. biodiversity, nitrate concentration in groundwater) and intermediate indicators, which can be further classified as system state indicators and emission indicators. Lebacq et al. (2013) also point out a certain trade-off between the use of means-based and effect-based indicators with respect to data availability (low vs. high) and environmental relevance (high vs. low).

- Social sustainability indicators

  These indicators can be categorised into internal or private (related to the farming community, such as quality of life, well-being, etc.) and external or public (related to society, such as contribution of farms to cultural heritage or vitality of rural regions) indicators (Lebacq et al., 2013). Indicators related to farm labour and employment (e.g. workforce composition and qualification) also fall into the category of social indicators.

- FADN data for sustainability assessments

  FADN data, which is one of the central data sources to be used within LIFT, is also used for sustainability assessment of farms in the scientific literature. Despite the pan-EU nature of FADN, such analyses mostly cover individual countries, partly integrating further national/regional data sources into their analyses (e.g. Barnes and Thomson, 2014). Recently, aggregated FADN data at country level has also been used to assess sustainability of agricultural production states by combining it with societal metabolism accounting (SMA) (Matthews et al., 2021). In the context of FADN-based sustainability indicators, Kelly et al. (2018) provide a general overview of the suitability of FADN data and of studies using FADN data for this purpose. They conclude that FADN has very comprehensive economic information, offering a broad range of already readily available indicators and the possibility to calculate numerous further indicators. At the same time they also conclude that FADN offers only very limited data with respect to the environmental and social sustainability dimension. However, since FADN is currently in a transition to FSDN, this will improve information with respect to these two sustainability dimensions in the near future. Kelly et al. (2018) provide also several recommendations on which data to add in the context of this transition.

3.2 LIFT farm sustainability performance assessment

3.2.1 Methodological approach

The LIFT sustainability performance assessment is indicator-based and relies on a means-orientated view of sustainability. Specifically, we analyse farm performance, based on different quantitative performance indicators and make implicit assumptions about how these indicators relate to desired outcomes such as economic viability of farms, positive environmental effects or labour demand. This also means, we do not define target values for the performance indicators included in our assessment, which a farm has to reach to be considered as sustainable.

Despite this, the indicator system allows to compare the performance of farms relative to other farms, based on their degree of uptake of ecological practices. By investigating all performance dimensions considered within LIFT (technical-economic, private social, employment and environmental) in this manner jointly, we arrive at what we denote as farm level sustainability performance or farm level sustainability in the further text.

As FADN data is one of the central databases used within the LIFT project for sustainability assessment of farms, the farm sustainability assessment system developed in LIFT and presented here is flexibly adjustable to incorporate new data, particularly in course of the upcoming transition of FADN to FSDN. In this context, the evident weaknesses of FADN with respect to environmental and social sustainability data as outlined in the previous section need to be acknowledged. At the same time, our sustainability assessment system is based on readily available data and is easy to apply, so that it can be used for a broad range of use cases, such as long-term monitoring of the uptake of ecological approaches (e.g. shares of farms having adopted such approaches) and their relative sustainability or identification of synergies and trade-offs within and between sustainability dimensions. Also, since within the LIFT project data from other sources (e.g. the LIFT large-scale farmer survey) is also available, the system is also flexible in terms of the data source used.

Overall, our methodological approach consists of a four-step approach, as outlined in Figure 1.

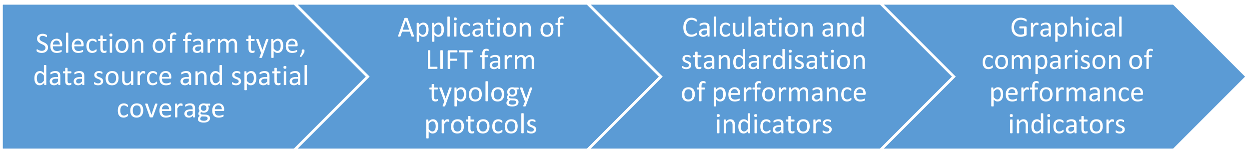

Figure 1: Four-step approach of LIFT farm sustainability performance assessment

3.2.1.1 Selection of farm type, data source and spatial coverage

In the first step, a farm type and a data source are selected. We focus on one farm type at a time, as the performance levels of, as well as trade-offs and synergies associated with, ecological farming approaches may differ to a considerable degree, depending on the farm type and spatial coverage of the analysis (Azad and Ancev, 2010; Matthews et al., 2021). Theoretically, the approach could also pool various farm types and/or countries /regions together, but the more heterogenous such a dataset, the harder it becomes to interpret results. In terms of data we predominantly consider on the one hand secondary data from the FADN[6], which was managed in LIFT WP3, and on the other hand primary data from the LIFT large-scale farmer survey, which was collected and managed in LIFT WP2. Compared to FADN, the LIFT large-scale farmer survey database offers some more detailed data, in particular regarding the adoption of farming practices, as well as further ecological, labour-related and social data on farms throughout various case-studies covered within LIFT (Tzouramani et al., 2019).

3.2.1.2 Application of LIFT farm typology protocols

In the second step the farming approaches (or farming systems) of the LIFT farm typology developed in WP1, are identified with the data (see Rega et al., 2021 for more details). In the LIFT farm typology six main farming approaches have been defined based on different ecological criteria. Conservation Agriculture describes farms adhering to farming practices associated with conservation agriculture. Low-Input farming is associated with an overall lower level of use of environmentally detrimental inputs. Integrated/Circular farming evolves around the circularity of input use (e.g. share of self-produced feed for livestock). Organic farming, describes farming according to EU organic farming certifications. Agroecological farming is characterised by a certain minimum performance level in all of the above-described criteria plus the presence of ecological infrastructure. These farming approaches are not mutually exclusive, resulting in various possible combinations of farming approaches (e.g. Low-Input farming AND Integrated/Circular farming, Conservation Agriculture AND Low-Input farming AND Integrated/Circular farming AND Organic farming, etc.)[7]. Finally, Standard farming is mutually exclusive with respect to the other five farming approaches and is thus a residual group of farms, which do not stand out in any of the ecological criteria that are relevant for the other farming approaches. Standard farming can thus be seen as a reference group of 'mainstream' farms with medium to low performance regarding the above-described criteria (see Figure 2 for a schematic representation of the LIFT farm typology).

For the empirical analyses in chapter 4, depending on the considered farming approaches and combinations thereof, the procedure to calculate the farm typology and formation of groups based on these calculations may vary to some degree from case to case. However, in general, LIFT farm typology protocols for FADN data and for LIFT large-scale farmer survey data are used.

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[6] https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html

[7] Throughout this deliverable, we use AND in capital letters to refer to combinations of two or more farming approaches.

For analyses based on FADN data, we use the LIFT farm typology protocols outlined in Rega et al.(2021) and consider the following possible farming approaches and their combinations, besides Standard farming that is included in all analyses: (1) Low-Input farming, (2) Integrated/Circular farming and (3) Organic farming. In order for a farm to be classified into one or more of these ecological farming approaches, it has to cross certain threshold values for various indicators depicted in the LIFT farm typology protocol, reflecting the ecological criteria associated with the respective ecological farming approaches of the LIFT farm typology. Here, we use threshold values based on a European panel data set of 2011-2015, as they were presented in Rega et al. (2021). This means that, after correcting for price differences between countries, the thresholds for all farms underlying the LIFT farm typology calculations are the same throughout all analyses, irrespective of the region/country, which allows to compare the presence and shares of the farming approaches and their combinations over different countries.

For analyses based on LIFT large-scale farmer survey data, we use a further developed version of the LIFT farm typology protocol for the LIFT large-scale farmer survey data (see Rega et al., 2021) and consider the following farming approaches and their combinations: (1) Conservation Agriculture, (2) Low-Input farming, (3) Integrated/Circular farming and (4) Organic farming.

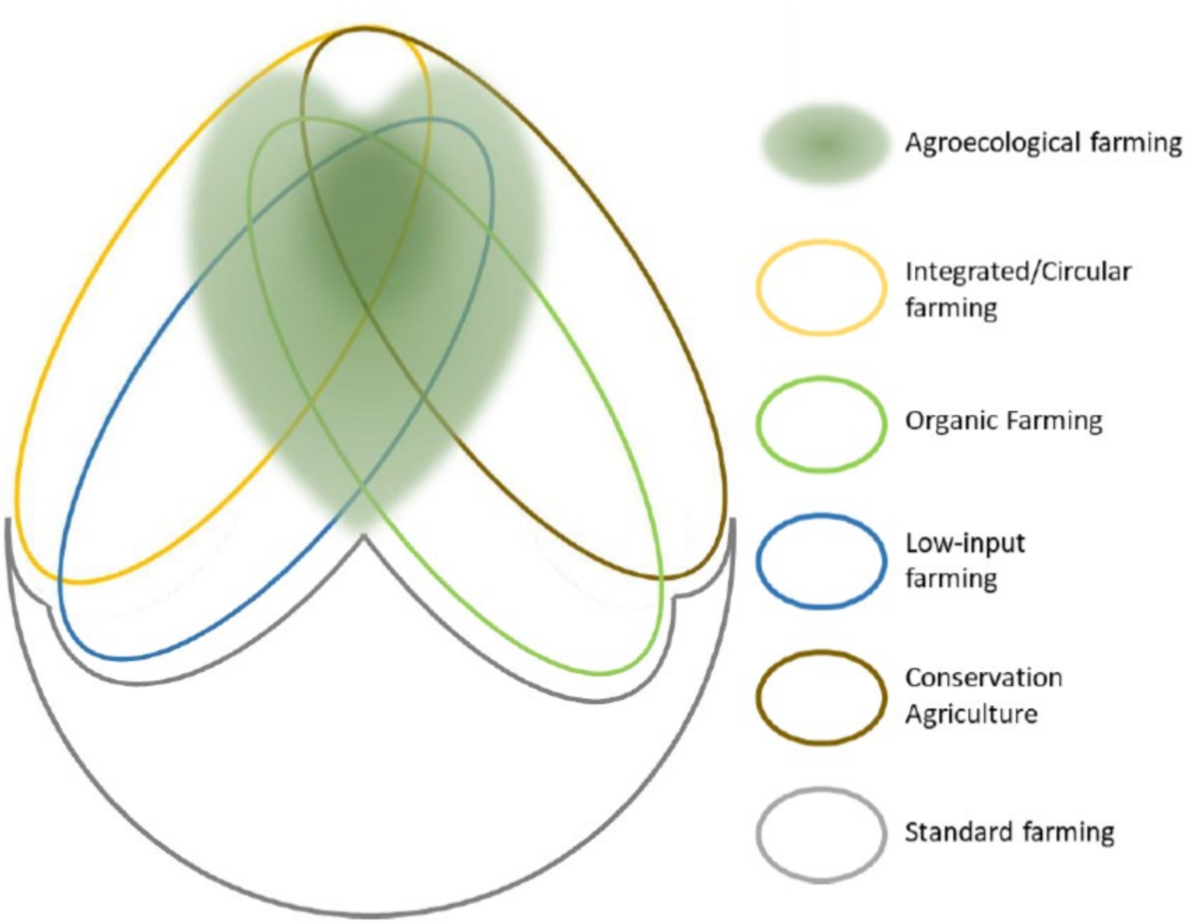


Figure 2: Schematic representation of the LIFT farm typology (Rega et al., 2021)

Regardless of the data source used (FADN or LIFT large-scale farmer survey), the sizes of the identified groups may vary considerably. For example, there may be cases, where most farms will be classified into one farming approach only (e.g. particularly if ecological farming practices do not play an important role in certain contexts, most farms will be classified as Standard farms). Additionally, the possible combinations of farming approaches other than Standard farming can lead to various groups. For example, if there are Low-Input farms, Organic farms and farms which are Low-Input as well as Organic, there would be three distinct groups: Low-Input, Organic, Low-Input AND Organic. In such cases, we treat such combinations of farming approaches (Low-Input AND Organic, in the example) as separate groups, since combining farming approaches may have different effects than adopting one farming approach only. In the example, we therefore keep the three groups. However, this strategy may further reduce the number of farms in the individual groups. Therefore, as a rule of thumb, we decided that all of the resulting groups (including Standard farms) should not be smaller than 10-20 farms per group in order to ensure a somewhat 'robust' comparison of farm performance between groups. If the group sizes are smaller than that, these farms can either be dropped from the analysis, or merged together to aggregated 'mixed' groups. For example, if there are only small numbers of Low-Input farms and of Integrated/Circular farms in a sample, the two groups could also be merged together to form a group of farms, adopting Low-Input OR Integrated/Circular farming. However, in principle the sustainability performance assessment results could also be depicted for individual farms.

3.2.1.3 Calculation and standardisation of performance indicators

In the third step, performance indicators for each performance dimension, covered in the LIFT project (economic, environmental, private social, employment/labour) are calculated. Since we only have very limited data for the private social performance dimension and the employment/labour related dimension, we summarise these two dimensions into one dimension, which we refer to as social/labour dimension in the remainder of the text. After calculation of the indicators, these are further standardised, so that indicators with different measurement scales (e.g. monetary units, ratios or other scales) can be easily compared. Finally, average farm performance (based on arithmetic means) is compared across all performance indicators and sustainability dimensions between the identified groups. For such a comparison, it is essential to have a meaningful frame of reference, on which comparisons can be based on. As our interest lies in disentangling differences in performance associated with an increased uptake of ecological approaches, we choose the Standard farming approach as a benchmark, since it contains all farms which are not classified into any of the other ecological farming approaches. This allows us to analyse how an increasing uptake of ecological approaches by farms, ranging from the adoption of individual farming approaches to combinations of farming approaches, is linked to differences in farm sustainability performance.

The normalisation of indicators is described in the formula below, where a performance indicator for a single farm is represented with *PI*, the subscripts *i*, *j* and *k* denote individual farms, performance dimensions and indicators within a performance dimension, respectively, while the superscript *g* refers to the different groups (farming approaches and combinations thereof). Essentially, we standardise each performance indicator with respect to the Standard farming approach via a z-standardisation[8]. In other words, for each farm *i*, performance dimension *j* and performance indicator *k* within the respective performance dimension, we first subtract the sample mean value of the Standard farming approach $\overline{PI}_{ijk}^{g=Standard}$ from the respective value of the farm in a specific ecological farming approach

[8] Z-standardisation of multidimensionally scaled data to one measurement scale, referred to as standard score or z-score is a common procedure in statistics.

PI_{ijk}^{g} (e.g. indicator value of an Organic farm minus mean value of this indicator for the Standard farming approach) and then divide the result by the sample standard deviation *(sd)* of that indicator of the Standard farming approach $sd(PI_{ijk}^{G=standard})$, so that we get a standardised indicator $\widetilde{PI}_{ijk}^{g}$ with a homogenous unit of measurement (standard deviations of the Standard farming approach).

$$\widetilde{PI}_{ijk}^{g} = PI_{ijk}^{g} - \overline{PI}_{ijk}^{g=standard} / sd(PI_{ijk}^{g=standard})$$

The result of this standardisation is that the mean values of standardised performance indicators for all farms of the Standard farming approach $\overline{\widetilde{PI}}_{jk}^{g=standard}$ are 0 for all performance indicators *k* in all performance dimensions *j*, and the mean values of standardised performance indicators for farms in each of the other farming approaches $\overline{\widetilde{PI}}_{jk}^{g\neq standard}$ for all performance indicators *k* in all performance dimensions *j* now reflect the average relative difference of each farming approach relative to the Standard farming approach, measured in standard deviations of the Standard farming approach. This allows us to disentangle, how each farming approach performs compared to the Standard farming approach (worse, similar, better) throughout individual performance indicators and also across the considered performance dimensions and thus is able to reveal potential strengths and weaknesses of ecological farming approaches in comparison to the Standard farming approach.

3.2.1.4 Graphical comparison of performance indicators

In the fourth and final step, we graphically depict this comparison with spider web diagrams[9]. In the example in Figure 3, we show a schematic depiction of such a spider web diagram, where the average performance of Standard farming, Integrated/Circular farming and Organic farming is compared. In the figure, Organic farms perform on average better than Standard farms (somewhere between 1.5 and 2 standard deviations) in terms of all economic and environmental indicators and also the first social/labour related indicator, but worse than Standard farms for the second and third social/labour related indicator. Integrated/Circular farms perform overall worse than Standard farming in the economic performance dimension and also mostly in the social/labour dimension for two out of the three depicted performance indicators, but show higher performance in the environmental dimension.

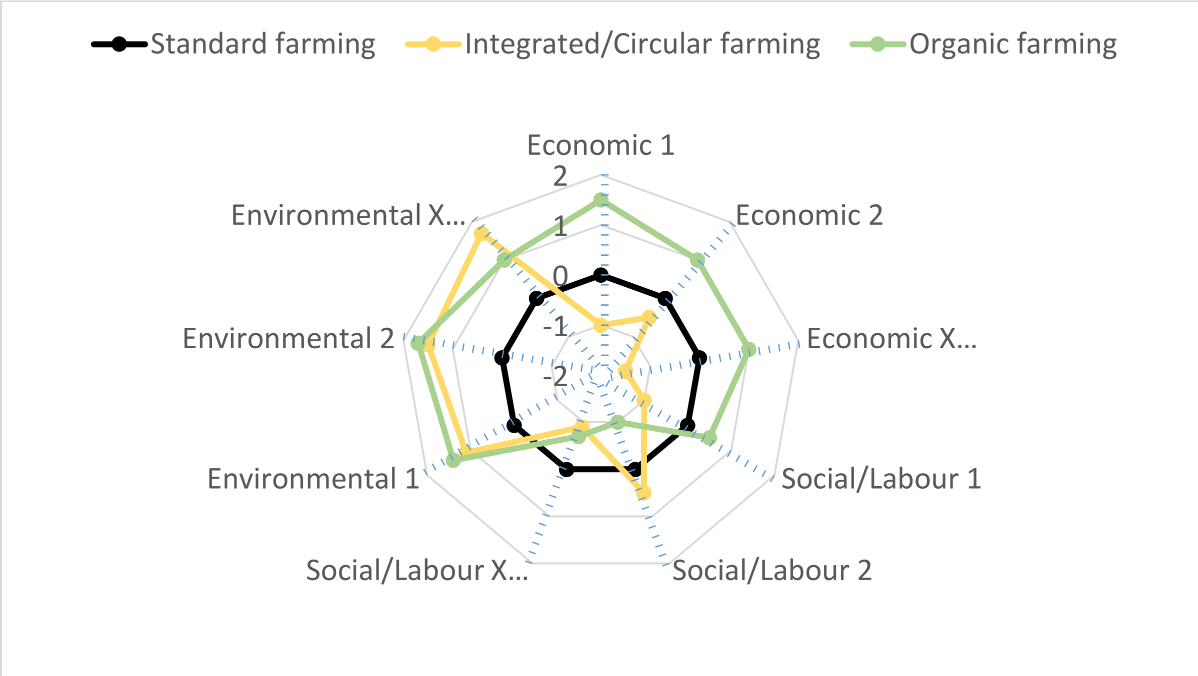
While we generate numeric results with this approach and depict them in spider webs, one needs to be careful when interpreting the differences between farming approaches in the spider web diagrams due to several reasons. Firstly, the differences depend on the standard deviation of the Standard farming approach (e.g. if the group of Standard farms has a very low or very high standard deviation, the same absolute magnitude of difference appears higher or lower). Secondly, the approach can be sensitive to outliers, especially if group sizes are small. Thirdly, the approach consists of a naive group comparison without an underlying statistical test for statistically significant differences between groups and it does not consider any other potential factors, driving differences between the compared farming approaches apart from the adoption of ecological approaches (e.g. site conditions, etc.). We thus see this approach primarily as a useful first exploratory possibility to differentiate, where farming approaches might perform better/similar/worse compared to the Standard farming approach and it is not possible to make any causal inference, based on these graphs alone.

Also, a feature which is inherent to this approach is that it is built on relative comparisons between groups, taking performance of the Standard farming approach as a baseline. While this is on the one

[9] Even though the usage of spider web / radar diagrams has also been criticised, they offer a visually easily accessible comparison of average farm performance across farming approaches, and similar representations to depict multidimensional sustainability performance have been used throughout the literature (e.g. Meul et al. (2012); Frater and Franks (2013)).

hand ideal for focussing on a comparison of farm sustainability performance between farming approaches, it does on the other hand not contain information regarding the absolute performance levels of the considered farming approaches.

Finally, depending on the definition of a performance indicator, it may be necessary to invert it (subtract each observed value of the indicator from the maximum value of that indicator), before carrying out the z-standardisation. This ensures that in the spider web diagrams, higher/lower values, compared to the standard farming approach always also depict higher/lower performance. This is for example the case for almost all environmental indicators (see subsequent sections for more details).



Note: Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 3: Schematic representation of spider web diagram for an integrative assessment of farm-level performance of different farming approaches, considering all performance dimensions (economic, social/labour, environmental) jointly (farm sustainability performance).

3.2.2 Farm sustainability performance indicators for FADN data

In this section, we present definitions of farm performance indicators for FADN data. These data are harmonised throughout the EU, making it possible to calculate these indicators in all countries, covered by FADN.

3.2.2.1 Technical-economic performance

Andreas Niedermayr, Jochen Kantelhardt (all BOKU, Austria)

<u>Overview of indicators:</u>

In terms of economic indicators, we differentiate between indicators based on profitability, liquidity and financial stability. A detailed description of these indicators for FADN data is given in Table 2.

- Profitability indicators: Revenue cost ratios (RCR), meaning a revenue indicator divided by a cost indicator. Here, a ratio > 1 means a farm can cover all costs. The ratios are calculated using two different definitions of revenues (R) and costs (C) (see Table 2). Based on these different definitions, three distinct revenue cost ratios are calculated in order to better reflect differences in profitability, due to (1) public payments and (2) opportunity costs of production factors (land, labour and capital).
- Liquidity: The cash-flow to assets ratio gives an indication of liquidity of farm holdings in relation to their assets.
- Financial stability: The net worth (equity) to assets ratio provides information about the capital structure and thus long-term financial stability of farms.

<u>Interpretation of indicators:</u>

- For each indicator, a higher value depicted in the spider diagrams is associated with higher performance.

Table 2: Definitions of common indicators of farm technical-economic performance based on FADN data

Name	**Description**	**Definition in FADN (codes according to FADN common names)**
Profit incl. subsidies	Revenue-cost-ratio including public payments and excluding remuneration of owned production factors: (Revenue + subsidies) / (intermediate expenses + depreciation + paid interest + paid labour + paid rent) Expresses ability of a farm to cover costs, not having to cover costs for owned production	(SE131 + SE605) / (SE275 + SE360 + SE370 + SE375 + SE380)

	factors, with its private revenues and public subsidies	
Profit excl. subsidies	Revenue-cost-ratio excluding public payments and excluding remuneration of owned production factors: Revenue / (intermediate expenses + depreciation + paid interest + paid labour + paid rent): Expresses ability of a farm to cover costs, not having to cover costs for owned production factors, with its private revenues	SE131 / (SE275 + SE360 + SE370 + SE375 + SE380)
Profit excl. subs. and incl. costs of own production factors	Revenue-cost-ratio excluding public payments and including remuneration of owned production factors: Revenue / (intermediate expenses + depreciation + paid interest + paid labour + paid rent + equity * estimated interest rate + unpaid labour in hours * estimated wage per hour + own land * estimated rent Expresses ability of a farm to cover all costs, including those for owned production factors with its private revenue	SE131 / (SE275 + SE360 + SE370 + SE375 + SE380 + SE016 * estimated labour costs for unpaid labour + (SE025-SE030) * estimated rent for own land + ((SE436 - ALNDAGR_CV) / SE436) * SE501 * estimated interest rate for equity)
Cashflow to assets ratio	Cash-flow / total assets Expresses liquidity of a farm in relation to its assets	SE532
Net worth to assets ratio	Net worth / total assets Expresses financial stability of a farm in relation to its assets	SE501 / SE436

<u>Comments on profitability indicator profit excl. subs. and incl. costs of own production factors:</u>

This indicator considers the remuneration of all production factors (that is to say including own land, unpaid family labour and equity) in order to be able to compare farms with different land, labour and capital structure (e.g. a farm with mostly own land vs. a farm with mostly rented land, a farm with mostly unpaid family labour vs. a farm with mostly paid labour, etc.). The costs of own production factors can be derived primarily based on the average costs of external production factors (e.g. average rental price a farm pays for land), primarily based on opportunity costs of own production factors (e.g. what rental price would a farmer get on average, if own land is rented out) or a (weighted) average of both.

In Table 2, valuation of external production factors is based on the actual financial costs (e.g. paid rent for rented land), while the cost of own production factors is based on estimates, based on regional (NUTS2[10]) average costs coefficients (e.g. average regional rental price per ha paid by farms). The advantage of this approach is that the cost coefficients used to valuate own production factors are

[10] NUTS is for Nomenclature of territorial units for statistics: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Nomenclature_of_territorial_units_for_statistics_(NUTS)

calculated directly from the data and it is thus possible to apply this approach to different datasets in different countries and for different farm types without having to make assumptions about potential opportunity costs on a case-by-case basis. However, it also needs to be noted that these calculated cost coefficients do not necessarily always reflect the actual opportunity costs of own production factors for individual farms.

We propose the following rules for calculation of the costs of the own production factors land, labour and capital for profitability indicator #3 (Profit excl. subs. and incl. costs of own production factors):

- Land: We use regional (NUTS2) median rental prices per ha for rented land (calculated only based on farms with non-zero rented land and non-zero rental payments) as estimates for an imputed land rent for own land.
- Labour: We use regional (NUTS2) median wage rates per hour for paid labour (calculated only based on farms with non-zero paid labour and non-zero labour payments) as estimates for labour costs per hour to impute unpaid labour (including unpaid family labour) for all farms.
- Capital: If a farm has non-zero paid interest and non-zero liabilities (total sum of short-term and long-term liabilities), then an estimated interest rate can be calculated by dividing paid interest by total liabilities in a similar fashion as for the imputed costs of own land and unpaid labour above. A remaining problem here is, that we do not have any information on the duration of loans, which also influences the magnitude of the interest rate. Nevertheless, we use regional (NUTS2) medians of this calculation (applied only to farms with non-zero liabilities and non-zero interest payments) as estimates for an imputed interest rate for net worth (equity) for all farms. The calculation differs slightly from those for own land and unpaid labour, as the remuneration of land is already carried out when calculating the imputed land rent above. The interest rate is thus not only multiplied with net worth, but also with a further reduction factor, which expresses the fraction of the value of agricultural land from the overall value of assets.

3.2.2.2 Social/labour performance

Laure Latruffe (INRAE, France), Alastair Bailey (UNIKENT, United Kingdom), Andreas Niedermayr (BOKU, Austria)

<u>Overview of indicators:</u>

Compared to economic information, there is only little information on social and labour-related performance in the FADN data. We decided to depict three main indicators in the spider webs, while calculating three additional indicators, which however are not shown in the spider web. The three main indicators are the total labour input, measured in annual working units (AWU), total labour input who is paid in number of persons and total labour input in AWU in relation to farm size (proxied by total revenue). While the first two indicators correlate positively with farm size, the third indicator is normalised with the above-mentioned farm size proxy. A detailed description of these indicators for FADN data is given in Table 3.

<u>Interpretation of indicators:</u>

For the first two indicators, a higher value is associated with higher performance, meaning that more labour and more jobs are interpreted in a positive manner, as both indicators express the labour demand of farms and consequently potential employment in agriculture (either considering all labour or only paid jobs). The third indicator as well as the first two further indicators were inverted, so that a higher value depicted in the spider diagrams also corresponds to higher performance (i.e. higher labour productivity). These indicators are marked with an asterisk (*) in Table 3.

Table 3: Definitions of common indicators of farm social/labour performance based on FADN data

Name	**Description**	**Definition in FADN (codes according to the FADN common names)**
Main indicators (displayed in spider web diagrams)		
Total labour	Total labour input in annual working units – AWU, where one AWU is a full-time equivalent	SE010
Total jobs	Total jobs in number of persons employed at farm	Computed_X + WPROTH_P + WPCCA_W1 where Computed_X is the number of managers paid, and can be calculated as follows: = 1 if WPRM_W1_TOT > 0 = 0 if WPRM_W1_TOT = 0
Labour productivity*	Total labour input in AWU in relation to farm size (proxied by total revenues)	SE010 / SE131
Further potential indicators (not displayed by default in spider web diagrams)		
Labour productivity (land)*	Total labour input in AWU per ha of UAA (for TF 1, 2, 3, 4 – see Table 24 in the appendix)*	SE010 / SE025
Labour productivity (livestock)*	Total labour input in AWU per livestock unit (for TF 5, 6, 7, 8 – see Table 24 in the appendix)*	SE010 / SE080
Total jobs (AWU)	Total labour input who is paid, in AWU	WPRM_W1_TOT + WPROTH_W1 + WPCCA_W1

Note: indicators denoted with an asterisk (*) were inverted, so that a higher value corresponds to higher performance.

3.2.2.3 Environmental performance

Laure Latruffe (INRAE, France), Andreas Niedermayr (BOKU, Austria)

Overview of indicators:

Similar to social/labour indicators, there is only limited information for environmental indicators in FADN data. As environmental effects of farms depend on the farm type, we propose to select the environmental indicators to be shown in the spider web, based on FADN type of farming (TF). A detailed description of these indicators for FADN data is given in Table 4. The definitions of the TF8 farm types are provided in Table 24 in the appendix. For indicators, where two definitions are given, the appropriate indicator should be selected, based on the TF8 farm type – e.g. for dairy farms, the indicators per livestock unit (LSU) should be taken, while for field crop farms the indicators per ha of utilised agricultural area (UAA) should be taken. The last three indicators (that are shaded in grey) in Table 4 can only be calculated with FADN data from 2018/2019 onwards and sometimes 2015 (depending on the countries) and are thus not included as main indicators in the spider webs.

Interpretation of indicators:

As almost all environmental indicators describe environmental pressure (e.g. livestock density, expenses for fertiliser per ha UAA, etc.), for such indicators a higher value would by default be associated with lower performance. The only exceptions are the share of grassland from total UAA and the share of fallow land from total UAA, where a higher indicator value is by default associated with higher performance. Thus, all indicators describing environmental pressure were inverted, so that a higher value depicted in the spider diagrams also corresponds to higher performance. These indicators are marked with an asterisk (*) in Table 4.

Table 4: Definitions of common indicators of farm environmental performance based on FADN data

Name	**Description**	**Definition in FADN (codes according to the FADN codes)**	**Relevant FADN type of farm (TF8 code)**
Main indicators (to be displayed in spider web diagrams)			
Feed autonomy (own feed)*	Livestock density per ha of UAA*	SE080 / SE025	7, 8
Feed autonomy (own feed)*	Density of ruminant grazing livestock per ha of forage area*	SE120	5, 6
Feed autonomy (concentrate)*	Value of purchased concentrated feedstuffs and coarse fodder per livestock unit*	(IGRFEDCNCTRPUR_V + IGRFEDCRSPUR_V + IPIGFEDPUR_V + IPLTRFEDPUR_V) / SE080	5, 6, 7, 8
Feed autonomy (grass)	Share of grassland from total UAA	CTOTALGRASS_A / SE025	5, 6, 8
Fertiliser autonomy*	Value of purchased fertilisers and soil improvers per ha of UAA*	SE295 / SE025	1, 2, 3, 4
Plant protection autonomy*	Value of plant protection products, traps and baits, bird scarers, anti-hail	SE300 / SE025	1, 2, 3, 4

	shells, frost protection, etc. (excluding those used for forests) per ha of UAA*		
Fuel autonomy*	Value of motor fuels and lubricants per ha of UAA*	IFULS_V / SE025	1, 2, 3, 4
Share of fallow land	Share of fallow land from total UAA	SE074 / SE025	1, 2, 3, 4
Fuel autonomy*	Value of motor fuels and lubricants per livestock unit*	IFULS_V / SE080	5, 6, 7, 8
Veterinary autonomy*	Veterinary expenses value per livestock unit*	IVET_V / SE080	5, 6, 7, 8
Further potential indicators (not displayed by default in spider web diagrams)			
Water autonomy*	Water value per ha of UAA*	IWATR_V / SE025	1, 2, 3, 4
Water autonomy*	Water value per livestock unit*	IWATR_V / SE080	5, 6, 7, 8
Fertiliser auton-omy (N)*	Quantity of N in mineral fertilisers used per ha of UAA*	SE296 / SE025	1, 2, 3, 4
Fertiliser autonomy (P)*	Quantity of P2O5 in mineral fertilisers used per ha of UAA*	SE297 / SE025	1, 2, 3, 4
Fertiliser autonomy (K)*	Quantity of K2O in mineral fertilisers used per ha of UAA*	SE298 / SE025	1, 2, 3, 4

Note: indicators denoted with an asterisk (*) were inverted, so that a higher value corresponds to higher performance.

3.2.3 Farm sustainability performance indicators for LIFT large-scale farmer survey data

Compared to FADN data, definitions of performance indicators based on the LIFT large-scale farmer survey data are more flexible. This has to do on the one hand with the level of detail of recorded data in the survey and on the other hand with partially missing data (e.g. if farmers did not provide answers to specific questions). In this section, we therefore outline general definitions of performance indicators (based on variable codes from the LIFT large-scale farmer survey questionnaire in Tzouramani et al. (2019)). However, individual LIFT partners were able to modify performance indicators due to the reasons outlined above. These additional assumptions and/or modifications by individual LIFT partners are provided in the individual case-study reports in chapter 4.

3.2.3.1 Technical-economic performance

Andreas Niedermayr, Jochen Kantelhardt (all BOKU, Austria)

Overview of indicators:

In order to be comparable to technical-economic performance indicators based on FADN data, we use the same set of indicators as for FADN data and calculations of indicators approximate the FADN-based calculations as best as possible, if some information was not recorded in the LIFT large-scale farmer survey. For example, it was necessary to propose assumptions to make on a case-by-case basis, where detailed data was in general not recorded in the LIFT large-scale farmer survey or farmers did not provide some economic data. A detailed description of these indicators is given in Table 5.

- Profitability indicators: Revenue cost ratios (RCR), meaning a revenue indicator divided by a cost indicator. Here, a ratio > 1 means a farm can cover all costs. The ratios are calculated using two different definitions of revenues (R) and costs (C). Based on these different definitions, three distinct revenue cost ratios are calculated in order to better reflect differences in profitability, due to (1) public payments and (2) opportunity costs of production factors (land, labour and capital).
- Liquidity: The cashflow to assets ratio gives an indication of liquidity of farm holdings in relation to their assets.
- Financial stability: The net worth (equity) to assets ratio provides information about the capital structure and thus long-term financial stability of farms.

Interpretation of indicators:

- For each indicator, a higher value is associated with higher performance.

Table 5: Definitions of common indicators of farm technical-economic performance based on LIFT large-scale farmer survey data

Name	Description	Definition in LIFT large-scale farmer survey questionnaire (codes according to the variable description)
Profit incl. subsidies	Revenue-cost-ratio including public payments and excluding remuneration of owned production factors: (Revenue + subsidies) / (intermediate expenses + depreciation + paid interest + paid labour + paid rent) Since paid interests are not available in LIFT large-scale farmer survey data, an assumed interest should be used. Expresses ability of a farm to cover costs, not having to cover costs for owned production factors, with its private revenues and public subsidies	(Q69 + Q70 + Q71 + Q72_tot) / (Q68 columnB * Q68 columnD + Q65 columnD + Q70 columnA * Q70 columnC + Q66_sq03 + Q66_sq02 * interest rate + IF(Q15SQ9 = Yes; (52 – Q15SQ8) * Q15SQ10; 0) + Q16 * Q17SQ6et7_sq02 * + Q12_sq02 * estimated average rental price, based on a weighted average of the rental prices in Q62 in connection with the land use shares in Q11)
Profit excl. subsidies	Revenue-cost-ratio excluding public payments and excluding remuneration of owned production factors: Revenue / (intermediate expenses+ depreciation + paid interest + paid labour + paid rent) Since paid interests are not available in LIFT large-scale farmer survey data, an assumed interest should be used. Expresses ability of a farm to cover costs, not having to cover costs for owned production factors, with its private revenues	(Q69 + Q70 + Q71) / (Q68 columnB * Q68 columnD + Q65 columnD + Q70 columnA * Q70 columnC + Q66_sq03 + Q66_sq02 * interest rate + IF(Q15SQ9 = Yes; (52 – Q15SQ8) * Q15SQ10; 0) + Q16 * Q17SQ6et7_sq02 * + Q12_sq02 * estimated average rental price, based on a weighted average of the rental prices in Q62 in connection with the land use shares in Q11)
Profit excl. subs. and incl. costs of own production factors	Revenue-cost-ratio excluding public payments and including remuneration of owned production factors: Revenue / (intermediate expenses + depreciation + paid interest + paid labour + paid rent + equity * estimated interest rate + unpaid labour in hours * estimated wage per hour + own land * estimated rent Since paid interests are not available in LIFT large-scale farmer survey data, an assumed interest should be used. Expresses ability of a farm to cover all costs, including those for owned production factors with its private revenues	(Q69 + Q70 + Q71) / (Q68 columnB * Q68 columnD + Q65 columnD + Q70 columnA * Q70 columnC + Q66_sq03 + Q66_sq01 * assumed interest rate + IF(Q15SQ9 = Yes; (52 – Q15SQ8) * Q15SQ10) + Q16 * Q17SQ6et7_sq02 + IF(Q15SQ9 = NO; (52 – Q15SQ8) * assumed wage + Q11_sqTOT * estimated average rental price, based on a weighted average of the rental prices in Q62 in connection with the land use shares in Q11)

Cashflow to assets ratio	Cash-flow / total assets Expresses liquidity of a farm in relation to its assets As there is no cash-flow indicator in the farm survey data, we approximate it by summing up expenses from Q68 (variable inputs), Q65 columnD (contract work), Q70 (purchases of livestock), Q66_sq02 (liabilities, multiplied with an assumed interest rate), Q15 (paid family labour), Q16&Q17 (paid external labour), Q12 (land rent)	(Q68 columnB * Q68 columnD + Q65 columnD + Q70 columnA * Q70 columnC + Q66_sq02 * assumed interest + IF(Q15SQ9 = Yes; (52 – Q15SQ8) * Q15SQ10; 0) + Q16 * Q17SQ6et7_sq02 + Q12_sq02 * estimated average rental price, based on a weighted average of the rental prices in Q62 in connection with the land use shares in Q11) / Q66_sq01
Net worth to assets ratio	Net worth / total assets Expresses financial stability in relation to its assets	1 – (Q66_sq02/ Q66_sq01)

Comments on the calculation of costs of land, labour and capital for the profitability indicators:

We propose the following rules for calculation of the costs of the main production factors land, labour and capital (both, owned by the farm or not owned by the farm) for profitability indicators based on LIFT large-scale farmer survey data:

- Land: Q12 provides the number of ha of rented UAA and Q11 provides the total UAA and different shares of land use (share of arable land, share of grassland, share of permanent crop area, etc). However, we do not know the land use shares of rented land. In absence of this information, we assume, that the land use shares for own and rented land are both distributed like the land use shares of the overall UAA. Consequently, the costs for rented UAA are calculated as regional rental price for the respective land use category from Q62 multiplied with share of the respective land use category from Q11 with the number of ha of rented land.
- Labour: the costs of paid labour can be calculated by summing up the payments for paid family labour from Q15 and hired workers (Q16 and Q17). For unpaid labour, the total hours worked can be calculated based on Q15, considering only those family members which were not paid. In the next step, one can either assume a wage per hour which fits to the respective case study (and use this wage per hour for all farms) or one can calculate a wage rate similar to how it is done for FADN data (calculate the total costs for hired labour and divide the result through hours worked by the hired labour force, but only for farms with non-zero paid labour and non-zero labour payments, as not excluding 0 values would lead to a downward bias of results). The median of this calculation can then be alternatively used as wage per hour for all farms with unpaid labour, when calculating labour costs for unpaid labour.
- Capital: In the LIFT large-scale farmer survey, there is no data regarding paid interest. However, based on Q66 the value of total assets, liabilities and consequently also the net worth (equity), by subtracting the liabilities from total assets, can be calculated. If an interest rate is assumed, then it is possible to calculate estimates for paid interest (by multiplying liabilities with the assumed interest rate) and estimates for imputed interest for equity (by multiplying equity with the assumed interest rate).

3.2.3.2 Social/labour performance

Laure Latruffe (INRAE, France), Andreas Niedermayr (BOKU, Austria)

Overview of indicators:

In order to be comparable to employment and labour-related performance indicators in the FADN data, we depict three main indicators in the spider webs, which are similar to those based on FADN data. These three main indicators comprise the total number of worked hours on the farm, the total number of people working on the farm, and the total number of worked hours on the farm in relation to farm size (proxied by turnover). While the first two indicators correlate positively with farm size, the third indicator is normalised with the above-mentioned farm size proxy. Additionally, a fourth indicator, describing work satisfaction is proposed. However, this indicator requires additional data, that was collected separately through a survey on working conditions in the frame of Task 3.3 (Hostiou et al., 2021) and could thus only be included in the Austrian case-study report here (see section 4.2.1). Also, three additional indicators are proposed, which however are not shown in the main spider web and are also similar to the FADN-based indicator definitions. A detailed description of these indicators is given in Table 6.

Interpretation of indicators:

For each indicator, except for the third, fourth and fifth indicator, a higher value is associated with higher performance.

Table 6: Definitions of common indicators of farm social/labour performance based on LIFT large-scale farmer survey data

Name	**Description**	**Definition in LIFT large-scale farmer survey questionnaire (codes according to the variable description)**
Main indicators (displayed in spider web diagrams)		
Total labour	Total number of worked hours on the farm	(i) Number of worked hours from family members (totfamlab) + (ii) Number of worked hours from hired members (tothiredlab) Where (i) totfamlab = sum over all members a to j of [Q15SQ7et8_b_Q15sq7 * (52 – Q15SQ7et8_c_Q15sq8)] (ii) tothiredlab = [Q17SQ3a5_Q17sq4_SQ001 * (52 – Q17SQ3a5_Q17sq5_SQ001)] * Q16
Total jobs	Total number of people working on the farm	Q15 + 1 + Q16

Labour productivity*	Total number of worked hours on the farm in relation to farm size (proxied by turnover)	totlab (see first row) / Q10SQ1
Work satisfaction	Satisfaction level of the farmer with his/her working conditions This indicator could only be calculated, if data from the additional survey on working conditions was available together with the data of the LIFT large-scale farmer survey. This was only the case in the Austrian case study regions, where results of this indicator are presented.	(Sum of QA24 to QA28) / 5 QA24: How do you rate your level of satisfaction concerning your daily work in general (over the past 5 years)? [Level of satisfaction concerning your daily work] (scale 0 to 5) QA25: How do you rate your level of satisfaction concerning your work life balance in general (over the past 5 years)? [Level of satisfaction concerning your work life balance] (scale 0 to 5) QA26: How do you rate your level of satisfaction concerning being a farmer in general (over the past 5 years)? [Level of satisfaction concerning being a farmer] (scale 0 to 5) QA27: How do you rate your level of satisfaction related to be free to make decisions in general (over the past 5 years)? [Level of satisfaction related to be free to make decisions] (scale 0 to 5) QA28: How do you rate your level of satisfaction concerning your quality of life in general (over the past 5 years)? [Level of satisfaction concerning your quality of life] (scale 0 to 5)
Further potential indicators (not displayed by default in spider web diagrams)		
Labour productivity (land)*	Total number of worked hours on the farm per ha of UAA (for TF 1, 2, 3, 4 – see Table 24)	totlab (see first row) / q11_sqtot
Labour productivity (livestock)*	Total number of worked hours on the farm per livestock unit (for TF 5, 6, 7, 8 – see Table 24)*	totlab (see first row) / number of LSU calculated with Eurostat coefficients (see Table 9)
Total jobs (AWU)	Number of worked hours from hired members (tothiredlab)	[Q17SQ3a5_Q17sq4_SQ001 * (52 – Q17SQ3a5_Q17sq5_SQ001)] * Q16

Note: indicators denoted with an asterisk (*) were inverted, so that a higher value corresponds to higher performance.

3.2.3.3 Environmental performance

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<u>Overview of indicators:</u>

Compared to FADN data, the LIFT large-scale farmer survey offers more detailed environmental data, making it possible to consider for example the physical amount of environmentally relevant inputs instead of expenses for these inputs in many cases. Again, as environmental effects of farms depend on the farm type, we propose to select the environmental indicators to be shown in the spider web, based on whether the farms are mainly crop farms or mainly livestock farms (this can be decided based on the FADN type of farming (TF)). A detailed description of these indicators is given in Table 7. The definitions of the TF8 farm types are provided in Table 24 in the appendix. For indicators, where two definitions are given (either per ha of UAA or by number of livestock units), the appropriate indicator should be selected, based on the TF8 farm type – e.g. for specialist dairy farms, the indicators per LSU should be taken, while for arable farms the indicators per ha of UAA should be taken. Since data on livestock in the LIFT large-scale farmer survey was recorded based on head counts and not livestock units, we calculated livestock units based on the conversion coefficients from FADN which are given in Table 25 in the appendix.

It may not be possible to calculate all indicators for each sample of farms, depending on the quality of the data that have been collected during the survey. Also, if for a sample, other indicators seem to be more relevant and with better quality data, they would be computed. In the case of indicators related to agricultural land, another land area may be more appropriate depending on the farm type, e.g.:

Q11_sqTOT	UAA in ha
Q11_sq1	Total arable area in ha
Q11_sq2	Total grassland area in ha
Q11_sq3	Total perennial crops area in ha.

<u>Interpretation of indicators:</u>

As almost all the environmental indicators describe environmental pressure, for each indicator listed in Table 7, except the grassland share, a higher value is associated with lower performance. Thus, these indicators should be inverted by subtracting for each observation the value of the respective indicator from the maximum value of the respective indicator so that they can be interpreted in the same way as economic and social indicators (i.e. higher value means higher performance and vice versa).

Table 7: Definitions of common indicators of farm environmental performance based on LIFT large-scale farmer survey data

Name	**Description**	**Definition in LIFT large-scale farmer survey questionnaire (codes according to the variable description)**	**Relevant FADN type of farm (TF8 code)**
Main indicators (displayed in spider web diagrams)			
Feed autonomy (own feed)*	Livestock density per ha of UAA*	Number of livestock heads or number of livestock units (calculated from Q31A with Eurostat livestock unit coefficients) / q11_sqtot	5, 6, 7, 8
Feed autonomy (concentrate)*	Use of concentrated feed per livestock unit*	CONCENT / number of LSU where CONCENT is one of the variables below (to be selected based on the best data quality) – below is an example for ruminants, which can be adapted to other farm types Q68SQ4BD_sq0i_B1 (Average quantity purchased: in kg) Q68SQ4BD_sq0i_B2 (Average quantity purchased: in ton) Q68SQ4BD_sq0i_B3 (Average quantity purchased: in m3) Q68SQ4BD_sq0i_B4 (Average quantity purchased: in litre) Q68SQ4BD_sq0i_D2 (Average purchase price for total quantity)	5, 6, 7, 8
Feed autonomy (grass)*	Share of grassland from total UAA	Q11_sq2 / q11_sqtot	5, 6, 8
Fertiliser autonomy*	Use of chemical fertilisers (quantity or value, depending on the data available) per ha of UAA*	FERTIL / Q11_sq1 where FERTIL is one of the variables below (to be selected based on the best data quality) Q68SQ3BD_sq0c_B1 (Average quantity purchased: in kg) Q68SQ3BD_sq0c_B2 (Average quantity purchased: in ton) Q68SQ3BD_sq0c_B3 (Average quantity purchased: in m3) Q68SQ3BD_sq0c_B4 (Average quantity purchased: in litre) Q68SQ3BD_sq0c_D2 (Average purchase price for total quantity)	1, 2, 3, 4

Plant protection autonomy*	Use of chemical pesticides (quantity or value, depending on the data available) per ha of UAA*	PESTIC / Q11_sq1 where PESTIC is one of the variables below (to be selected based on the best data quality) Q68SQ3BD_sq0e_B1 (Average quantity purchased: in kg) Q68SQ3BD_sq0e_B2 (Average quantity purchased: in ton) Q68SQ3BD_sq0e_B3 (Average quantity purchased: in m3) Q68SQ3BD_sq0e_B4 (Average quantity purchased: in litre) Q68SQ3BD_sq0e_D2 (Average purchase price for total quantity)	1, 2, 3, 4
Fuel autonomy*	Use of fuel per ha of UAA*	(FUEL_1 + FUEL_2) / Q11_sq1 where FUEL_1 (Fuel for agricultural production) is one of the variables below (to be selected based on the best data quality) Q68SQ7BD_sq0b_B1 (Average quantity purchased: in kg) Q68SQ7BD_sq0b_B2 (Average quantity purchased: in ton) Q68SQ7BD_sq0b_B3 (Average quantity purchased: in m3) Q68SQ7BD_sq0b_B4 (Average quantity purchased: in litre) Q68SQ7BD_sq0b_D1 (Average purchase price for total quantity) FUEL_2 (Fuel for other processes) is one of the variables below (to be selected based on the best data quality) Q68SQ7BD_sq0c_B1 (Average quantity purchased: in kg) Q68SQ7BD_sq0c_B2 (Average quantity purchased: in ton) Q68SQ7BD_sq0c_B3 (Average quantity purchased: in m3) Q68SQ7BD_sq0c_B4 (Average quantity purchased: in litre) Q68SQ7BD_sq0c_D1 (Average purchase price for total quantity)	1, 2, 3, 4

Share of fallow land	Share of fallow land from total UAA	Q11_sq4A / q11_sqtot	1, 2, 3, 4
Fuel autonomy*	Use of fuel per livestock unit*	(FUEL_1 + FUEL_2) / number of LSU where FUEL_1 and FUEL_2 are defined in the above row	5, 6, 7, 8
Veterinary autonomy*	Veterinary expenses value per livestock unit*	Q68SQ8BD_sq0a / number of LSU	5, 6, 7, 8
Further potential indicators (not displayed by default in spider web diagrams)			
Water autonomy*	Water consumption from irrigation per ha of UAA*	Q40C_1_1 + Q40C_2_1 / q11_sqtot	1, 2, 3, 4
Fertiliser autonomy (N-mineral)*	Quantity of N in mineral fertilisers used per ha of crop area (categories of kg of N)*	Q26E_4	1, 2, 3, 4
Fertiliser autonomy (N-manure)*	Quantity of N in animal manure fertiliser used per ha of crop area (categories of kg of N)*	Q26E_5	1, 2, 3, 4

Note: indicators denoted with an asterisk (*) were inverted, so that a higher value corresponds to higher performance.

4 Assessment of farm level sustainability performance

This chapter covers assessments of farm level sustainability performance, using the LIFT farm sustainability performance assessment described in the previous chapter. An overview of all analyses considered in this chapter is provided in Table 8.

As can be seen from the table, a total of 9 analyses are carried out based on FADN data (all included in section 4.1). These analyses cover specialist dairy farms in Austria, France and Romania, specialist beef cattle farms in Ireland, other grazing livestock farms in Scotland namely sheep and cattle farms, specialist granivore (pig/poultry) farms in Poland, specialist cereal, oil and protein crop farms in Hungary, specialist other field crop farms in the United Kingdom, and specialist orchards – fruits farms in Italy. The number of farms included in each analysis varies from case to case and is closely related to the overall size of the FADN sample of each country/region and the considered farm types as described above.

As regards the shares of identified farming approaches and combinations thereof, a major pattern which arises from the analysed FADN samples is that Standard farming seems to be the dominating farming approach, ranging between 48% and 93% of all farms. Other ecological farming approaches or combinations thereof are not as common, but play a moderate to important role in several cases, for example Integrated/Circular farming, Organic farming and a combination of these two farming approaches for dairy farms in Austria, Low-Input farming, Integrated/Circular farming and a combination of these two farming approaches for dairy farms in Romania, Low-Input farming for beef farms in Ireland and sheep and cattle farms in Scotland, Integrated/Circular farming for granivore farms in Poland, Low-Input farming for other field crop farms in the United Kingdom and Integrated/Circular farming for orchards – fruits farms in Italy.

In section 4.2, analyses are carried out based on LIFT large-scale farmer survey data. The analyses cover dairy farms in Austrian case study regions (Salzburg und Umgebung and Steyr-Kirchdorf) and French case study regions (Ille-et-Vilaine, Puy-de-Dôme, Sarthe) as well as olive farms in the Greek case study region (Eastern Crete). As the LIFT large-scale farmer survey aimed to cover a wide variety of ecological farms, here the shares of other ecological farming approaches are overall higher than those in analyses based on FADN data.

More detailed results and nuanced discussions thereof are provided in the respective analyses. The sections of these analyses are provided in the first column of Table 8. Apart from this first overview of the studies included in this chapter, a synthetic summary of farm level sustainability performance results across all analyses covered in this chapter and of the results regarding the further aspects considered in the in-depth analyses in chapter 5 is provided in section 6.1.

Table 8: Overview of assessments of farm level sustainability performance in chapter 4

Sec-tion	Data source	Country/ region	Farm type	n	Standard farming	Conservation Agriculture	Low-Input farming	Integrated/Circular farming	Organic farming	Combinations of ecological approaches	Short summary of results (performance of other groups (e.g. better/similar/worse) is expressed in comparison to that of the Standard farming approach)
4.1.1	FADN	Austria	Dairy	787	55%			18%	16%	11%	Combinations of ecological approaches perform better in the economic dimension, but for single ecological approaches the tendency is less clear. In the social/labour dimension all groups tend to perform worse in terms of labour productivity, but better in the environmental dimension, particularly again combinations of ecological approaches.
4.1.2	FADN	France	Dairy	1,005	84%		3%	6%	4%	3%	Combinations of ecological approaches perform better in the economic dimension, but for single ecological approaches the tendency is less clear. In the social/labour dimension results indicate lower labour productivity of ecological farming approaches, especially for Integrated/Circular farming and Low-Input farming. In the environmental dimension, all ecological farming approaches perform on average better than Standard farming.
4.1.3	FADN	Romania	Dairy	312	48%		12%	25%		15%	In the economic dimension, Low-Input farms and combinations of ecological approaches perform better, while Integrated/Circular farms perform worse. In the social/labour dimension, ecological groups tend to have a lower labour productivity, in particular Integrated/Circular farms, which are also smaller in terms of absolute labour input. In the environmental dimension, combinations of ecological approaches perform better, while Low-Input farms and Integrated/Circular farms only perform better for some indicators.
4.1.4	FADN	Ireland	Beef cattle	363	76%		24%				In the economic dimension, Low-Input farms tend to perform similar or better than Standard farms. In the social/labour dimension, they show particularly a lower labour productivity and are slightly smaller in terms of absolute labour input. Their environmental performance is overall better.
4.1.5	FADN	Scotland	Sheep and Cattle	184	74%		26%				In the economic dimension, there is no clear tendency. Low-Input farms perform for some indicators worse, similar or better. In the social/labour dimension, Low-Input farming has a slightly higher labour input and lower labour productivity. From an environmental point of view, Low-Input farms perform on average better.
4.1.6	FADN	Poland	Granivore	702	87%			13%			In the economic dimension, Integrated/Circular farms perform overall similar, with differences in profitability, depending on subsidies and opportunity costs. In the social/labour dimension, Integrated/Circular farms are slightly smaller in total labour and total jobs and show a clearly lower labour productivity. Environmental performance of Integrated/Circular farms is better.

4.1.7	FADN	Hungary	Cereal, oil and protein crop	777	93%		5%	3%			In the economic dimension, there is no clear tendency. Profitability of ecological approaches depends on the inclusion of subsidies and opportunity costs of own production factors. In the social/labour dimension, particularly Integrated/Circular farms perform overall worse. Low-Input farms, while being smaller in terms of total labour and total jobs, show a slightly higher labour productivity compared to Standard farms. In the environmental dimension, both ecological approaches perform overall clearly better than Standard farming, Low-Input farming even more so.
4.1.8	FADN	United Kingdom	Other field crop	159	38%		56%		6%		In the economic dimension, results are mixed, with an overall tendency of similar or slightly lower performance of ecological groups. In the social/labour dimension, labour productivity is slightly higher for Low-Input farms, but slightly lower for Low-Input AND Organic farms and both groups are slightly smaller in total labour and total jobs. In the environmental dimension, both groups perform better, combinations of ecological approaches even more so.
4.1.9	FADN	Italy	Orchards - fruits	176	60%			33%	7%		In the economic dimension, there is no clear overall tendency. Profitability of ecological approaches depends on the inclusion of subsidies and opportunity costs of own production factors. In the social/labour dimension, ecological farming approaches tend to show a lower labour productivity. Particularly Organic farms have more total labour and total jobs. In the environmental dimension both groups perform better, Organic farming even more so.
4.2.1	Survey	Austrian case study regions	Dairy	80	39%		6%	2%	13%	40%	In the economic dimension, ecological groups tend to perform worse. In the social/labour dimension labour productivity is lower for ecological groups and gets lower with a decreasing degree of uptake of ecological approaches. In the environmental dimension, ecological groups perform overall better.
4.2.2	Survey	French case study regions	Dairy	108	23%	24%	21%			31%	In the economic dimension, the two considered indicators show slight differences across farming approaches. In the social/labour dimension, ecological groups perform similar or slightly better in terms of labour productivity, while for the other indicators results are mixed. In the environmental performance dimensions, results are also mixed.
4.2.3	Survey	Greek case study region	Olive	66	47%	11%			14%	29%	In the economic dimension results are mixed. Organic farms and farms combining Organic farming with other farming approaches perform similar or slightly better, while Conservation Agriculture farms as well as Low-Input farms tend to perform similar or worse than Standard farms. In the social/labour as well as the environmental dimension results are also mixed.

Note: n = number of farms included in the respective analysis. Percentages indicate the share of farms in the respective farming approaches. FADN = Farm Accountancy Data Network. The term survey refers to the LIFT large-scale farmer survey (Tzouramani et al. 2019). The column 'Combinations of ecological approaches' comprises different combinations, which can vary from analysis to analysis. The detailed composition of these groups is provided in the respective sections, where the full analyses are presented. Due to rounding percentages may not always sum up to 100.

4.1 Analyses based on FADN data

4.1.1 Specialist dairy farms (TF14 = 45) in Austria

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4.1.1.1 Background

The present analysis is based on Austrian FADN data of 787 specialist dairy farms (FADN TF14 = 45) from the year 2015. The degree of uptake of ecological practices is calculated based on the LIFT farm typology for FADN data, leading to the following farming approaches: Standard farming (55%), Integrated/Circular farming (18%), Organic farming (16%) and a combination of Integrated/Circular AND Organic farming (11%), where the order, reflects an increasing uptake of ecological practices. Additional farming approaches and/or combinations of farming approaches were identified as well, but the number of farms in these groups was too small to include them in the calculations. These farms (a total of 10 farms, thereof 5 classified as Low-Input AND Integrated/Circular and 5 classified as Low-Input AND Integrated/Circular AND Organic) were thus excluded from the subsequent analysis.

4.1.1.2 Results

Starting with economic performance, the three revenue-cost ratios in Figure 4, representing profitability show different results. While ecological farming approaches are more profitable if public payments are included, these advantages disappear if public payments are not included and only Integrated/Circular AND Organic farming performs on average slightly better than the Standard farming. If opportunity costs of own production factors are also considered, ecological farming approaches are on average less profitable than Standard farming, in particular Integrated/Circular farming. With respect to liquidity (cashflow to assets ratio) and financial stability (net worth to assets ratio) there are only slight differences between farming approaches.

From an environmental point of view, ecological farming approaches perform on average better than Standard farming. While the differences are rather small when looking at fuel autonomy, ecological farming approaches have on average a clearly higher feed autonomy (grass), a higher feed autonomy (own feed) and higher feed autonomy (concentrate), with the exception of Organic farming, which performs slightly worse than the Standard farming approach with respect to this last indicator.

In the social/labour dimension, ecological farming approaches perform worse than Standard farming. The first two indicators (total labour and total jobs) additionally also reflect the average size of farms with respect to labour input (i.e. farms in these farming approaches are smaller in terms of absolute labour input, considering both total jobs as well as total labour). If such farm size effects are eliminated by normalising labour input with the total monetary output of farms (labour productivity), results indicate that more ecological farming approaches are also less productive in their use of labour input, especially Integrated/Circular farming.

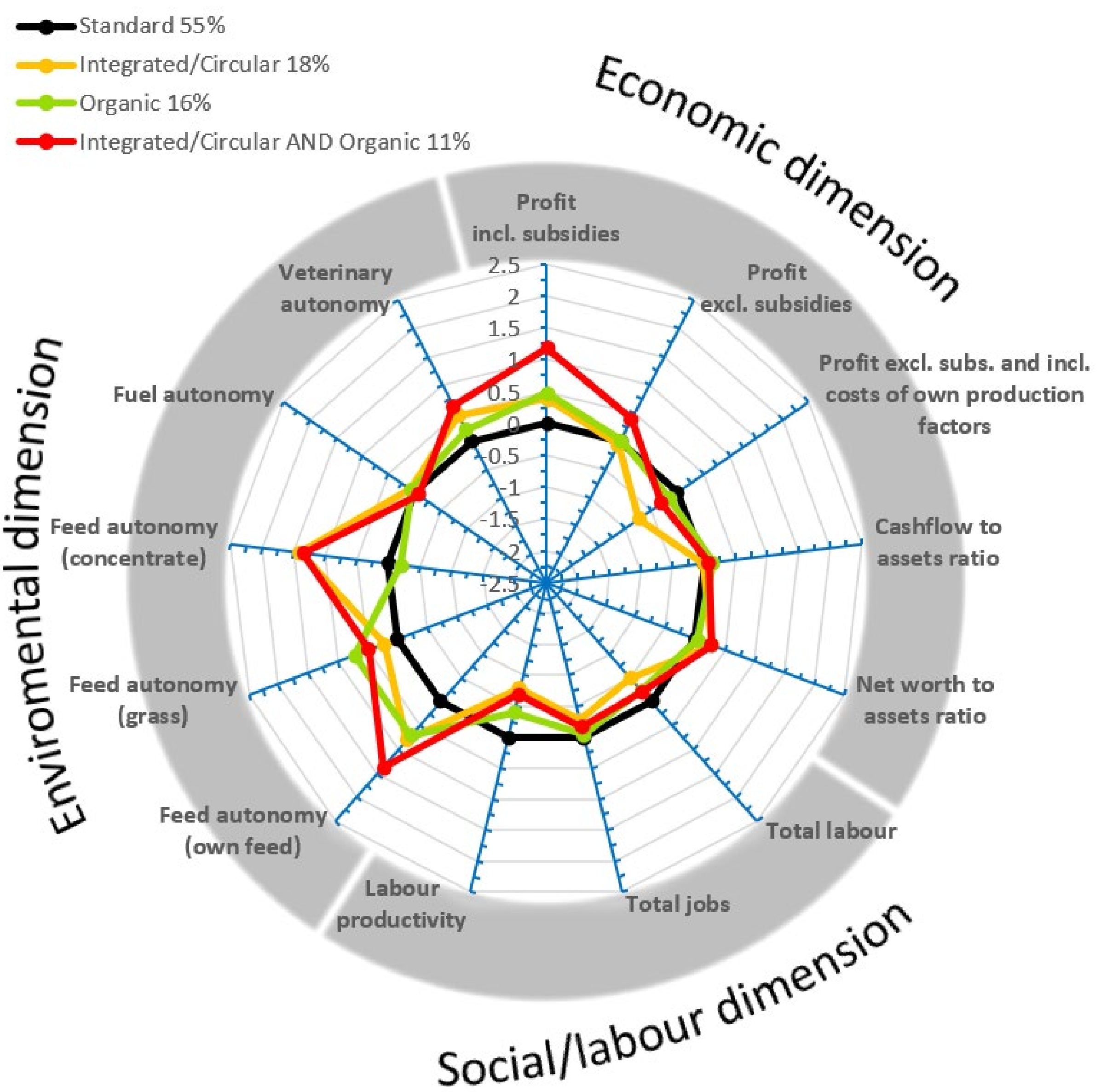
4.1.1.3 Discussion and conclusion

Results of economic performance are in line with findings derived from LIFT WP3 (Niedermayr et al., 2021). In general, the profitability of ecological farming approaches is positively related to the degree of uptake of ecological approaches. For Austrian dairy farms this is most likely connected to specific certifications schemes, in particular haymilk Traditional Speciality Guaranteed (TSG) or organic haymilk TSG. These certifications offer farmers an additional price premium for their milk, conditional on certain regulations (e.g. no fermented fodder and limitation of the share of concentrate feed).

When considering structural change in agriculture, a continuously growing share of the production factors land, labour and capital will no longer be owned by farmers, leading to higher expenses (e.g. due to a higher share of rented land or hired labour). As these farming approaches are less productive in their use of e.g. land and labour (see Niedermayr et al. (2021), for more details), current advantages in profitability are likely to decrease or the picture may even reverse in the future, as indicated by the third profitability indicator.

The overall better environmental performance of ecological farming approaches is not surprising. However, looking at the results in detail also reveals certain limitations of the data currently available in the FADN and underlines the need of a more detailed collection of environmental data in the FSDN. For example, the relatively low performance of Organic farming for the indicator related to the expenses for concentrate feed (feed autonomy (concentrate)) is attributable to higher prices for organic concentrate feed. In contrast, Integrated/Circular and Integrated/Circular AND Organic farms are characterised by a higher degree in the circularity of input use and consequently also buy less concentrate feed, resulting in a better performance for this indicator.

Overall, we discussed our results extensively with regional stakeholders. We are thus confident that the identified farming approaches and results of our performance assessment provide a realistic picture of the situation of dairy farms in Austria. Moreover, our analysis also shows how such an integrative assessment of economic, environmental and social/labour performance offers a nuanced picture of possible effects of an increased uptake of ecological approaches by farms. While positive environmental effects are to be expected, it is of particular importance to consider public payments as well as current and future farm structure (share of own and external production factors) from an economic point of view. Finally, regarding the social/labour dimension, ecological farming approaches are associated with a higher workload. As Austrian dairy farms operate mostly only with unpaid family labour, limited capacity of additional unpaid family labour, availability of qualified workers on the job market and administrative effort, when starting to hire external labour, seem to be the biggest hurdles for an increased uptake of ecological approaches.



Note: year = 2015, n = 787 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 4: Comparison of farm level sustainability performance of different farming approaches for specialist dairy farms (FADN TF14 = 45) in Austria, based on FADN data.

4.1.2 Specialist dairy farms (TF14 = 45) in France

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4.1.2.1 Background

The present analysis is based on French FADN data of 1,005 specialist dairy farms (FADN Type of Farming = 45) from the year 2015. The full sample was in fact 1,021 farms, but we excluded 16 farms: one outlier farm, and farms in ecological types with insufficient numbers of farms to draw meaningful conclusion. The classification in ecological types is based on the LIFT farm typology for FADN data, leading to the following farming approaches: **Standard farming (84% of the sample), Low-Input farming (3%), Integrated/Circular farming (6%), Organic farming (4%) and a combination of Integrated/Circular AND Organic farming (3%)**, where the order reflects an increasing uptake of ecological practices.

4.1.2.2 Results

Starting with economic performance, the three revenue-cost ratios (profit incl. subsidies, profit excl. subsidies, profit excl. subs. and incl. costs of own production factors) in Figure 5, representing profitability show different results. While ecological farming approaches are more profitable than Standard farming if public payments are included (profitability incl. subsidies on Figure 5), these advantages disappear for Organic and Integrated/Circular farms if public payments are not included (profitability excl. subsidies on Figure 5). In this case, only Low-Input farms and farms combining Integrated/Circular AND Organic farming perform on average slightly better than Standard farming. If opportunity costs of own production factors are also considered (profitability excl. subsidies and incl. costs of own production factors on Figure 5), the disadvantage of ecological farming approaches compared to Standard farming is increased, in particular for Integrated/Circular farming. This suggests that those farms are not profitable enough to remunerate their own factors. The exception is farms combining Integrated/Circular AND Organic farming, which are the only type of farms that are more profitable than Standard farming. With respect to liquidity (cashflow to assets ratio) and financial stability (net worth to assets ratio), all ecological farms perform better than Standard farms except for one type of ecological farming which perform similarly to Standard farming: Integrated/Circular farms in the case of liquidity and Organic farms in the case of financial stability.

From an environmental point of view, all ecological farming approaches perform on average better than Standard farming. The differences with Standard farming are high but are rather small across ecological types when looking at feed autonomy (grass) and feed autonomy (own feed). Regarding fuel autonomy, all ecological farming types perform only slightly better than Standard farming, except for Low-Input farms which are highly performing. Finally, in the case of feed autonomy (concentrate), while organic farming performs only slightly better than the Standard farming approach, the other ecological farming types perform much better.

In the employment and labour-related dimension, farms implementing Integrated/Circular farming or Low-Input farming perform worse than Standard farming in terms of total labour, but similarly in terms of total jobs. Organic farming performs similarly in terms of both employment indicators, while farms combining Integrated/Circular and Organic farming perform much better. These two employment indicators (total labour and total jobs) additionally also reflect the average size of farms with respect to labour input (i.e. Integrated/Circular farming or Low-Input farming are smaller in terms of absolute labour input, considering both unpaid as well as total jobs). If such farm size effects are eliminated by normalising labour input with the total monetary output of farms (labour productivity), results indicate that more ecological farming approaches are less productive in their use of labour input, especially

Integrated/Circular farming and Low-Input farming. However, this also means that ecological farming is more likely to create jobs.

4.1.2.3 Discussion and conclusion

Results of economic performance show that the higher liquidity, financial stability and profitability (when the latter accounts for public subsidies) of ecological farming approaches are positively correlated with the degree of uptake of ecological approaches. This superiority is reduced for Integrated/Circular AND Organic farming when subsidies are excluded from profitability calculation, revealing the dependence of these two approaches on subsidies. On the other hand, these subsidies could also be seen as payment for the ecosystem services provided by these ecological farming systems. When the costs of own production factors are accounted for in profitability assessment, only the most ecological type, namely farms implementing Integrated/Circular and Organic farming, is more profitable than Standard farms. The lower profitability of the other ecological types is consistent with the fact that the productivity of labour and land is lower and that the total cost in relation to production is therefore lower. The value of the products must then be much higher to compensate for these extra costs, which seems to be the case for Organic farming systems whose labelled products receive a higher willingness to pay from the consumer.

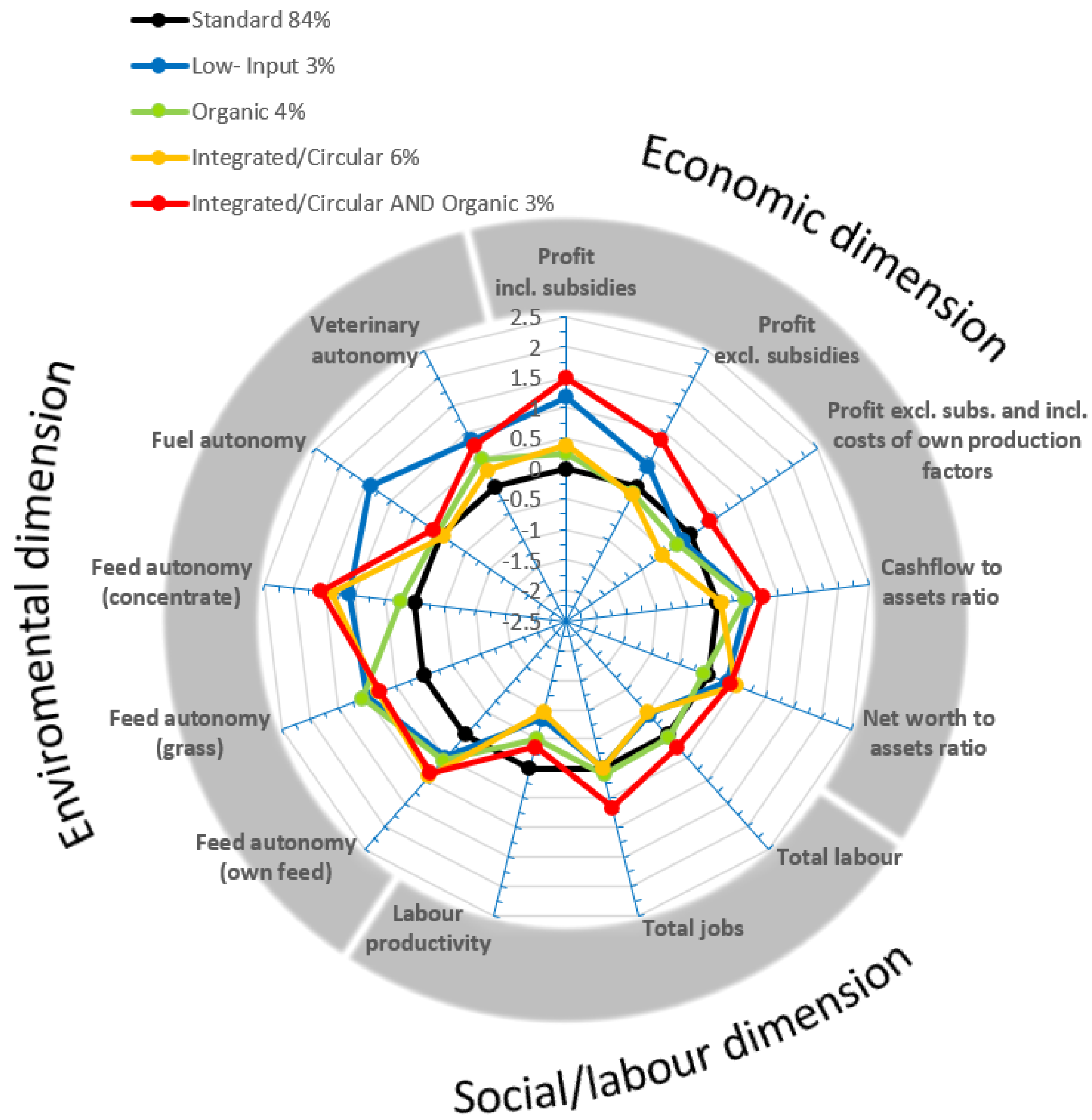
The overall better environmental performance of ecological farming approaches is not surprising. Findings highlight the high performance of Low-Input farming with respect to fuel use. As regards, the relatively low performance of Organic farming for the indicator related to the expenses for concentrate feed, it is attributable to higher prices for organic concentrate feed.

The higher contribution of ecological farming approaches to employment compared to Standard farming is visible for the most ecological type only, namely farms implementing Integrated/Circular AND Organic farming. Organic farming contributes to employment similarly than Standard farming while Low-Input farms and Integrated/Circular farms contribute less than Standard farming in the case of total labour but similarly in the case of total jobs. This suggests a reduced need of family labour for these approaches. The returns to labour are however lower than Standard farming for all ecological farming types. With a similar profitability for Standard and ecological farming systems, higher labour and better environmental impact on ecological farms, the latter seem to be superior systems from a sustainability point of view.

These results are somewhat different from other results in France during the last decade. When comparing ecological and non-ecological farms in the case of organic farming, certified organic farms and farms in conversion to organic farming outperform other farms (i.e. non-ecological farms). Even though organic dairy farms use more land (+10 to 15%), more labour (+10 to 12%), and more cows (+8%) to produce 18% less milk, they are more profitable. Organic dairy systems have better economic results because they can use fewer inputs, get a better price for milk and receive more subsidies. However, we note that organic systems require more assets to produce. Therefore, while they are low operating input systems, they are high structural input systems. This is also true for labour, but it means that organic dairy farms create more jobs. Organic systems have the highest net income/AWU.

From an environmental perspective, these results are also similar to other studies in France, again when we consider organic and non-organic farming. Organic systems use fewer inputs in terms of veterinary and fertilisation costs, and of course chemical pesticides which are banned. They also use less concentrate feed because dairy farmers chose to reduce the yield of their cows and probably used more grass, which is cheaper to produce than corn. Thus, they were able to reduce their negative environmental impacts.

The differences in results between the present LIFT analysis and above-mentioned studies in France could come from the fact that we have a more precise ecological typology. Indeed, other studies generally only consider organic vs non-organic farms, and do not distinguish between low-input, integrated/circular and organic farming systems contrary to the present LIFT analysis.



Note: year = 2015, n = 1,005 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 5: Comparison of farm level sustainability performance of different farming approaches for specialist dairy farms (FADN TF14 = 45) in France, based on FADN data.

4.1.3 Specialist dairy farms (TF14 = 45) in Romania

Mihai Chițea (IAE-AR, Romania), Marioara Rusu (IAE-AR, Romania), Andreas Niedermayr (BOKU, Austria)

4.1.3.1 Background

The present analysis is based on Romanian FADN data of 312 specialist dairy farms (FADN Type of Farming =45) from the year 2015. In order to evaluate the degree of uptake of ecological practices, the LIFT farm typology protocol was applied to the dataset, resulting the following farming approaches: Standard farming (47.5%), Low-Input farming (11.8%), Integrated/Circular farming (25.3%), and a combination of Low-Input AND Integrated/Circular farming (15.4%). Data processing did not reveal any farms belonging to the Organic farming approach.

4.1.3.2 Results

Looking first at the economic performance of the identified farming approaches, two of them stand out, namely Low-Input and Low-Input AND Integrated/Circular – Figure 6. They are very close when it comes to the profit incl. subsidies and, evidently, better than the Standard farming. This advantage remains also if the subsidies are not included (profit excl. subsidies), the Low-Input farming approach showing a better performance in this case compared to the Low-Input AND Integrated/Circular one. If we take into consideration also the costs of own production factors (profit excl. subs, and incl. costs of own production factors), the same two farming approaches are more profitable than the Standard farming, again, with a slight advantage for the Low-Input approach. As regards liquidity (cashflow to assets ratio), this time the Low-Input AND Integrated/Circular farms take the lead, followed by the Low-Input farms, both with an evident advantage compared to the Standard farming approach. This is not the case when we look at the financial stability (net worth to assets ratio), all three farming approaches holding only a slight advantage on the Standard farming. In this context, the overall picture of the economic performance highlights one farming approach that constantly performs lower than the Standard farming, namely the Integrated/Circular farming.

Moving on to the environmental performance of Romanian FADN dairy farms, the results highlight some evident differences, only one farming approach performing better than Standard farming for all indicators, namely Low-Input AND Integrated/Circular, but especially when it comes to feed autonomy (own feed), feed autonomy (grass) and fuel autonomy. At the same time, the Integrated/Circular approach, while performing better in terms of feed autonomy (own feed), feed autonomy (grass) and feed autonomy (concentrate), falls below the Standard farming approach when it comes to fuel autonomy and veterinary autonomy. A mirror like representation, but almost overlapping the Standard farming is evident in the case of the Low-Input farming, that perform slightly lower in terms of feed autonomy (own feed), almost the same in terms of feed autonomy (grass) and feed autonomy (concentrate), and better in case of fuel autonomy and veterinary autonomy.

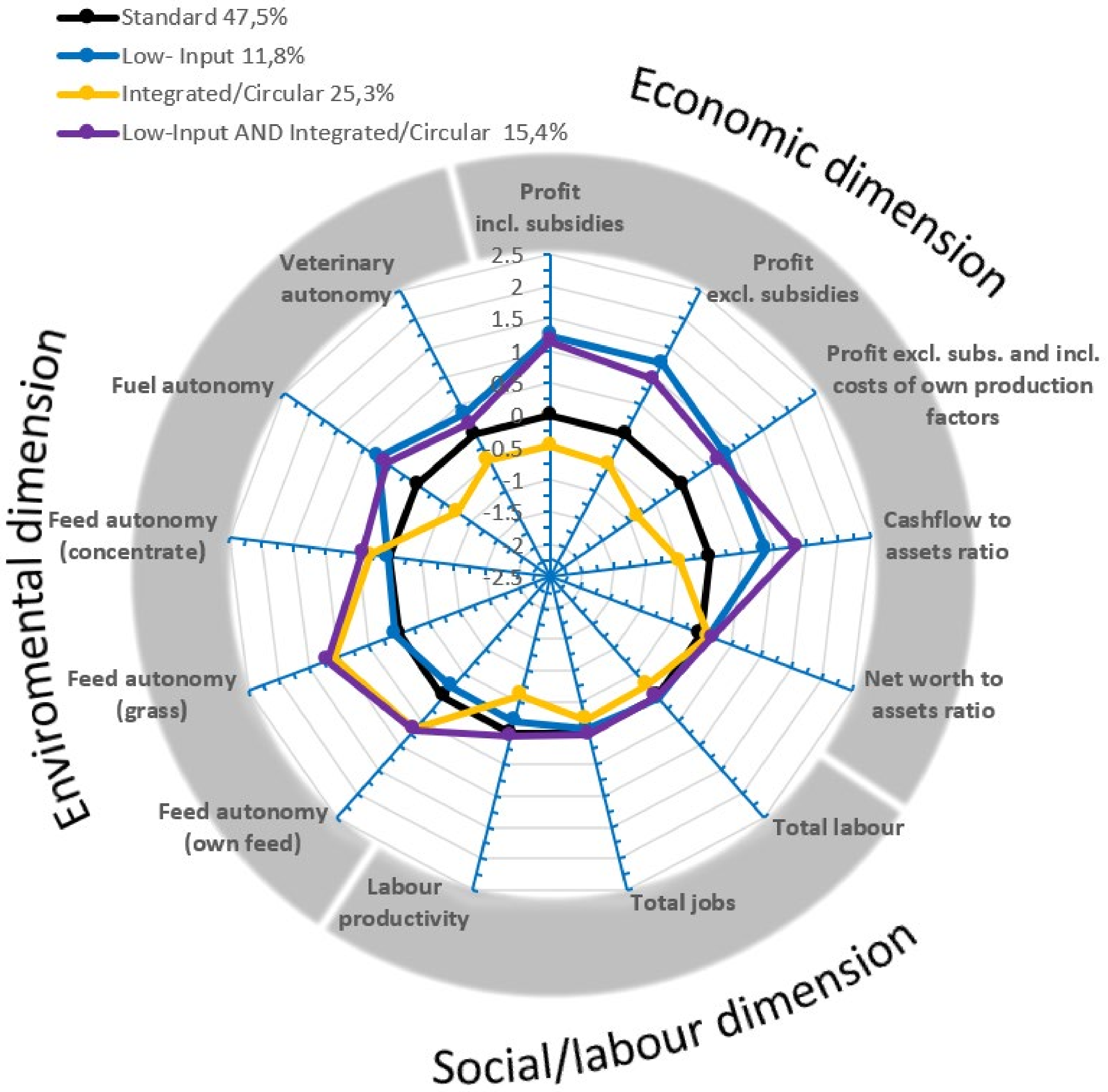
As regards the social/labour dimension, the Integrated/Circular and Low-Input farming perform worse than the Standard farming, especially when it comes to the total jobs and total labour (with an evident smaller total labour input in AWU in the case of Integrated/Circular approach). At the same time, the Low-Input AND Integrated/Circular farming performs slightly better than Standard farming, the advantage, though, being very small. Taking into consideration the labour productivity it seems that farming approaches that share some common characteristics with ecological ones tend to be less productive when it comes to using labour input, in our particular case of Romanian FADN dairy farms, especially Integrated/Circular farming.

4.1.3.3 Discussion and conclusion

In terms of economic performance, although no dairy farms were included in the Organic farming group, the ones that performed better as compared to the Standard farming, namely Low-Input and Low-Input AND Integrated/Circular, present some common characteristics of the agroecological farming. The fact that these two categories, together with Integrated/Circular farming were the main approaches resulting from applying the typology protocol, is in line with the 2015 situation of Romanian dairy farms, many of them relying on traditional agricultural practices, with a lower use of external inputs and also on the own production of feed for livestock, manure and other organic fertilisers for the pastures and hay production. Nevertheless, the organic dairy sector has been increasing in Romania in the last years, both in terms of dairy farms and processing units, and based on the rising demand but also on interactions with the stakeholders from the case study area it will continue to develop over the next years.

As regards the environmental performance the results of the farming approaches are, somewhat, different. While the Low-Input AND Integrated/Circular and Integrated/Circular farming perform better in terms of feed autonomy (own feed), feed autonomy (grass) and feed autonomy (concentrate), when it comes to fuel autonomy and veterinary autonomy the Low-Input farming takes the lead. Overall, the best environmental performance, as compared to the Standard farming, is registered by the Low-Input AND Integrated/Circular farming approach.

Last but not least, as regards the social/labour performance of the Romanian dairy farms, the identified ecological farming approaches perform roughly similar to Standard farming in terms of total jobs and total labour, while labour productivity tends to be slightly lower for Integrated/Circular farming. The Romanian dairy farms mainly operate with unpaid family labour due to the particularities of traditional agricultural activities but also to the lack of external labour force that affects, especially, the agricultural sector. We have discussed our results with the stakeholders from Suceava case study area, known for the traditional dairy farms. Their feedback highlighted the expected increase of the number of organic dairy farms in the future, but also the fact that many of them are already using traditional farming practices in line with organic ones, but lack the necessary certification.



Note: year = 2015, n = 312 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 6: Comparison of farm level sustainability performance of different farming approaches for specialist dairy farms (FADN TF14 = 45) in Romania, based on FADN data.

4.1.4 Specialist beef cattle farms (TF14 = 49) in Ireland

Yan Jin, Kevin Kilcline, Mary Ryan and Cathal O'Donoghue (all Teagasc, Ireland)

4.1.4.1 Background

The analysis is based on Irish FADN data of 384[11] specialist beef farms (FADN TF 14 = 49: specialist cattle including rearing and fattening) from the year 2015. The degree of uptake of ecological practices was calculated based on the LIFT farm typology for FADN data. They include Organic farming (four observations, 1%), Integrated/Circular farming (seven observations, 2%), a combination of Integrated/Circular AND Low-Input farming (six observations, 2%), a combination of Integrated/Circular AND Organic farming (two observations, 1%), a combination of Organic and Low-Input farming (one observation, 0.3%), Standard farming (278 observations, 72%) and Low-Input farming (86 observations, 22%). The number of farms in some groups was too small and could cause potential bias, therefore, these farms were excluded from subsequent analysis. Thus, the assessment of farm level sustainability of ecological farming focused on Standard and Low-Input farms.

4.1.4.2 Results

From an economic perspective, the three profitability indicators in Figure 7 show consistent results. Low-Input farms score higher in terms of profitability compared to Standard farming, regardless of the inclusion of subsidies. While remaining more profitable, the magnitude of profitability decreases when opportunity costs of own production factors are taken into consideration. Regarding liquidity (cash flow to assets ratio) and financial stability (net worth to assets ratio), Low-Input farms are only slightly more profitable than Standard farms.

From an environmental perspective, Low-Input farms perform better than Standard farms for all environmental indicators, especially in relation to veterinary autonomy, fuel autonomy and feed autonomy (concentrate), thus for these indicators, low expenditure is considered as an indication of high performance. Therefore, as explained in chapter 3, these indicators have been inverted in order to display them graphically, so that higher/lower values, compared to the Standard farming approach always depict higher/lower performance i.e. high performance in relation to these indicators refers to low expenditure. Low-Input farms also have higher feed autonomy (grass) and higher feed autonomy (own feed).

Compared to the economic and environmental dimensions where Low-Input farms perform better on average, these farms show poorer performance in the social/labour dimension. Indicators include the total labour measured in AWU and total jobs measured in number of persons. These indicators are positively correlated with farm size. The third indicator is total labour divided by output (inverted), which eliminates the farm size effects by normalising labour input with the total monetary output of farms (labour productivity). The results show that Low-Input farms perform poorly in terms of labour productivity.

4.1.4.3 Discussion and conclusion

Economic analysis undertaken in LIFT WP3 (Niedermayr et al., 2021) shows that Irish dairy farms that have a higher degree of ecological practices have lower profits and productivity as the dominant dairy model is based on low-input, high-yielding cows. This analysis of beef farms, however, shows different patterns in terms of profitability, as both profitability including and excluding subsidies are higher in Low-Input farming. This is consistent with *a priori* expectations as subsidies play an important role in

[11] One observation was excluded as an outlier as purchased coarse fodder is over 100 times more than the average. This observation is categorised as Standard farm based on the LIFT typology developed in Rega et al. (2021).

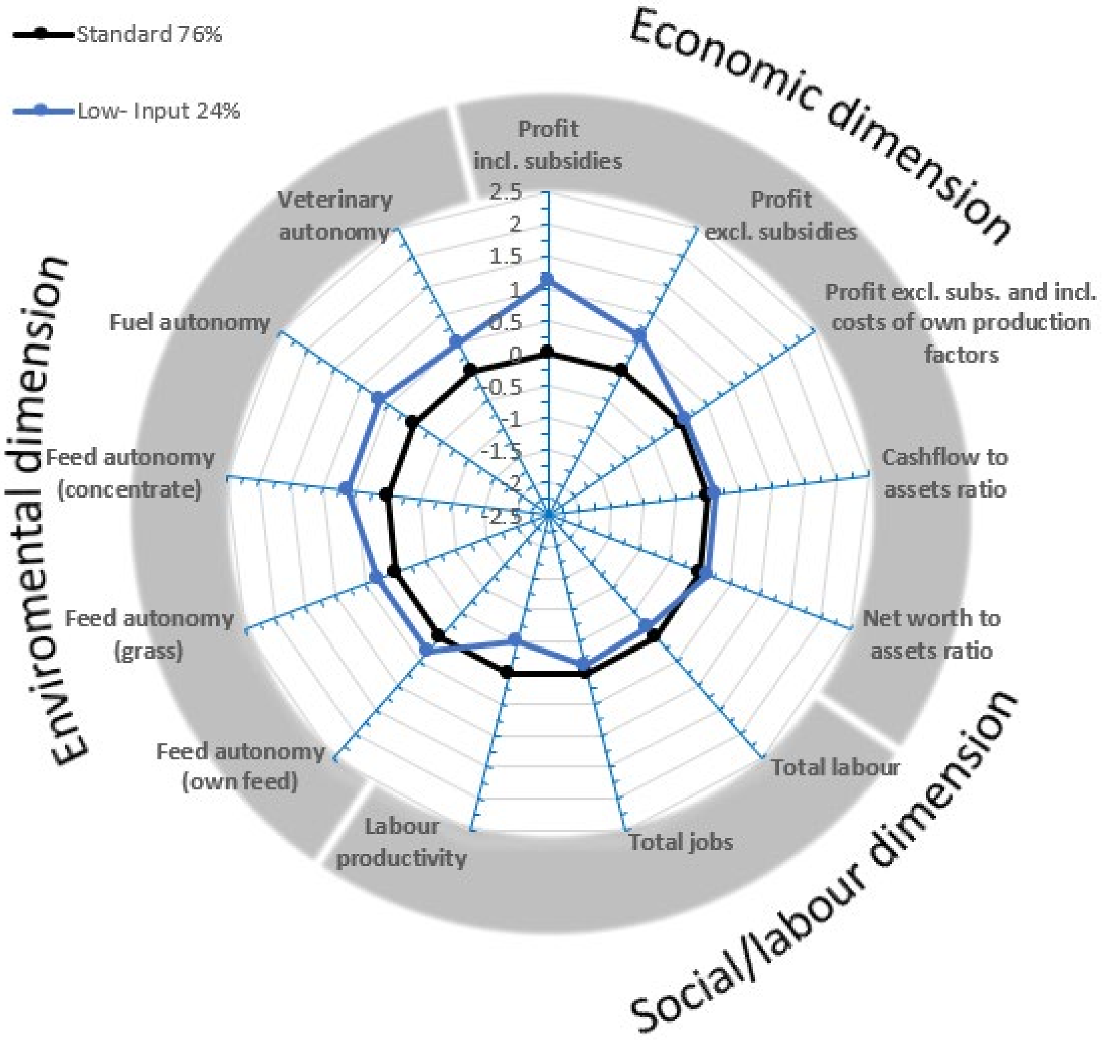
beef farming, which is generally more extensive in nature and undertaken on less productive farms. The high level of reliance on subsidies is reflected in the mean and median of revenue-cost ratio excluding subsidies that are smaller than one, indicating that on average, beef farms do not make a positive return from the market. This is consistent with the recent Teagasc Outlook Report[12] that estimates beef farms to have earned an average negative net margin of -€30 per hectare for suckler farms and -€36 per hectare for finishing farms in 2021.

Sustainability plays an important role on these farms. For example, Bord Bia, the State food marketing agency, runs accredited Quality Assurance Schemes[13] in response to the growing demand from purchasers of Irish meat products for proof that the meat is produced sustainably on Irish beef farms. Accreditation is based on sustainability principles, as part of which, farmers in the scheme are provided with constructive feedback aimed at improving their sustainability performance. This is achieved through implementing measures to enhance the environmental performance, as well as minimising inputs. These sustainability measures deliver economic benefits through lower costs of production in veterinary, fuel and concentrate feed.

While Low-Input farms perform better on the environmental indicators overall, it is not possible to illustrate how the better environmental performance of Low-Input farms is related to agronomic and environmental condition with the available FADN data. It is however expected that more detailed agronomic and environmental data will be collected as part of FSDN.

To conclude, this analysis identified Low-Input farming using FADN data and performed an integrative assessment of the performance of Low-Input farms compared with Standard farms for the Irish beef system. From an economic perspective, the importance of considering the costs of own production factors and public subsidies is high, as they are strong determinants of profitability. From an environmental perspective, we showed the expected positive environmental performance of Low-Input farms, but more agronomic and environmental data are needed in order to decompose and develop a stronger understanding of the positive environmental impact. From a social/labour perspective, Low-Input farm are less efficient in terms of labour input. As Irish beef farms are mainly based on unpaid family labour, this is an important consideration for policy makers in incentivising Low-Input agroecological approaches and particularly in relation to facilitating greater adoption of Organic beef farming by Low-Input beef farms in order to achieve EU Farm to Fork targets.

[12] https://www.teagasc.ie/publications/2021/outlook-2022---economic-prospects-for-agriculture.php
13 https://www.bordbia.ie/farmers-growers/get-involved/become-quality-assured/sustainable-beef-and-lamb-assurance-scheme-sblas/



Note: year = 2015, n = 363 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better performance and values smaller than 0 indicate worse performance), measured in standard deviations of the Standard farming approach.

Figure 7: Comparison of farm level sustainability performance of different farming approaches for specialist beef farms (FADN TF14 = 49) in Ireland, based on FADN data.

4.1.5 Sheep and cattle farms (TF8 = 6) in Scotland

Bethan Thompson, Andrew Barnes, Luiza Toma (all SRUC, Scotland)

4.1.5.1 Background

The present analysis is based on Scottish FADN data of 193 sheep and cattle farms (FADN TF8 = 6) from the year 2015. The degree of uptake of ecological practices is calculated based on the LIFT farm typology for FADN data, leading to the following farming approaches: Standard farming (70%), Low-Input farming (25%), Organic farming (3%), a combination of Low-Input AND Integrated/Circular farming (1%), and a combination of Low-Input AND Organic farming (3%). We proceed with a comparison of Standard and Low-Input farming (n = 184 farms) due to the low number of farms in the remaining categories.

4.1.5.2 Results

Starting with economic performance, there are three revenue-cost ratios in Figure 8, representing different measures of profitability. Low-Input farming is as profitable as Standard farming if public payments are included, these advantages disappear if public payments are not included (profitability excl. subsidies) and Low-Input farming performs worse than Standard farming. If opportunity costs of own production factors are also considered, Low-Input farming performs similarly to Standard farming. With respect to liquidity (cashflow to assets ratio). Low-Input farming performs marginally better than Standard farming, and in terms of financial stability (net worth to assets ratio) the two approaches have similar results.

From an environmental point of view, Low-Input farms perform on average better than Standard farming across all measures selected. While the differences are small for veterinary expenses, Low-Input farms perform a lot better in terms of feed autonomy (own feed), feed autonomy (grass), feed autonomy (concentrate) and fuel autonomy.

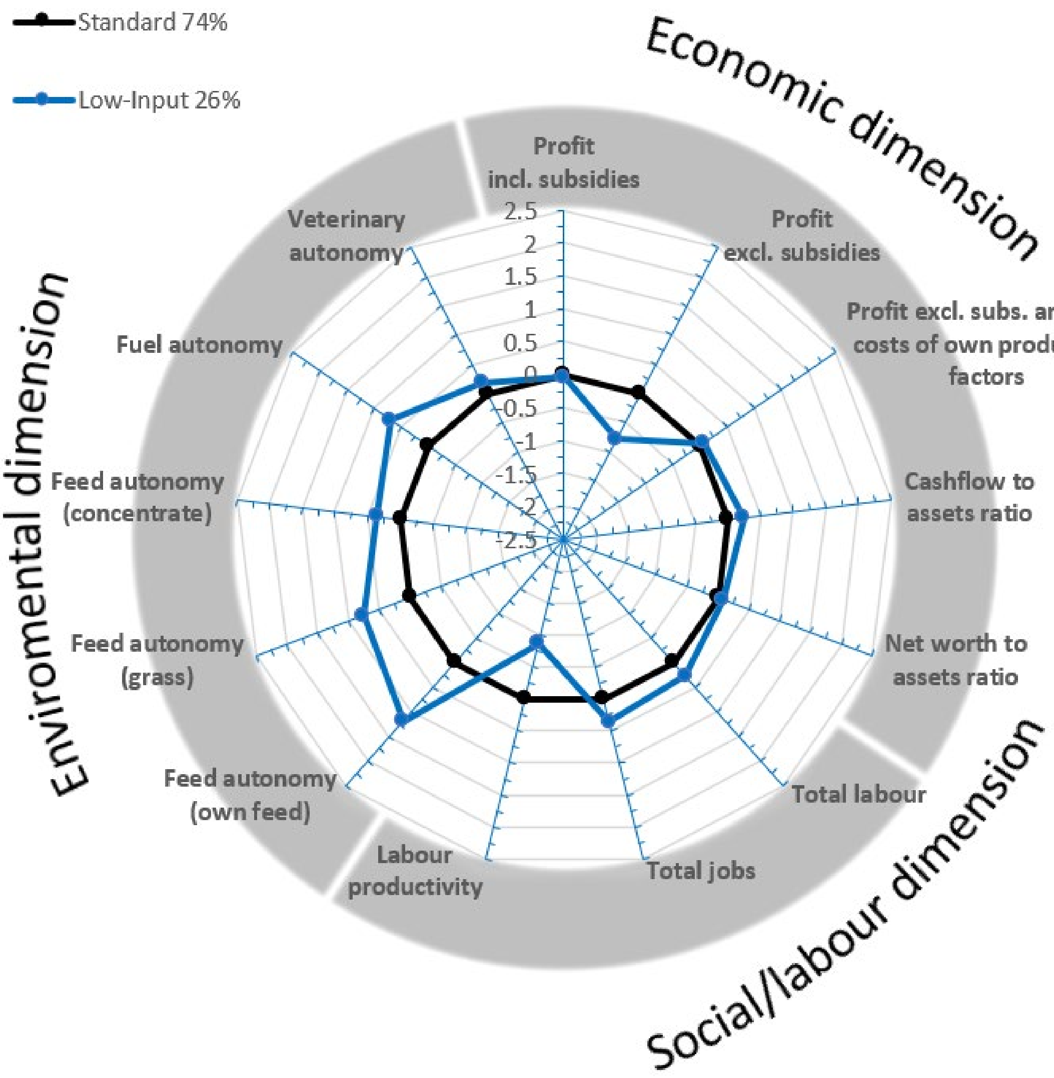
In the social/labour dimension, Low-Input farming performs better than Standard farming on the first two indicators (total labour and total jobs). These reflect the average size of farms with respect to labour input. When such farm size effects are eliminated by normalising labour input with the total monetary output of farms (labour productivity), results indicate that more ecological farming approaches are less productive in their use of labour input, a finding that tallies with work on social indicators in LIFT WP3 (Davidova et al., 2021; Niedermayr et al., 2021).

4.1.5.3 Discussion and conclusion

The overall better environmental performance of Low-Input farming is not surprising but also points to limitations in the FADN data. For example, fuel autonomy and feed autonomy (own feed) are two indicators used to identify Low-Input farms. While here we consider fuel autonomy and feed autonomy (concentrate), improved data that captures environmental outcomes of interest such as overall greenhouse gas emissions and/or biodiversity indicators are needed to judge the impact of different farming approaches. We should also note that we are considering both specialist cattle and specialist sheep farms in our sample due to the need for a larger sample size. 18% of the Standard farming group was specialist sheep whereas 90% of the Low-Input group was specialist sheep. While most farms are mixed – 85% of the specialist sheep farms also had cattle – the average livestock unit for cattle in Standard farms was 161 versus 96 on Low-Input farms. This difference is likely to account for some of the differences overserved in feed autonomy, concentrate use for example.

In terms of the economic performance, we see that Low-Input farms have similar liquidity and financial stability as Standard farms, but that without subsidies, their operations are less profitable than Standard farming counterparts. Much of this is likely to be due to less-favoured area (LFA) payments with Low-Input farms receiving on average much higher LFA subsidies than the Standard farms as they have more land with limiting conditions in their UAA (median of € 21,100 for Low-Input farms versus median of € 7,853 for Standard farms). This also indicates that many of the Low-Input farms may not be Low-Input by choice, rather by circumstance.

Finally, regarding the social/labour dimension, Low-Input farming approaches are associated with a higher workload. We see both that on average Low-Input farms use more labour (total labour), but they also have a slightly higher labour productivity.



Note: year = 2015, n = 184 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better and smaller than 0 indicate worse performance), measured in standard deviations of the Standard farming approach.

Figure 8: Comparison of farm level sustainability performance of different farming approaches for sheep and cattle farms in Scotland, based on FADN data.

4.1.6 Specialist granivore farms (TF14=50) in Poland

Vitaliy Krupin, Katarzyna Zawalińska (all IRWiR PAN, Poland)

4.1.6.1 Background

The following analysis has been carried out based on the Polish FADN data, which includes a total of 755 granivore farms in its 2015 database, yet only 4 farms have an organic farming certificate and none are in the process of conversion. For the purpose of the in-depth analysis of uptake of various farming approaches, 702 specialist granivore farms (FADN TF14 = 50) from the year 2015 are singled out from the above database. The degree of uptake of ecological practices is calculated based on the LIFT farm typology for FADN data, allowing to define two key farming approaches in Polish database: Standard farming (87%) and Integrated/Circular farming (13%). Other ecological approaches to farming according to the LIFT farm typology are also present, but their representation is substantially lower than the FADN farm aggregate data presentation limit. In total these are 23 farms, out of which 13 represent Low-Input AND Integrated/Circular farms, 5 are Low-Input farms, and 5 are defined as Organic farms. The data for these farms, along with data of defined outliers, have been removed from the aggregate dataset due to inflicted distortions upon the results (primarily through low feed autonomy (own feed) and low feed autonomy (concentrate)). Important to point out, out of the 702 granivore farms analysed, 646 farms represent specialist pig production, while the rest 56 farms are defined as specialist poultry or various combined granivore farms.

4.1.6.2 Results

The aggregated economic, environmental and social/labour results are presented in Figure 9.

In terms of profitability indicators, the results have shown that farms implementing ecological approaches (being Integrated/Circular) are more profitable compared to Standard granivore farms, both in case of presence of subsidies or their exclusion. Yet the influence of own inputs plays an important role in this case, as if costs of own production factors are considered with subsidies being excluded (profit excl. subs. and incl. costs of own production factors), this leads to profitability of Integrated/Circular farms lower than that of Standard farming. The liquidity and financial stability, represented by cashflow to assets ratio and net worth to assets ratio accordingly, do not show major differences with the Standard farms.

Environmental performance reveals that Integrated/Circular farms have lower expenses for veterinary services (high veterinary autonomy) and concentrate feed (high feed autonomy (concentrate)), while also having more agricultural land per livestock unit for the potential production of own feed (feed autonomy (own feed)) compared to the Standard farming. Farms implementing ecological approaches are also more efficient in fuel expenses (high fuel autonomy), even though this advantage is relatively smaller compared to the previously stated environmental indicators.

Analysis of labour aspects manifests lower performance of farms implementing ecological approaches, with the total labour being far below the standard farms. The differences for the total jobs and total labour are not as drastic, yet still less compared to the Standard farming. Uptake of ecological approaches in granivore farming leads to more intense, yet less efficient labour use, which is also more typical for farms of smaller sizes.

4.1.6.3 Discussion and conclusion

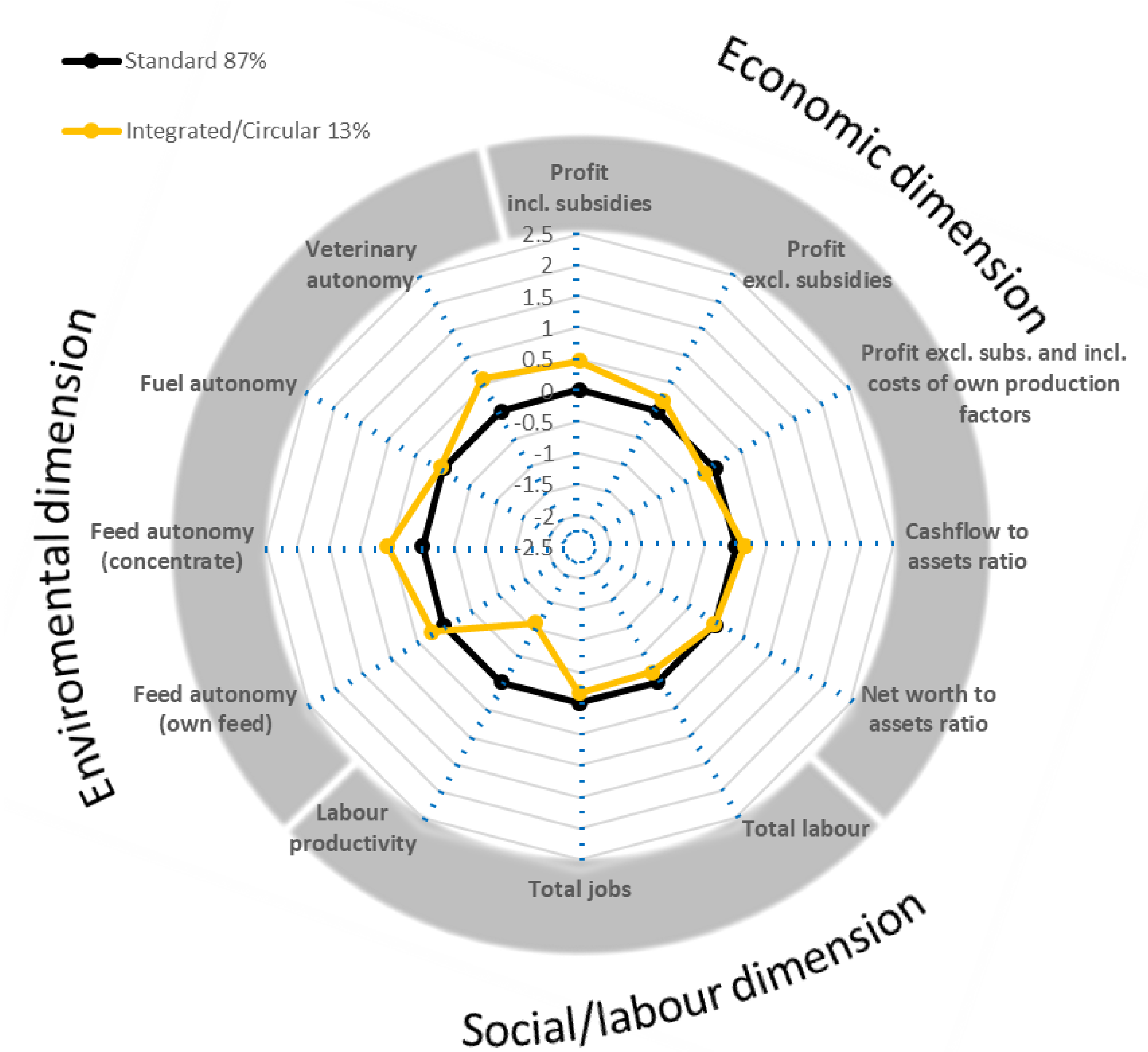
Economic aspects derived within the study show higher profitability levels of farms implementing ecological approaches, even without the official ecological certification. Thus, these were mostly farms receiving subsidies not associated with support of ecological/organic farming. Key issue in this aspect is accounting of costs of own production factors, which in case of small farms may be a relatively more difficult task. Support schemes for ecologically-oriented farms in economic sense seem to be quite promising in order to further boost economic performance of such farms.

Environmental performance of farms implementing ecological approaches is as expected exceeding the Standard farming. Integrated/Circular farms are more oriented towards circularity in input usage, while also being extensive in terms of input intensity.

Labour involvement is still a fragile issue in Poland, including the granivore farms. The smaller the farm, the larger is the use of family labour. In addition, Polish farms typically hire seasonal workers from abroad, yet this has been gradually becoming more difficult, both in terms of availability and costs.

The background of the sector's development in Poland is also important to understand the implications and possible uptake of ecological approaches. Pig production in Poland undergoes both reduction of population and decrease of farms involved in this economic activity. Constant processes of concentration are undergoing since the accession of Poland to the EU, as the larger pig farms are more resilient to fluctuation of meat prices. Production of poultry, both in case of meat and eggs, is highly concentrated and large-scale already. At the same time overall ecological activity in Polish farming is considered low (the share of Organic farms oscillates around 2%) and is gradually declining, and this is especially the case with the livestock sector, yet even more with granivores (pig and poultry).

It has been emphasised upon by the local stakeholders in Poland that ecological approaches in granivore farming are not being incentivised enough compared to the other agricultural sectors. In addition, processes of concentration undergoing in the Polish pig and poultry sectors are additionally directing it towards Standard farming approaches, use of intensive production technologies and utilising the economies of scale effect. Major problems of granivore farms aiming to implement ecological approaches include the need to accumulate land sufficiently to produce their own feed, in order to avoid the need to purchase expensive feed mixes (especially in case of certified organic production). Next, it is the lack of easily found intermediaries, as well as final consumers, both of which are associated with consumer habits and demand.



Note: year = 2015, n = 702 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 9: Comparison of farm level sustainability performance of different farming approaches for specialist granivore farms (FADN TF14 = 50) in Poland, based on FADN data.

4.1.7 Specialist cereal, oilseed and protein farms (TF14=15) in Hungary

Lajos Baráth, Zoltán Bakucs and Imre Fertő (all KRTK, Hungary)

4.1.7.1 Background

The present analysis is based on Hungarian FADN data of 777 specialist cereal, oilseed and protein crops producing farms (FADN Type of Farming = 15) from the year 2015. The degree of uptake of ecological practices is calculated based on the (weighted) LIFT farm typology for FADN data, leading to the following farming approaches: Standard farming (93%), Integrated/Circular farming (3%) and Low-Input farming (5%). Additional farming approaches and/or combinations of farming approaches were identified as well, but the number of farms in these groups was too small to include them in the calculations. These farms (a total of 8 farms, thereof 6 classified as Low-Input AND Integrated/Circular, 1 as Low-Input AND Integrated/Circular AND Organic and 1 classified as Organic) were thus excluded from the subsequent analysis.

4.1.7.2 Results

In this section we start with describing the differences between the identified farming approaches in terms of economic performance, environmental performance and social/labour related performance. Results are presented in Figure 10.

First, we report the economic performance. The three revenue-cost ratios in Figure 10, representing profitability, show different results. Low-Input farming approaches are more profitable with respect to both profitability categories (with and without public subsidies), however these advantages disappear if the cost of own production factors is considered and subsidies are excluded. Integrated/Circular farms perform better compared to standard farms if public subsidies are considered, but in terms of the other two profitability categories, their performance is the weakest. With respect to liquidity (cashflow to assets ratio) and financial stability (net worth to assets ratio) Low-Input farms perform better than Standard farms, whereas Integrated/Circular farms perform better in terms of financial stability and perform similarly (slightly lower) to Standard farms regarding liquidity.

From an environmental point of view, both Low-Input farms and Integrated/Circular farms perform on average better than Standard farming. The differences are rather high in every environmental indicator (share of fallow land, fuel autonomy, plant protection autonomy, fertiliser autonomy). The performance of Low-Input farms and Integrated/Circular farms are similar in terms of fertiliser autonomy, but in all other categories Low-Input farms perform better.

In the social/labour dimension, Integrated/Circular farm performance is weaker in all of the examined indicators compared to Standard farms. Low-Input farm performance is weaker in terms of total labour and total jobs, but it is better in terms of labour productivity.

The first two indicators (total labour and total jobs) additionally also reflect the average size of farms with respect to labour input (i.e. these farming approaches are smaller in terms of absolute labour input, considering both unpaid as well as total jobs; the difference is more pronounced in the case of Low-Input farms). If such farm size effects are eliminated by normalising labour input with the total monetary output of farms (labour productivity), results indicate that Low-Input farming approaches are more productive in their use of labour input, but Integrated/Circular farms perform still worse compared to both of the other two evaluated farming practices.

4.1.7.3 Discussion and conclusion

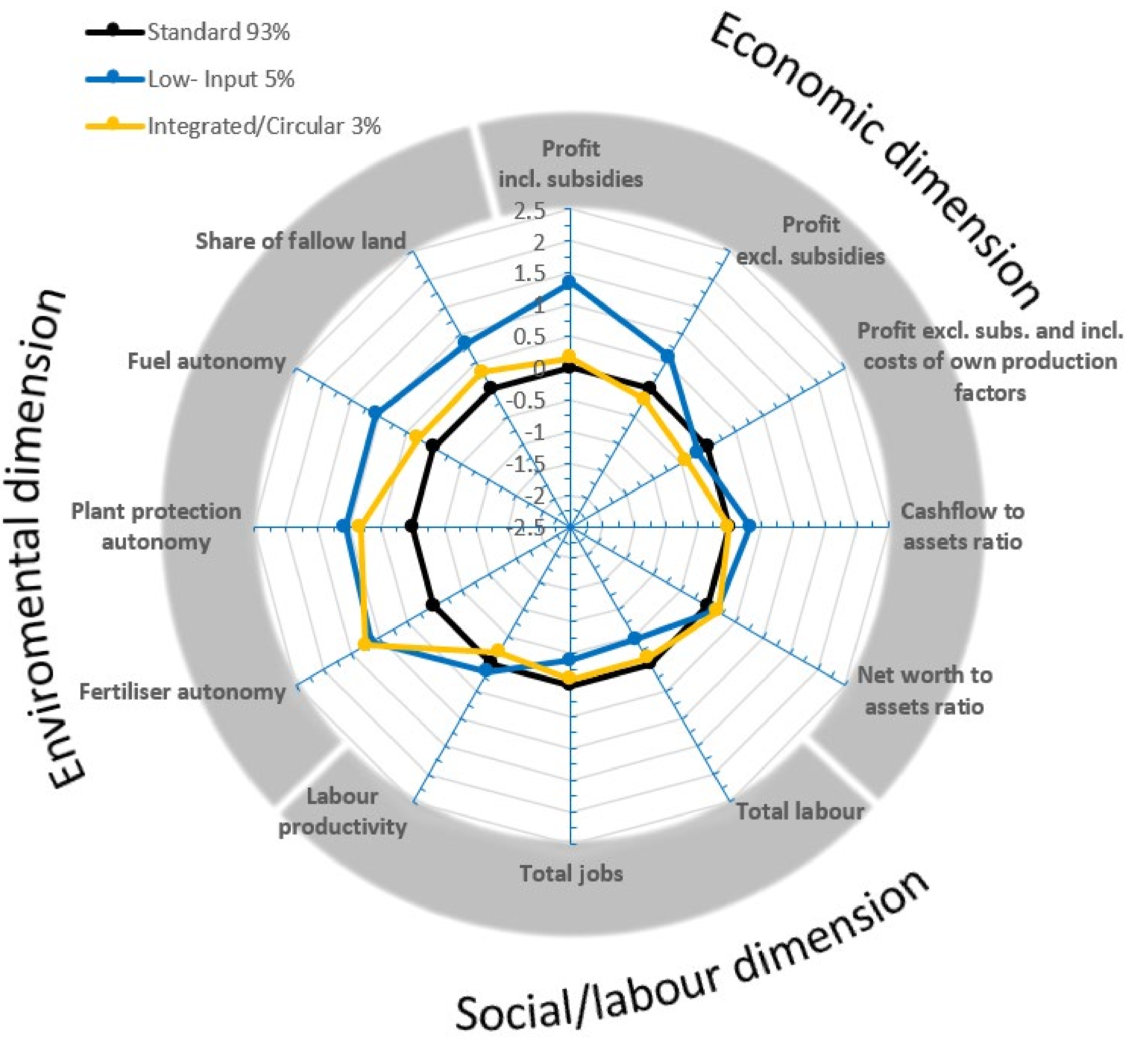
This integrative assessment of economic, environmental and social/labour related performance sheds light on some of the main differences between the analysed farming approaches.

As it is expected, the environmental performance of Low-Input and Integrated/Circular farming approaches is clearly better compared to Standard farming. The comparison of Low-Input and Integrated/Circular farming with each other show that in most of the environmental indicators (except fertiliser autonomy), Low-Input farms performed better.

Labour related performance in general is better in Standard farms compared to Low-Input and Integrated/Circular farms, except labour productivity, which is slightly better for Low-Input farms.

The comparison of economic performance is not as clear as the environmental performance. The analysis showed that the calculation method of profitability indicator is crucial. It is especially important whether the costs of own production factors are included or not.

In sum, this method is adequate to get a first overview about the performance of different farming approaches from different perspectives. The results are basically in line with local stakeholders' opinions. However, there might exist additional background factors that influence the results of this simple comparison. Therefore, additional research is required with more rigorous statistical methods to get a clearer picture regarding the performance differences of these farming approaches.



Note: year = 2015, n = 777 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, *based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.*

Figure 10: Comparison of farm level sustainability performance of different farming approaches for cereal, oilseed and protein crop farms in Hungary, based on FADN data.

4.1.8 Specialist other field crop farms (TF14=16) in the United Kingdom

Stuart Henderson (UNIKENT, United Kingdom)

4.1.8.1 Background

The present analysis is based on United Kingdom (UK) FADN data of 159 specialist other field crop farms, i.e. field crop farms that are not cereal, oilseed and protein farms (i.e. FADN Type of Farming = 16) from the year 2015. The degree of uptake of ecological practices is calculated based on the LIFT farm typology for FADN data, leading to the following farming approaches: Standard farming (38%), Low-Input farming (56%) and a combination of Low-Input AND Organic farming (6%), where the order reflects an increasing uptake of ecological practices. An additional farming approach was identified as well, but the number of farms in this group was too small to include them in the calculations. These farms (a total of 2 farms, both organic farming) were thus excluded from the subsequent analysis. 3 outliers were removed for potentially introducing biases in the results, 1 Standard farm for using far more total labour than all other farms, 1 Low-Input AND Organic farm for much higher rent paid for land, and much higher use of P205 and K20 in mineral fertilisers used and lastly another Standard farm for much higher relative motor and fuel expenses. Care needs to be taken when studying the performance of Low-Input AND Organic farms here given the small size of this group.

4.1.8.2 Results

Starting with technical-economic performance, the three profitability indicators show different results (Figure 11). While ecological farming approaches are marginally more profitable if public payments are included, they are less profitable than Standard farming if public payments are not included and the Low-Input AND Organic farms perform even worse. If opportunity costs of own production factors are also considered, ecological farming approaches remain on average less profitable than Standard farming, more so the Low-Input farms in this instance, but the drop in profitability is not as severe without opportunity costs and subsidies. With respect to liquidity (cashflow to assets ratio) and financial stability (net worth to assets ratio) there are only slight differences between farming approaches, Low-Input farms performing slightly better in these measures and Low-Input AND Organic just a little worse in terms of liquidity.

From an environmental point of view, ecological farming approaches perform better than Standard farming across all measures. The Low-Input AND Organic approach performs best followed by the Low-Input approach. These approaches leave more land fallow, spend less on fuel, plant protection and fertiliser relative to the farm’s UAA.

In the social/labour dimension, ecological farming approaches seem to require slightly less or just the same amount of labour as Standard farming. The first two indicators (total labour and total jobs) additionally also reflect the average size of farms with respect to labour input - i.e. in absolute terms, these farming approaches use a smaller overall labour input: Low-Input farms are smaller in both total labour and total jobs whereas Low-Input AND Organic farms are very similar compared to Standard farms. If such farm size effects are eliminated by normalising labour input with the total monetary output of farms (labour productivity), results indicate that Low-Input AND Organic farms are less productive in their use of labour input, but Low-Input farms are slightly more productive than Standard farms.

4.1.8.3 Discussion and conclusion

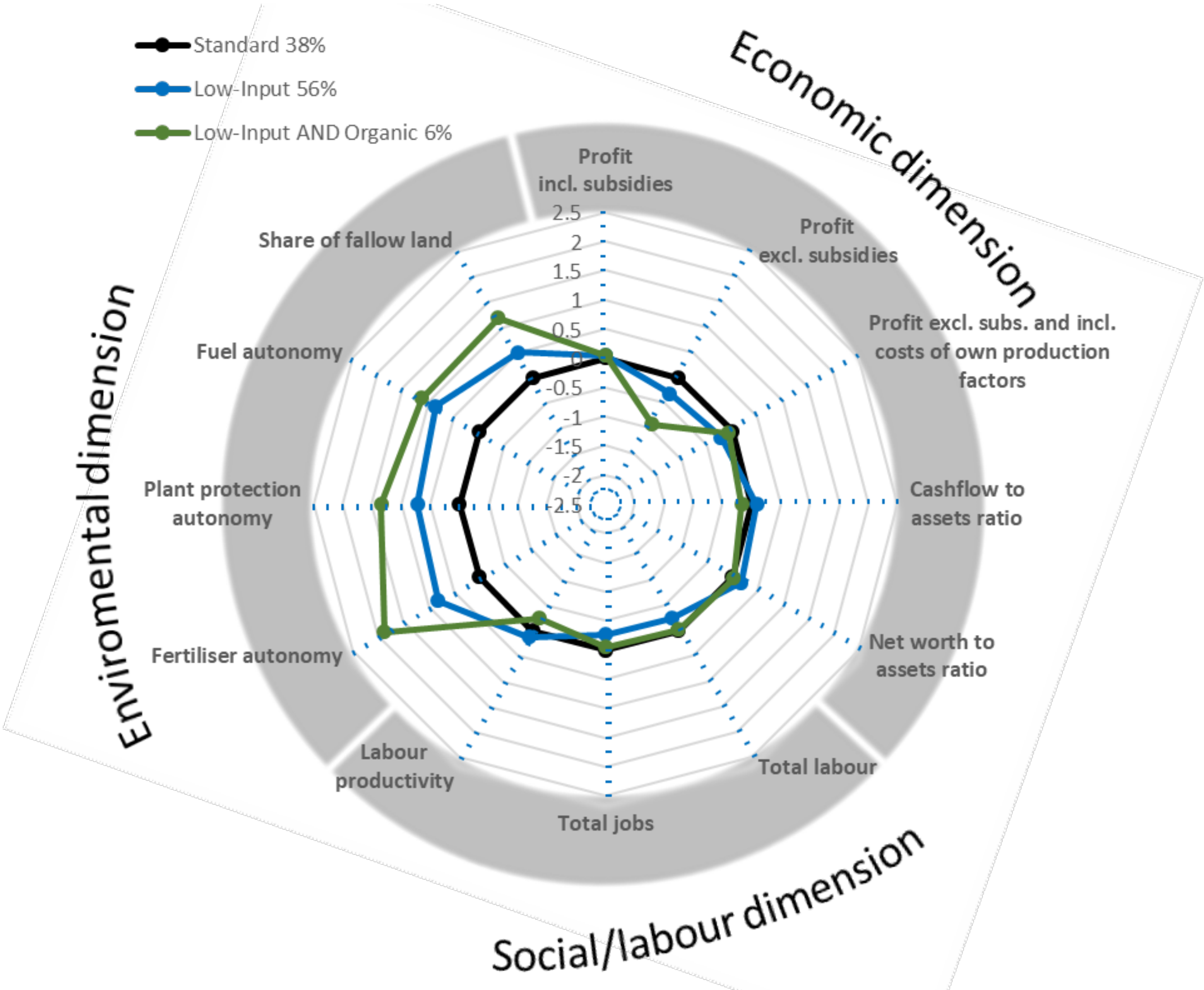
Results of technical-economic performance are in line with findings derived from LIFT WP3 (Niedermayr et al., 2021). Ecological farming approaches are just as profitable as Standard farming. However, this profitability depends significantly on subsidies, which once excluded show a dramatic fall in profitability for both ecological farming approaches and more so for Low-Input AND Organic farms. Stakeholders in the UK argue that crop yields in Standard crop farms have plateaued leaving little prospect for additional income through selling a higher quantity of crops. This has switched the focus of farmers to other sources of income and/or savings (therefore profit) which are through environmental subsidies, or agri-environmental payments, and minimising input use. This pursuit of future profit is leading farmers into Low-Input farming and Low-Input AND Organic farming which would be more likely to receive agri-environmental payments. However, in their dependence on agri-environmental payments for profit, yields may suffer and there is little price premium for specialist other field crop farms that are Low-Input farms.

Some profitability seems to offset the exclusion of subsidies for ecological farming approaches when including costs from the farm's factors of production namely land, labour and capital. Although total jobs may be lower in ecological farming approaches, share of rented land may not be very different, machinery is expected to be less important by stakeholders in interviews (Bailey et al., 2021). Machinery is expected to be smaller, more specialised and shared more between farmers thus reducing associated capital costs for ecological farming approaches. These stakeholder viewpoints are also in line with results from (Davidova et al., 2021) where capital is more intensively used on Standard farms.

The overall better environmental performance of ecological farming approaches is not surprising. In their nature of being Low-Input farms, they would also minimise their expenses on fuel, plant protection and fertiliser use which is reflected in the environmental indicators where the Low-Input AND Organic farms perform best followed by the Low-Input farms. Fallow land is also much higher in both ecological farming approaches reflecting a need to keep land fallow for agri-environmental payments.

Labour productivity is slightly higher for Low-Input farms, but slightly lower for Low-Input AND Organic farms. A possible explanation for this could be that a Low-Input approach for the analysed arable farms is associated with less field work, but that combining this farming approach with Organic farming results in an overall labour increase, since this farming approach limits the usage of chemical plant protection, resulting in potentially more work associated with other means of plant protection. Although the findings in Davidova et al. (2021) suggest that Low-Input farms are more labour intensive, it also shows that for the UK (and other countries) at lower levels of input use, labour use acts a complement whereby reducing the use of fertiliser and plant protection products reduces the requirement for someone to apply them.

Overall, our results seem to be in line with what we have seen in LIFT WP3 (Niedermayr et al., 2021) and with stakeholder views. We are thus confident that the identified farming approaches and results of our performance assessment provide a realistic picture of the situation of specialist other field crop farms in the UK. While positive environmental effects are to be expected, it is of particular importance to consider public payments as well as the requirement for hired labour in ecological farming approaches.



Note: year = 2015, n = 159 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 11: Comparison of farm level sustainability performance of different farming approaches for specialist other field crop farms in the United Kingdom, based on FADN data.

4.1.9 Specialist orchards – fruits farms (TF14=36) in Italy

Monserrath Ximena Lascano Galarza, Matteo Zavalloni, Riccardo D'Alberto, Meri Raggi, Davide Viaggi (all UNIBO, Italy)

4.1.9.1 Background

The present analysis is based on a subsample of the Italian FADN data from the year 2013, composed of 176 specialist orchards – fruits farms (FADN TF14 = 36). The degree of uptake of ecological practices is calculated based on the LIFT farm typology for FADN data, leading to the following farming approaches: Standard farming (60%), Integrated/Circular farming (33%), and Organic farming (7%). The order reflects an increasing uptake of ecological practices. Initially, five groups of farming approaches were identified (106 Standard farms, 58 Integrated/Circular farms, 12 Organic farms, 3 Integrated/Circular AND Low-Input farms, 3 Integrated/Circular AND Organic farms, and 1 Integrated/Circular AND Organic AND Low-Input farm), nevertheless, to allow a robust analysis, the groups formed by fewer than 10 farms were excluded from the subsequent study.

4.1.9.2 Results

Figure 12 shows slight differences between farming approaches regarding the economic performance indicators. The three revenue-cost ratios, representing profitability, show that farms, regardless of their farming approach, are equally profitable if public payments are included (profit incl. subsidies). If public payments are not included (profit excl. subsidies), Organic farming approaches are, on average, less profitable than Standard and Integrated/Circular farming. If opportunity costs of own production factors are also considered, Organic farms are on average more profitable than Standard farming, while Integrated/Circular farming is the worst performing farming approach. Moreover, ecological farming approaches (Organic and Integrated/Circular) perform slightly better than Standard farming with respect to financial stability (net worth to assets ratio), while in terms of liquidity (cashflow to assets ratio), Organic farms are the best performing farming approach.

In the environmental dimension, results show that, in general, ecological farming performs better than Standard farming approaches. Differences between Standard and Integrated/Circular farming are minor when looking at fuel autonomy and plant protection autonomy, yet Integrated/Circular farming performs better when looking at share of fallow land and fertiliser autonomy. Considering fuel autonomy, share of fallow land, and plant protection autonomy, Organic farms are the best performers; however, Organic farms show similar performance to Standard farming regarding fertiliser autonomy.

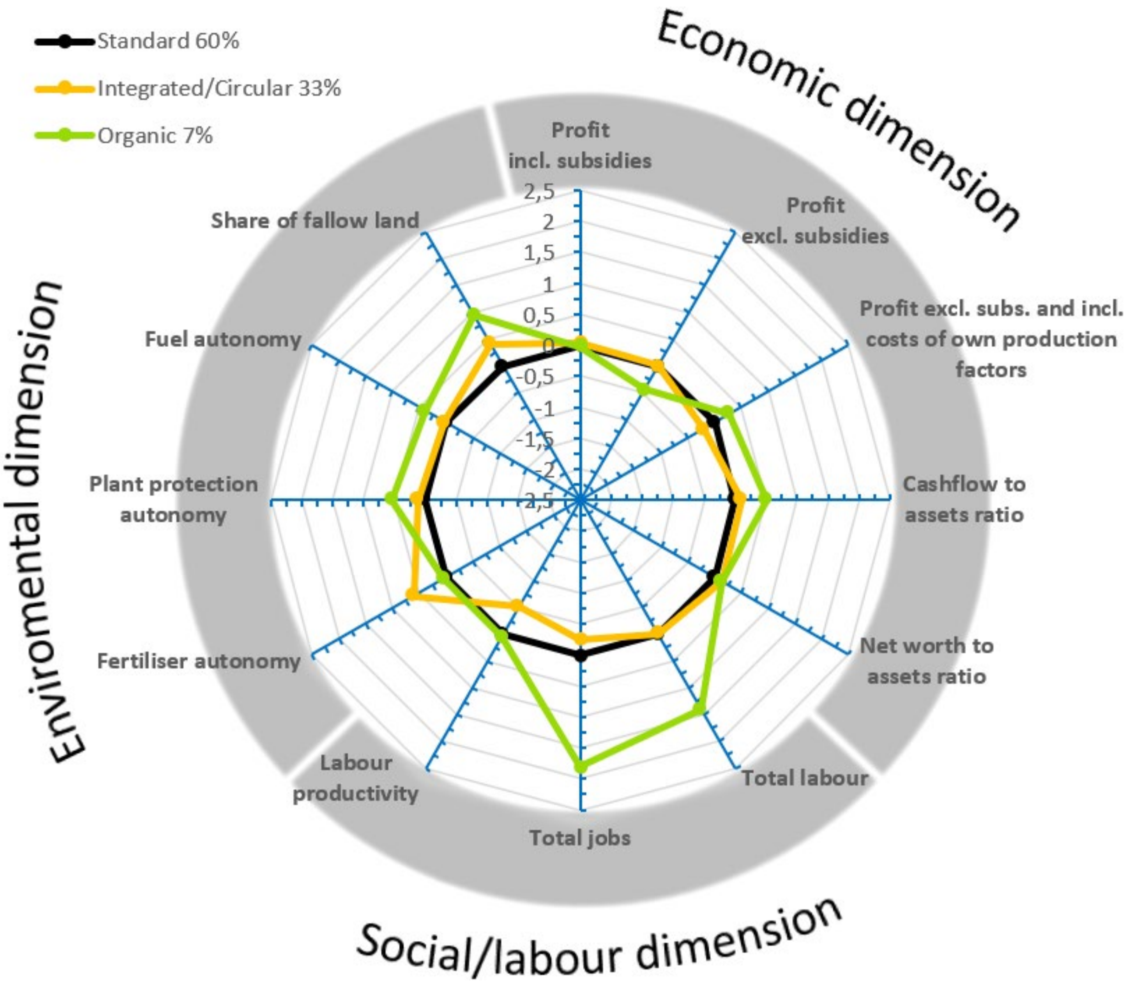
Ecological farming and Standard farming perform differently in terms of social/labour aspects. Considering the indicators that also reflect the farms' average size with respect to labour input (total labour and paid labour in AWU), Organic farms perform better than Integrated/Circular and Standard farms. However, after normalising the farms' input labour to revenues (labour productivity), results show that the Integrated/Circular farms are less productive than the other two groups of farming approaches and that Standard and Organic farms are equally productive.

4.1.9.3 Discussion and conclusion

Results of economic performance are in line with findings derived from LIFT WP3 (Niedermayr et al., 2021). In general, results suggest that a higher level of ecological farming approach is negatively related to economic performance and productivity indicators. In general, the profitability of Organic farms is lower when excluding subsidies compared to the Standard farms, which could indicate that the survival of this type of farming depends on subsidies. However, when measuring profitability by excluding subsidies and including opportunity costs, Organic farms outperform, suggesting that their opportunity cost of production outweighs the subsidies received.

From the environmental point of view, the findings in LIFT WP3 (Niedermayr et al., 2021) were ambiguous. To overcome such ambiguities, stakeholders suggested homogenising the farms (selecting only one type of specialisation), and considering inflation, especially when dealing with a panel data reporting inputs' price. The present analysis somehow considers the suggestions made by the stakeholders since the analysis is performed only on Specialist orchards farms only for the year 2013. The ambiguities reported in LIFT WP3 seem to have been overcome since results show an overall better performance of ecological farming approaches compared to Standard farming. Fertilisers, however, remain a point of concern since FADN does not provide data on the actual quantity of input use, but only on costs and at the aggregate level (not per crop). Considering only total values may bias the environmental performance analysis since organic products, as fertilisers, tend to be more expensive than conventional products.

Finally, regarding the social/labour dimension, it is not surprising to find that more ecological farming approaches are less productive (in terms of labour productivity) than Standard farming, given a higher amount of labour input, indicated by total labour and total jobs. These results are plausible since more ecological farming approaches entail constraints and restrictions that translate into higher workload and reduced productivity.



Note: year = 2013, n = 176 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 12: Comparison of farm level sustainability performance of different farming approaches for specialist orchard – fruit farms in Italy, based on FADN data.

4.2 Analyses based on LIFT large-scale farmer survey data

4.2.1 Specialist dairy farms (TF14 = 45) in Austrian case study regions

Andreas Niedermayr, Lena Schaller and Jochen Kantelhardt (all BOKU, Austria)

4.2.1.1 Background

The study is applied to dairy farms in Austria. The survey sample consists of 80 farms pooled across two NUTS3 regions (AT314 Steyr-Kirchdorf, AT323 Salzburg und Umgebung). As in these regions, dairy farms operate primarily on permanent grassland, conservation agriculture is not considered as a separate ecological approach. The application of the typology protocol to the survey data (Rega et al., 2021), excluding conservation agriculture, brings the following numbers of farms in the LIFT farm typology farming approaches and combinations thereof, from lowest to highest degree of adoption of ecological practices (number of farms in parentheses): Low-Input (5), Integrated/Circular (2), Low-Input AND Integrated/Circular (6), Organic (10), Low-Input AND Organic (8), Integrated/Circular AND Organic (2), Low-Input AND Integrated/Circular AND Organic (16). In order to have sufficiently large group sizes for the further analysis, we firstly merge Low-Input, Integrated/Circular as well as the combination of these two farming approaches into one group without Organic farming (13 farms), which we label **"Low-Input AND/OR Integrated/Circular"**. Secondly, we merge organic farms with the groups combining Organic farming with a second farming approach and label this group "Organic OR Organic plus one additional farming approach" or in short **"Organic(+)"**, consisting of 20 farms. As last group we keep the combination of all three investigated farming approaches (Low-Input AND Integrated/Circular AND Organic) as a separate group, consisting of 16 farms with the highest degree of uptake of ecological practices. We label this group "Organic plus two additional farming approaches" or in short **"Organic++"**.

As regards the performance indicators used in the present analysis, due to the unavailability of certain variables from the LIFT large-scale farmer survey for the Austrian case study regions, some modifications to the common definitions of performance indicators had to be made. As regards the economic performance dimension, this concerns the net worth to assets ratio, which was not available, since the interviewed farms did not report the necessary data for this indicator. In terms of the social/labour performance dimension, all three proposed performance indicators (total labour, total jobs and labour productivity with respect to output) could be included. Since all farms in the sample also completed the additional questionnaire on private social farm performance (Hostiou et al., 2021), an additional indicator, expressing the average work satisfaction level of the farmers could also be included in the spider web. With respect to environmental farm performance, all indicators proposed for grazing livestock farms in the spider web could be used, but two had to be calculated based on expenses for environmentally relevant inputs instead of their biophysical quantities. This concerns concentrate feed and fuel input, respectively.

4.2.1.2 Results

Results of performance comparison between the identified groups can be seen in Figure 13. In the economic performance dimension, ecological farming approaches perform mostly worse than Standard farming, except for the cashflow to assets ratio for Low-Input AND/OR Integrated/Circular and Organic(+) farms. Also, Organic++ farms perform slightly better in terms of profitability, if public payments are included. However, if public payments are excluded and subsequently also opportunity costs of own production factors (own land, family labour equity) are included in the profitability assessment, the performance of ecological farming approaches decreases further and is overall worse than that of Standard farms, with the performance gap increasing with a decreasing degree of adoption of ecological practices.

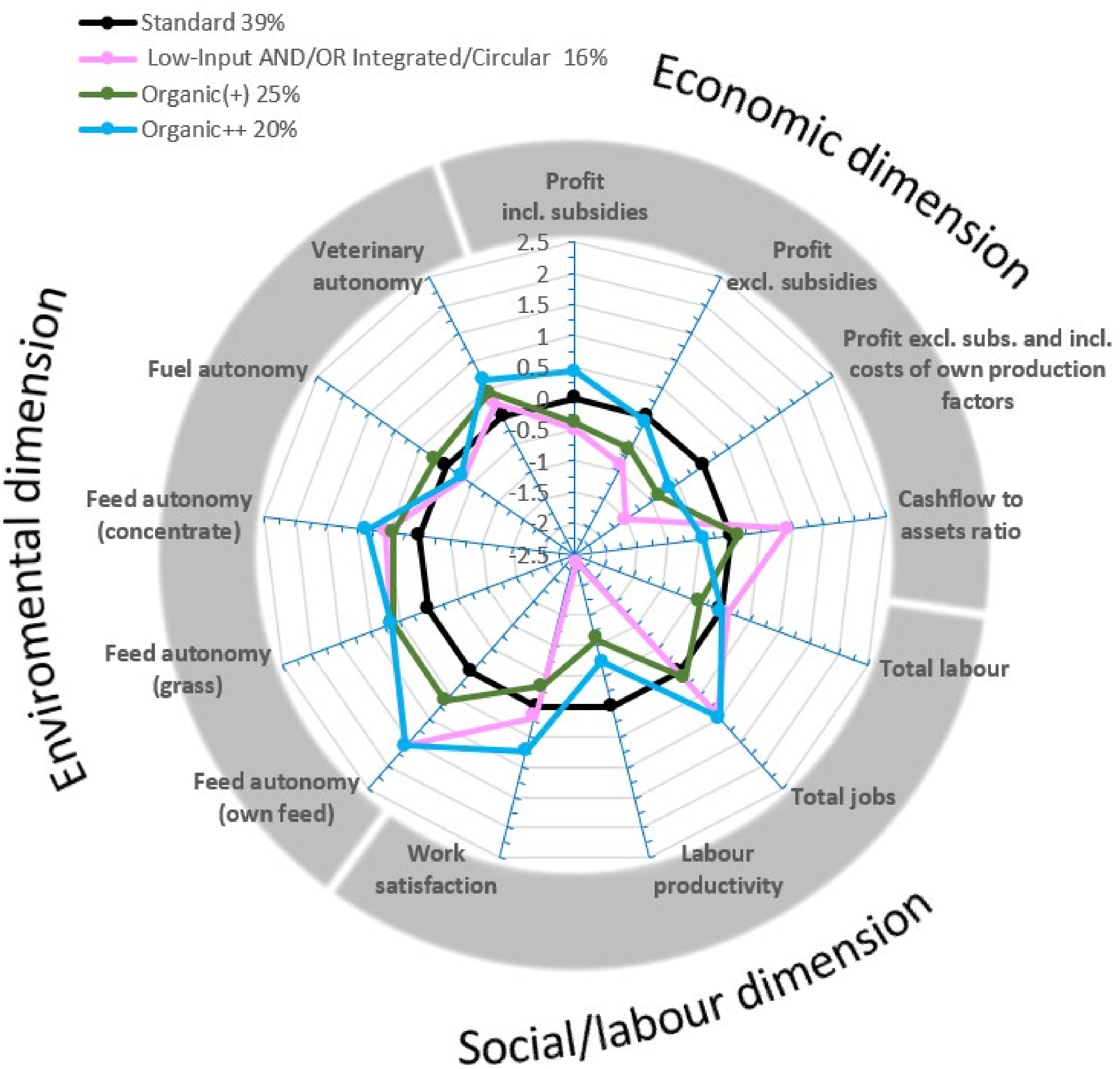
Looking at social/labour performance, all farming approaches have a comparable farm size with respect to total labour input, while the total number of jobs is to some extent higher for Low-Input AND/OR Integrated/Circular farms as well as Organic(+) farms. If labour input is normalised by farm size, the picture shown by the resulting labour productivity indicator is the opposite. This means that ecological farming approaches are less productive in their use of labour compared to Standard farms. Here, again the performance gap in comparison to Standard farms decreases with an increasing degree of adoption of ecological practices. In terms of work satisfaction, the findings show a different picture. While Organic(+) farms have a slightly lower work satisfaction level than Standard farms, the opposite is true for Low-Input AND/OR Integrated/Circular farms and also for Organic++ farms.

With respect to environmental performance, results show an overall performance advantage for the ecological farming approaches compared to Standard farming. The only exception is fuel autonomy, where Low-Input AND/OR Integrated/Circular farms and Organic++ farms perform slightly worse than Standard farms. In general, the mostly higher environmental performance of ecological farming approaches is not surprising, since the used performance indicators partly reflect information which was also used to identify the farming approaches of the LIFT farm typology.

4.2.1.3 Discussion and conclusion

The findings regarding economic farm performance and in particular profitability reflect to a large extent those of Niedermayr et al. (2021), even though the classification system of ecological farming approaches differs. As can also be seen from the overall performance comparison in section 4.1.1 for Austrian dairy farms using FADN data, the potential caveats in terms of (current) opportunity costs of own production factors, a higher workload due to lower labour productivity of ecological farming approaches and the possibility to substitute labour to some degree with higher capital input, as well as possible additional administrative burden associated with certifications, need to be considered in this context. The mostly higher performance of ecological farming approaches in the environmental dimension is as expected. Regarding the social/labour dimension, lower labour productivity of ecological farming approaches is also in line with findings from LIFT WP3 (Niedermayr et al., 2021). Here, the survey data is able to offer some insights into farmers' perceived social conditions, reflected in this analysis with the additional indicator summarising overall work satisfaction (see section 5.3 for further indicators) – something not possible with current FADN data. However, monitoring labour input, jobs and labour productivity in combination with social conditions is a crucial aspect in the ecological transition of EU agriculture.

Overall, we discussed our results with regional stakeholders. We are thus confident that the identified farming approaches and results of our performance assessment provide a realistic picture of the situation of dairy farms in the two case study regions. Moreover, our analysis also shows how such an integrative assessment of economic, environmental and employment and labour-related performance offers a nuanced picture of possible effects of an increased uptake of ecological approaches by farms.



Note: year = 2018, n = 80 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 13: Comparison of farm level sustainability performance of different farming approaches for dairy farms in the Austrian case study regions Steyr-Kirchdorf and Salzburg und Umgebung, based on LIFT large-scale farmer survey data.

4.2.2 Specialist dairy farms (TF14 = 45) in French case study regions

Laure Latruffe (INRAE, France), Yann Desjeux (INRAE, France), Philippe Jeanneaux (VetAgro Sup, France)

4.2.2.1 Background

The study is applied to dairy farms in France. The survey sample consists in 108 farms across three NUTS3 regions (Ille-et-Vilaine, Puy-de-Dôme, Sarthe). The application of the typology protocol applied to LIFT large-scale survey data (see Rega et al., 2021) brings the following numbers of farms in the farming approaches, from the lowest degree to the highest degree of uptake of ecological practices: Standard farming (25 farms); Low-Input farming (23 farms); Conservation Agriculture (26 farms); Integrated/Circular (0 farm); Organic farming (1 farm); combination of ecological farming approaches (33 farms). The latter group of 33 farms includes farms that are spread across several combinations of ecological farming approaches: Low-Input AND Organic (13 farms); Conservation AND Low-Input (5 farms); Low-Input AND Integrated/Circular (1 farm); Low-Input AND Integrated/Circular AND Organic (10 farms); Conservation AND Low-Input AND Integrated/Circular (1 farm); Conservation AND Low-Input AND Organic (1 farm); Conservation AND Low-Input AND Integrated/Circular AND Organic (2 farms). These figures show that the numbers of farms per combination group are low. They are not sufficient to draw meaningful conclusion in terms of performance for these groups alone, and therefore we merge all these ecological groups into one single group: the group of farms applying a combination of two or three ecological farming approaches. We consider that this group includes farms that have the highest degree of uptake of ecological practices. The low number of farms per group also applies to the case of Organic farming (1 farm). Since it is not possible to draw meaningful conclusion for one farm only, we merge the organic farm with the group of 33 farms applying a combination of two or three ecological farming approaches. We call this group: Organic farming or combination of ecological farming approaches (Organic OR Combination), consisting in 34 farms. This group has the highest degree of uptake of ecological practices.

Therefore, the following categories are used (on 108 farms):

- **Standard farming**: 25 farms (23%)
- **Low-Input farming** 23 farms (21%)
- **Conservation Agriculture**: 26 farms (24%)
- Organic farming or combination of ecological farming approaches (**Organic OR Combination**): 34 farms (32%).

4.2.2.2 Results

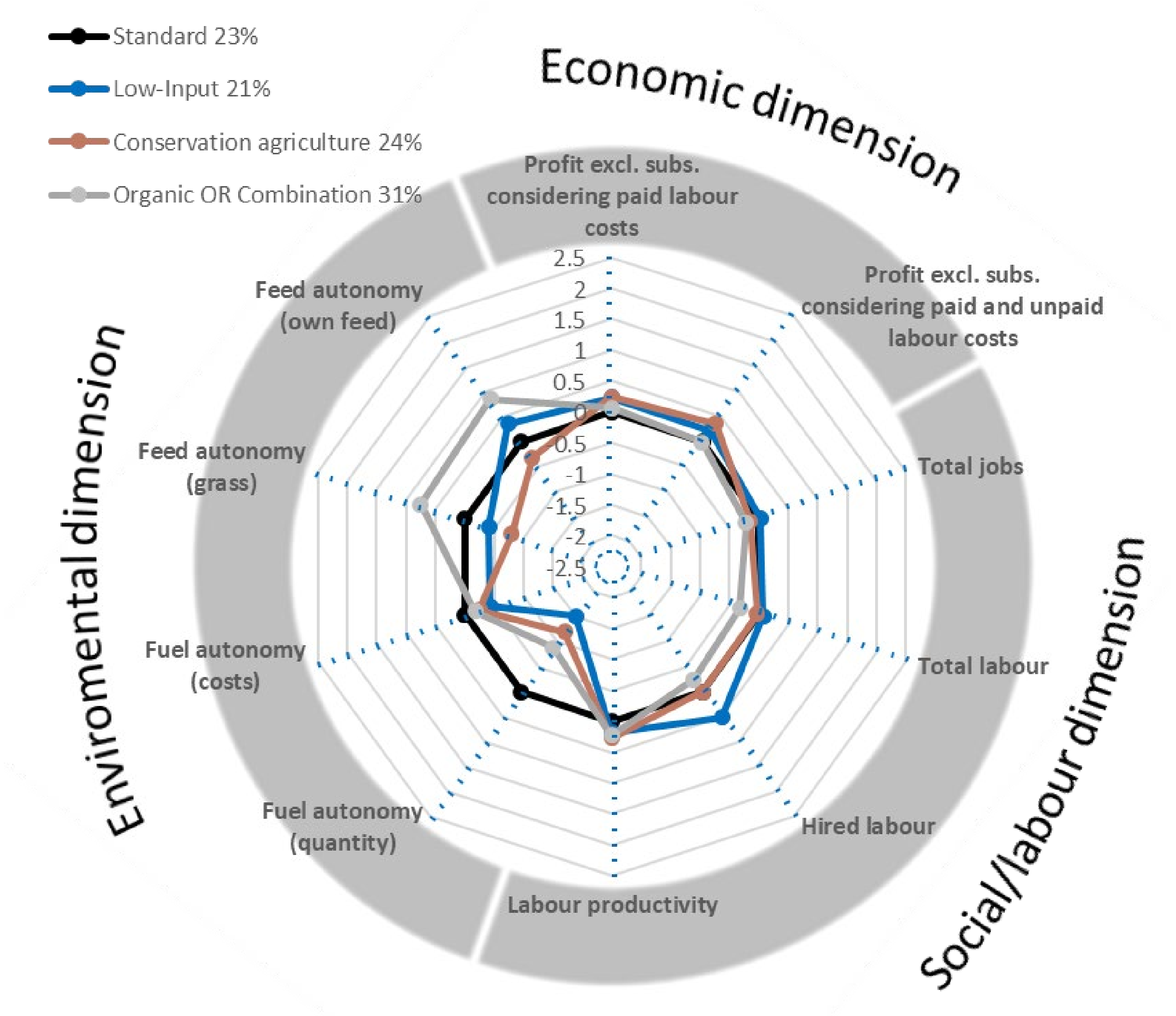
The spider graph on Figure 14 shows the performance dimensions for Standard farming and the ecological types, namely Low-Input farming, Conservation Agriculture, Organic farming or combination of ecological farming approaches. There are slight differences across farming approaches in terms of profitability defined by revenue (excluding subsidies) divided by labour cost, whether the cost excludes or includes cost of own labour. Nevertheless, Conservation Agriculture and Low-Input farming perform slightly better than Standard farming and better than the combination of ecological types. By contrast, the analysis on the French dairy farms from the FADN in 2015 showed that farms combining Integrated/Circular AND Organic farming were the only ones superior to Standard farms in terms of profitability excluding subsidies (see section 4.1.2). The difference here is that only labour costs could be accounted for (excluding or including own costs), while the FADN analyses accounted for costs for labour, land and capital (excluding or including own costs).

As regards social/labour indicators, there are almost no differences across farming approaches in terms of total jobs that is to say in terms of number of persons working on the farm. When labour is measured in hours instead of persons, the combinations of ecological approaches perform worse than other farming approaches. By contrast, when only hired labour (in hours) is considered, one system largely outperforms the others, namely Low-Input farming. All these findings are in opposite to the analysis on French FADN dairy farms (section 4.1.2), where Low-Input farming performs the worst and the combination of Integrated/Circular and Organic farming performs the best. In terms of labour productivity, all three ecological groups considered here perform similarly and better than Standard farming. This is completely in opposite to the analysis on French FADN dairy farms (section 4.1.2).

Finally, as regards environmental indicators, the combinations of ecological farming approaches perform best, while Conservation Agriculture performs the worst, in terms of feed autonomy (own feed) and feed autonomy (grass). This result conforms to the definition of Conservation Agriculture, which does not apply to grassland. Low-Input has a mixed performance: it performs better than Standard farming in terms feed autonomy (own feed) (lower feed autonomy (own feed)) but performs worse in terms of feed autonomy (grass) (lower feed autonomy (grass)). This is in contrast to the analysis on French FADN dairy farms (section 4.1.2), where all ecological groups largely outperform Standard farming in terms of these two environmental indicators. The fuel autonomy indicators show that all ecological groups perform much lower than Standard farming, and this lower performance is much more marked when fuel use is considered in quantity rather than in costs, with the worst performer being Low-Input farming. This is completely in opposite to the analysis on French FADN dairy farms (section 4.1.2), and suggests that the Low-Input farms in the LIFT large-scale farmer survey sample are low-fuel users.

4.2.2.3 Discussion and conclusion

Divergence in results between the present study on the data from the LIFT large-scale farmer survey and the study on the French FADN dairy farms (section 4.1.2), may be due to several reasons. A first reason may be the difference in protocol rules and thresholds between both datasets (Rega et al., 2021). The FADN protocol considers the large sample of the whole EU while the typology protocol was elaborated on a few farms only. A second reason may be that the samples are different. While the FADN sample includes commercial farms that are representative, the sample of the LIFT large-scale farmer survey has been made of willing farmers, and in some areas it specifically targeted ecological farms. A third reason for the difference in conclusions between both analyses may be that the definition of indicators is not similar. While in FADN the accountancy information is available and reliable as it comes from accountancy books, in the LIFT large-scale farmer survey data the information had to be specifically collected and farmers may not remember easily the accountancy information. This implies that for such variables a lot of information is missing and indicators had to be computed on information that is available only. Their definition is somehow different, due to the different information quality.



Note: year = 2015, n = 108 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 14: Comparison of farm level sustainability performance of different farming approaches for dairy farms in French case study regions Ille-et-Vilaine, Puy-de-Dôme and Sarthe, based on LIFT large-scale farmer survey data.

4.2.3 Olive farming in Greek case study region

Vasilia Konstantidelli, Irene Tzouramani, Alexandra Sintori, Penelope Gouta (all Demeter, Greece)

4.2.3.1 Background

This study aims to assess the sustainability performance of 66 olive farms in East Crete, Greece, within various ecological farming approaches. The data used in this analysis related to the year 2018 and were collected during the LIFT large-scale farmer survey in the two NUTS3 regions of Crete (EL431 Heraklion, EL432 Lasithi) located on the eastern side of the island. It should be noted that although the data collected during the LIFT large-scale farmer survey concern both olive and vineyard farms, the present study focuses on the specialist olive farms. As specialist olive farms, we consider those farms with two-thirds of their output (revenues) stemming from olives and predominantly from olive oil production (see Niedermayr et al., 2021, for more details). Nevertheless, it should be pointed out that as this analysis is performed at farm level, all the variables used in the calculations concern the agricultural activities of the farms and not only the olive cultivation.

The implementation of the typology protocol applied to LIFT large-scale survey data (see Rega et al., 2021), assigned the following number of farms in the LIFT farm typology farming approaches and their combinations, in ascending order according to the degree of uptake of ecological practices: **Standard** (31 farms), Conservation Agriculture (4 farms), Low-Input (3 farms), **Organic** (9 farms), Conservation Agriculture AND Organic (9 farms), Low-Input AND Organic (6 farms), Conservation Agriculture AND Low-Input AND Organic (4 farms). However, the small sample size led to the formation of small size groups. Thus, it was decided to merge some of the groups mentioned above to have adequately large size groups for further analysis. More specifically, “Conservation Agriculture” and “Low-Input” groups were merged into one group under the label “**Conservation OR Low-Input**”, as well as the three groups where the Organic approach is combined with other farming approaches (i.e., “Conservation Agriculture AND Organic”, “Low-Input AND Organic”, “Conservation Agriculture AND Low-input AND Organic”) into a single group under the label **“Organic+(+)**”.

Regarding the performance indicators used in the present analysis, some alterations to their initial definitions were deemed necessary, as some variables from the LIFT large-scale farmer survey were unavailable for the Greek case study. In particular, as regards the economic performance dimension, the net worth to assets ratio could not be calculated for our case study since the interviewed farms did not report the necessary data for this indicator, particularly the farm liabilities. Concerning the main indicators proposed for the social/labour performance dimension (i.e., total labour, total jobs and labour productivity with respect to output), all three of them could be calculated. Still, with some modifications regarding the first and third indicators (i.e., total jobs and labour productivity with respect to output). In specific, regarding the number of worked hours from hired members used for the calculation of the total labour, as in our case, there were only 4 farms with hired labour, the seasonal labour was also added as it is the primary non-family labour in olive cultivation due to the seasonality of the required works. In the case of the labour productivity for output, there are no reliable data regarding turnover, and thus the latter was replaced with revenues. Concerning the environmental farm performance, all indicators proposed for farms with permanent crops in the spider webs could be used. Nevertheless, as the indicator expressing the share of fallow land from total UAA is not significant for farms with permanent crops, it was decided not to use it. Instead, the additional indicator of water consumption from irrigation per ha of UAA was used in the spider web, as irrigation is an essential practice in our case study. In order to improve the quality of the raw data related to the variable of water consumption, the missing values were replaced with the mean.

4.2.3.2 Results

Figure 15 shows the results of the sustainability performance comparison among the identified groups. In the economic performance dimension, in terms of the profitability including subsidies and the profitability excluding subsidies, the ecological farming approaches do not show any significant difference in their performance compared to Standard farming. An exception is Conservation Agriculture OR Low-Input farms that perform worse than Standard farms. On the other hand, if the profitability is assessed excluding public payments and at the same time including opportunity costs of own production factors, Organic and Organic+(+) farms perform better compared to Standard farms. Same as before, the performance of Conservation Agriculture OR Low-Input farms is worse than that of Standard farms. With respect to the cash flow to assets ratio, Organic farming performance is significantly higher than that of Standard farming. In contrast, the performance of Conservation Agriculture OR Low-Input farms is slightly better than the Standard ones. Regarding the Organic(+) farms, they appear to have a slightly lower performance than Standard farms.

In terms of social/labour performance, results show that the total labour input is significantly higher for Organic and Organic+(+) farms, while the Conservation Agriculture OR Low-Input farms appear to have a lower total labour input than Standard farming. A similar picture is shown in the results concerning the total number of jobs, with the latter to be higher in Organic and Organic+(+) farms and lower in Conservation Agriculture OR Low-Input farms compared to the Standard ones. Regarding the labour productivity indicator in which the total labour input is normalised by farm size (proxied by revenues), the overall picture of the results is the opposite. Organic farms are far less productive in their use of labour, Organic+(+) slightly less productive and Conservation Agriculture OR Low-Input farms slightly more productive, all compared to Standard farms.

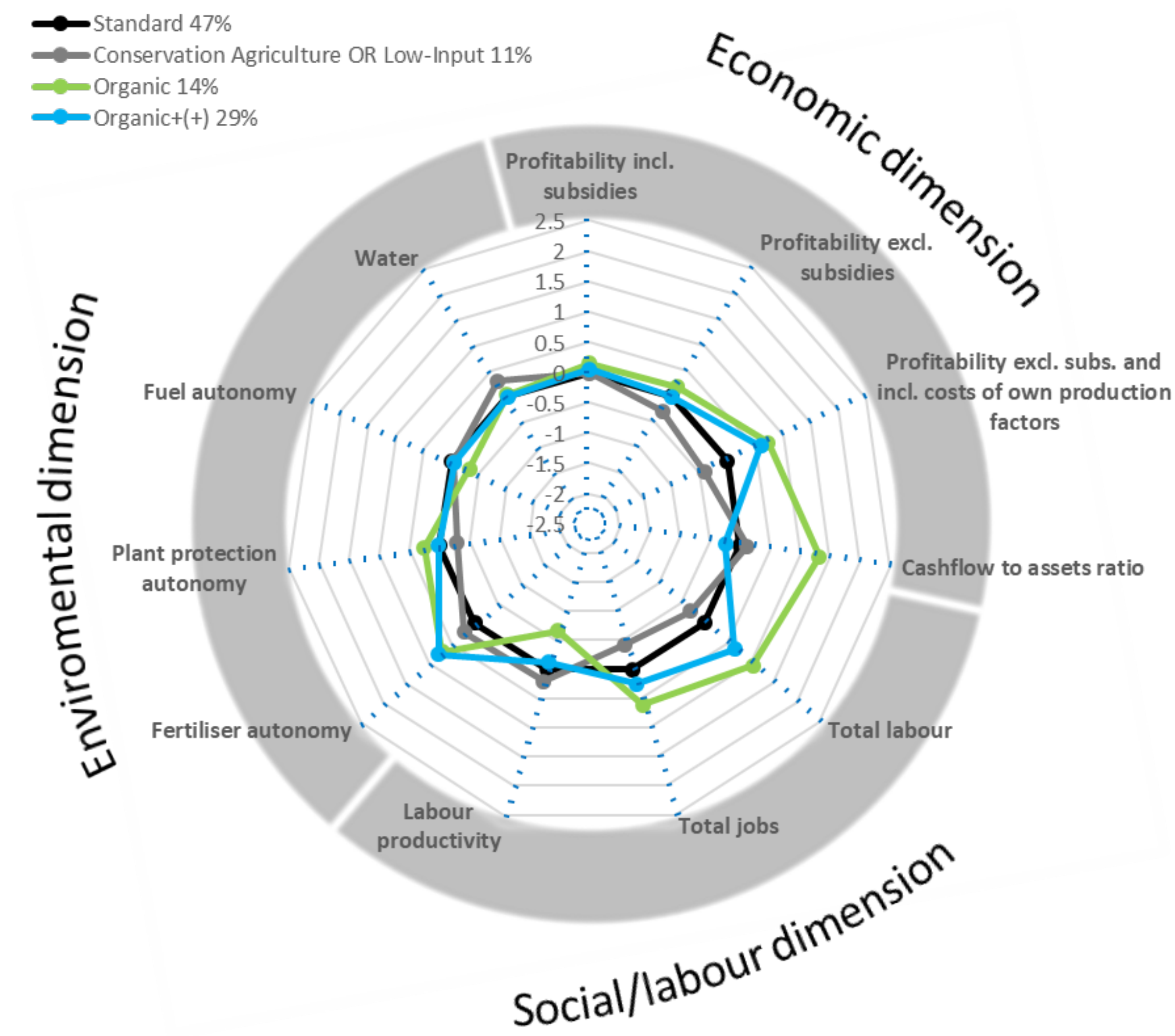
The results on the environmental performance show that regarding fertiliser autonomy, all ecological farms perform better than Standard farms, with the performance gap increasing with an increasing degree of ecological practices adoption. Concerning plant protection autonomy, the performance of Organic+(+) farms appears to have no difference compared to Standard farms. In contrast, Organic farms show slightly higher performance, and Conservation Agriculture OR Low-Input farms have a slightly lower performance. Furthermore, the performance of Conservation Agriculture OR Low-Input farms and Organic+(+) farms in relation to fuel autonomy seems to be infinitesimally lower than that of Standard Farms, while Organic farms perform slightly worse. Finally, the results on the environmental performance with reference to water show that Organic+(+) and Organic farms perform almost the same in comparison with Standard farms, while Conservation Agriculture OR Low-Input farms perform slightly higher.

4.2.3.3 Discussion and conclusion

Results on the economic performance show that for the first two profitability indicators (profitability incl. subsidies, profitability excl. subsidies) both Organic and Organic+(+) farms do not display any significant difference in their performance compared to Standard farming. Much of this is likely to be due to the extreme weather conditions and olive fruit fly problems that olive farms faced during the survey's reference year in the case study areas. On the other hand, when profitability is calculated by excluding subsidies and including opportunity costs of own production factors, both Organic and Organic+(+) farms perform substantially better than Standard farms. An interpretation of this could be that in case of Organic and Organic+(+) farms, their opportunity costs of own production factors exceed the amount of the subsidies received.

Regarding the social/labour indicators, the relative performance of Organic and Organic+(+) farms is expected (i.e., higher total labour input, higher total number of jobs and less productive in their use of labour input) as ecological farming approaches appear to be more labour intensive compared to Standard farming.

Results on environmental performance are in line with those in Niedermayr et al. (2021) showing that it is rather difficult to assess the overall performance of the farms in each group as there are some indicators in which they perform well and some others in which they perform poorly, but there is a wide margin for improvement. Regarding the indicator of fuel autonomy, there are no significant differences among the ecological farming approaches in respect to Standard farming, with only Organic farms performing slightly worse. This is in line with the findings from Niedermayr et al. (2021) in which fuel use was found to be remarkably high expressing the problem of fragmented farms that consist of many plots, often in dispersed locations, resulting in frequent field trips in order to perform the required work. The slightly worse performance in Organic farming could be attributed to the fact that some of the tasks need to be performed multiple times (e.g., manual and/or machine weeding, pest control with traps) compared to Standard farming. The similar performance among the Organic and Organic+(+) farms compared to Standard farms could be stressing that there are no restrictions or guidelines in the organic regulations regarding water use. Thus, maybe this input may be overused. The results on the fertiliser autonomy were expected, as Organic farms are obliged to comply with the organic regulations in which the use of inorganic fertilisers is prohibited. On the other hand, the similar performance of ecological farming approaches in relation to Standard farming may occur due to the olive fruit fly problems that farms faced in the case study regions during the reference period that could lead to more expenses for biological controls and/or the fact that the prices for such inputs are higher.



Note: year = 2018, n = 66 farms. Percentages in the legend indicate the share of farms in the respective farming approaches. Values in the spider diagram are standardised means, calculated for each farming approach through a z-standardisation, based on the means and standard deviations of farms belonging to the Standard farming approach. The average performance level of the Standard farming approach is thus 0 for all performance indicators and serves as a benchmark. The average performance levels of other farming approaches reflect the relative difference to the Standard farming approach (values greater than 0 indicate better, and smaller than 0 indicate worse, performance), measured in standard deviations of the Standard farming approach.

Figure 15: Comparison of farm level sustainability performance of different farming approaches for specialist olive farms in the Greek case study regions Heraklion and Lasithi, Crete, based on LIFT large-scale farmer survey data.

5 Analyses of selected trade-offs and synergies

In this chapter we provide the results of three in-depth analyses of specific aspects of major importance in the context of an assessment of farm level sustainability performance of ecological farming.

The first section (5.1) investigates the extension of the above-described LIFT farm sustainability performance assessment to bio-economic models. The analysis shows how the bio-economic model FarmDyn can be used to model a stepwise conversion to Conservation Agriculture for arable farms, dairy farms, beef farms and pig fattening farms in Germany. The detailed modelling of the conversion process in combination with detailed performance indicators, in particular regarding environmental and labour-related performance, provides nuanced results and additionally allows to understand causal effects associated with such a transition.

The second section (5.2) investigates the integration of supply of and demand for ecosystem services into the LIFT farm sustainability performance assessment. An indicator system is developed, where the spider web based assessment from chapter 3 can be supplemented with further composite environmental indicators, reflecting overall supply and region-specific demand of ecosystem services, associated with the different farming approaches.

The third section (5.3) shows the results of a detailed analysis of farmer's private social and employment sustainability in the context of an increasing uptake of ecological approaches, applied to specialist dairy farms or dairy and cattle farms in a few European case studies. This analysis presents firstly an **assessment of working conditions and employment on farms** for French dairy and cattle farms. Then, the section investigates how **specific aspects of working conditions** are related to the **uptake of ecological approaches**, based on an analysis of dairy farms from four case study regions in Austria and France.

5.1 Assessment of farm level sustainability of conservation agriculture for German case study farms based on the bio-economic model FarmDyn

Julia Heinrichs and Wolfgang Britz (all UBO, Germany)

5.1.1 Background

By focusing on the preservation and enhancing of soil structure and long-term fertility, conservation farming aims at reducing the negative effects on soil and supports long term agricultural activity (Kertész and Madarász, 2014; Mitchell et al., 2016). This addresses specifically the issue of soil degradation, resulting from wind and water erosion and soil pollution, which is considered as a substantial problem for the conservation of productive arable land in Europe (Jones et al., 2012; Mal et al., 2015). In Germany about 2 million hectares or around a sixth of arable land are categorised under highly endangered by soil erosion (Schmitz et al., 2013). Conservation Agriculture is defined as set of practices and farming approaches that include first, minimisation of soil disturbance by reduced or no-till practices along with crop residues retention and surface mulching and second, crop diversification including cover cropping to maintain soil coverage (Casagrande et al., 2017; Kertész and Madarász, 2014; Mitchell et al., 2016; Rega et al., 2021). Thereby, Conservation Agriculture is reported to offer further benefits such as water conservation and improvement of the soils water holding capacity, increasing the efficient use of soil nutrients, water, and biological resources and increase soil organic matter (Somasundaram et al., 2020). On the other hand, conservation agriculture farming systems can still use large quantities of chemical and other external inputs (Rega et al., 2021). Therefore, this analysis aims to assess the performance of Conservation Agriculture with regard to sustainability. Through a stepwise conversion from Standard farming to Conservation Agriculture, where changes in tillage and crop rotation are considered separately, the driving factors and trade-offs on different aspect of sustainability at farm level will be identified.

5.1.2 Method and data

The impact of the stepwise conversion from Standard farming to Conservation Agriculture is assessed based on simulations with the highly detailed bio-economic farm-scale model FarmDyn which depicts economically optimal farm management decisions, considering technical as well as work-time and financial constraints. FarmDyn simulates material flows and quantifies agronomic and economic as well as environmental and social impacts of changes in the farm management and their trade-off. FarmDyn builds on mixed integer linear programming and is realized in GAMS (Britz et al., 2021). In our study, the comparative-static version of FarmDyn is used. A complete documentation of FarmDyn is available online (Britz et al., 2018).

Impacts of the conversion to conservation farming is assessed at farm-scale level for case study farms in the German federal state of North Rhine-Westphalia (NRW). Divided into nine soil-climate regions, NRW is among the most diverse agricultural regions in Germany (Roßberg et al., 2007). For each of these nine soil-climate regions, one typical farm is selected based on the farm typology for NRW by Kuhn and Schäfer (2018). They distinguish farm types by farm specialisation according to standard output, the farm size and the stocking density. Typical farms are selected such that the share of agricultural area in NRW covered by these farms is maximised. This results in analysing three arable crop farms (*FADN Type of Farming = 15, 16*), three dairy farms (*FADN Type of Farming = 45*), two beef farms (*FADN Type of Farming = 46*) and one pig fattening farm (*FADN Type of Farming = 84*). For each farm type information on average crop and grassland shares as well as average number of livestock and farm sizes are reported (Table 10). Data from the farm typology are complemented by regional data on crop and grassland yields (Julius Kühn-Institut, 2019; LWK NRW). Crop yields are assumed to

remain unaffected by tillage practice, however, cost for plant protection measures increase (KTBL, 2019a).
We define four scenarios to assess the impacts of a stepwise conversion to Conservation Agriculture. All four scenarios keep herd sizes on animal farms unchanged. The first and baseline scenario depicts Standard farming (*Standard*), considering reported average crops shares (*Standard CR*) of the respective farm type and assuming ploughing as the tillage practice (*till*). In a second scenario (*Standard CR, notill*), crop shares are unchanged, but the soil disturbance is minimised (*notill*) by changing the farming practices of each crop. This includes refraining from ploughing in favour of conservation tillage practices as well as the adaption of direct seeding and mulching. Zero tillage is selected for all crops where related data on field operations are available (KTBL, 2019b), otherwise, reduced tillage is chosen. In a third scenario (*Conservation CR, till*), the tillage draws on ploughing, but crop rotations are adjusted to meet the requirements of Conservation Agriculture (*Conservation CR*). This includes a higher degree of crop diversification and the maintenance of soil coverage, for instance by cover cropping. Crop rotations of the eight case study farms cultivating arable land under Conservation Agriculture are defined with the help of experts (Lintel Höping, 2021), considering feeding requirements where applicable and characteristics of the respective soil-climate region. In the final scenario, conservation farming is analysed. The adjusted crop rotations are managed under conservation tillage (*Conservation*) such that the case study farms meet the requirements for Conservation Agriculture according to the LIFT farm typology. The scenarios do not consider public payments for Conservation Agriculture or potential price premiums paid by consumers.

The impact of Conservation Agriculture on the farm performance is assessed using the composite indicators shown in Table 9 (further details are in Table 10 and Table 11). As only changes on arable land are considered, grassland shares and farm sizes of the case study farms remain unaffected. In addition, as livestock production is kept constant, livestock density (feed autonomy (own feed)), veterinary costs (veterinary autonomy) and water costs (water autonomy) per animal stay constant as well. Irrigation water costs cannot be assessed as the case study farms use a rainfed system. Further, no distinction was made between paid and unpaid labour. However, as FarmDyn quantifies indicators in higher detail compared to what is possible with FADN and provides additional relevant information on farm performance. Examples include environmental pressure indicators such as N-leaching or greenhouse gas emission, biodiversity impacts or labour requirements by type of work.

Table 9: Farm performance indicators used in FarmDyn

	Economic performance	Environmental performance	Social/labour performance
Composite indicators	*Profitability indicators*	*Ratios of input use*	*Labour requirements* *Productivity indicators*
Additional indicators		*Biodiversity* *Pressure indicators (e.g. Global warming potential (GWP), N-Leaching, P-Erosion)*	*Labour requirements by type of work*

Table 10: Production Programs of the case study farms under Standard farming and Conservation Agriculture with bio-economic model FarmDyn

	Arable 1		Arable 2		Arable 3		Dairy 1		Dairy 2		Dairy 3		Beef 1		Beef 2	Pig 1	
	S	C	S	C	S	C	S	C	S	C	S	C	S	C		S	C
Arable land	57		100		78		35		49		38		31			109	
Winter Wheat	23	14	37	20	42	16	8	9			11	13				43	27
Summer Barley											7	6					
Winter Barley	13	14	12	20		16		9					2	7		32	14
Winter Rye									1	6			1				
Winter Triticale	4								5	6	3	6	8	6		8	14
Rape seed	12	14		20	7	15		8						6		16	27
Silage Maize							21	9	34	24	14	6	18	6			
Grain Maize	3	7	25	20	3	16											
Potatoes			14		2												
Sugarbeet			12	10	23	16										7	14
Field Beans		8		10													14
Field grass							6		9	13	3	6	2	6			
Catch Crops	3	14	17	20	13	13	6	9	8	9	6	12	5	4		7	
Idle	2												1			3	
Grassland							55		34		50		18		50		
idled							19	20			32	31			40		
Livestock							86		123		45		117		42	2600	

Note: Standard crop rotation (S) based on average crop shares in respective case study region; Conservation crop rotation (C) based on expert knowledge. Case study Dairy 2 does not manage arable land and is not converted to Conservation Agriculture.

Table 11: Sustainable farm performance of the case study farms in four scenarios in bio-economic model FarmDyn

		Arable 1				Arable 2				Arable 3				Dairy 1				Dairy 2				Dairy 3				Beef 1				Beef 2	Pig 1			
	Crop rotation	S		C		S		C		S		C		S		C		S		C		S		C		S		C			S		C	
	Tillage	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**		**S**	**C**	**S**	**C**
Economics	Profitability incl. Subsidies [€/€]	1.53	1.64	1.45	1.56	1.58	1.63	0.89	1.56	1.75	1.76	1.65	1.73	1.65	1.67	1.56	1.58	1.67	1.69	1.46	1.56	1.56	1.59	1.50	1.52	1.10	1.12	1.15	1.16	1.34	1.21	1.23	1.20	1.22
	Profitability excl Subsidies [€/€]	1.30	1.39	1.21	1.30	1.42	1.47	0.74	1.30	1.55	1.56	1.41	1.48	1.51	1.53	1.44	1.46	1.57	1.59	1.38	1.48	1.37	1.39	1.32	1.34	1.03	1.05	1.08	1.09	0.99	1.14	1.16	1.13	1.15
	Profitability excl. subsidies and incl. costs of own production factors [€/€]	0.75	0.81	0.69	0.74	0.97	1.01	0.61	0.78	0.95	0.98	0.83	0.87	0.82	0.83	0.83	0.84	0.92	0.92	0.86	0.89	0.70	0.71	0.70	0.71	0.77	0.77	0.78	0.79	0.50	0.91	0.94	0.90	0.92
Labour	Total labour [AWU]	0.68	0.58	0.68	0.58	1.13	0.98	0.95	0.79	0.93	0.81	0.80	0.69	3.28	3.25	3.09	3.04	4.03	4.07	4.07	4.13	2.34	2.28	2.48	2.42	1.34	1.32	1.49	1.47	0.50	1.64	1.41	1.61	1.38
	Total labour [AWU/€]	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Labour [AWU/ha]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.04	0.03	0.03	0.05	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.02	0.01	0.01	0.01
	Labour [AWU/LU]	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
	Labour Crop [h]	718	522	705	536	1506	1233	1166	885	1149	926	914	714	1032	976	772	681	1337	1318	1507	1514	842	744	1028	920	540	504	804	762	75	1238	830	1184	761
	Labour Herd [h]	-	-	-	-	-	-	-	-	-	-	-	-	3615	3615	3528	3528	4418	4517	4313	4421	2394	2394	2448	2448	1220	1220	1220	1220	510	689	689	689	689
	Labour Management [h]	514	514	515	515	535	535	535	535	525	525	525	525	1251	1251	1257	1257	1500	1500	1504	1504	974	974	986	986	653	653	658	658	321	1026	1026	1028	1028
Environment	Concentrate feed [€/LU]	-	-	-	-	-	-	-	-	-	-	-	-	236	236	250	250	245	244	284	259	253	253	241	241	114	114	114	114	106	371	371	371	371
	Fertiliser [€/ha]	209	209	197	197	205	205	189	189	217	217	206	206	31	31	33	33	58	56	83	66	50	50	51	51	133	133	130	130	16	104	104	105	105
	Plant protection [€/ha arable]	128	167	126	160	167	192	139	165	193	236	161	188	91	107	128	161	138	149	119	127	96	119	93	117	94	100	97	112	-	140	175	150	183
	Herbicide [€/ha arable]	55	71	65	80	90	102	84	96	112	130	101	113	70	78	67	81	124	134	94	101	55	65	43	52	70	75	52	59	-	63	79	84	98
	Fungicide [€/ha arable]	53	76	42	61	65	77	40	55	71	95	46	61	16	23	42	61	10	11	19	19	33	47	40	55	17	18	29	37	-	58	77	48	67
	Insecticide [€/ha arable]	6	6	7	7	5	5	5	5	4	4	5	5	3	3	7	7	-	-	-	-	3	3	3	3	-	-	5	5	-	5	5	7	7
	Growth control [€/ha arable]	14	14	12	12	7	7	9	9	6	6	9	9	2	2	12	12	3	3	7	7	4	4	7	7	7	7	12	12	-	15	15	11	11
	Fuel [€/ha]	46.3	23.4	48.7	26.7	47.9	35.6	45.8	28.2	46.3	28.5	39.2	22.0	23.4	21.0	22.2	14.7	35.3	32.9	38.7	35.1	18.1	10.7	19.9	11.8	38.9	31.6	43.9	34.7	3.9	35.5	10.5	37.2	12.5
	Fuel [€/LU]	-	-	-	-	-	-	-	-	-	-	-	-	19.3	17.4	18.4	12.1	18.8	17.6	20.7	18.8	28.5	16.9	30.6	18.2	23.2	18.9	26.2	20.8	6.8	27.9	8.3	29.3	9.9
	Stocking density [LU/ha]	-	-	-	-	-	-	-	-	-	-	-	-	1.21	1.21	1.21	1.21	1.87	1.87	1.87	1.87	0.63	0.63	0.65	0.65	1.67	1.67	1.67	1.67	0.58	1.27	1.27	1.27	1.27
	Stocking density [LU/ha grassland]	-	-	-	-	-	-	-	-	-	-	-	-	1.98	1.98	1.98	1.98	4.57	4.57	4.57	4.57	1.11	1.11	1.14	1.14	4.55	4.55	4.55	4.55	0.6	-	-	-	-
	Grassland share	-	-	-	-	-	-	-	-	-	-	-	-	0.61	0.61	0.61	0.61	0.41	0.41	0.41	0.41	0.57	0.57	0.57	0.57	0.37	0.37	0.37	0.37	1.0	-	-	-	-
	N-Min [kg/ha]	106	106	89	89	95	95	79	79	104	104	92	92	9	9	17	17	15	14	26	15	22	22	23	23	63	63	56	56	4	43	43	41	41
	P2O5 [kg/ha]	61.0	61.0	61.8	61.8	63.9	63.9	61.9	61.9	66.8	66.8	66.7	66.7	5.9	5.9	2.3	2.3	16.5	15.3	28.2	21.8	10.1	10.1	10.6	10.6	41.4	41.4	43.0	43.0	9.1	21.7	21.7	22.1	22.1
	K2O [kg/ha]	33.9	33.9	34.3	34.3	35.5	35.5	34.4	34.4	37.1	37.1	37.0	37.0	3.3	3.3	1.3	1.3	9.2	8.5	15.7	12.1	5.6	5.6	5.9	5.9	23.0	23.0	23.9	23.9	5.0	12.1	12.1	12.3	12.3
	N-Leaching [kg NO3/ha]	10.7	2.8	13.5	7.2	35.0	21.9	24.0	15.8	23.3	21.9	26.9	23.2	2.1	1.7	2.9	2.7	4.6	2.3	7.3	2.8	6.8	5.4	6.5	4.7	7.9	3.7	10.4	4.7	0.0	17.6	11.9	21.6	16.6
	P-Erosion [kg/ha]	1.35	1.35	1.66	1.66	1.55	1.55	1.59	1.59	1.55	1.55	1.55	1.55	1.22	1.22	1.25	1.25	1.57	1.57	1.59	1.59	0.98	0.98	1.08	1.08	1.52	1.52	1.54	1.54	0.28	1.43	1.43	1.38	1.38
	Global warming potential [t CO_2 eq/ha]	16.1	16.1	16.7	16.7	16.8	16.8	16.8	16.8	17.0	17.0	17.0	17.0	14.4	14.4	14.5	14.5	22.0	22.0	21.7	21.7	11.4	11.4	11.3	11.3	13.7	13.7	13.8	13.8	1.2	17.0	17.0	17.6	17.6
	SMART Biodiversity*	0.33	0.35	0.41	0.44	0.40	0.42	0.43	0.46	0.33	0.33	0.37	0.41	0.63	0.65	0.62	0.65	0.59	0.60	0.55	0.59	0.60	0.63	0.63	0.66	0.52	0.54	0.49	0.52	0.68	0.36	0.40	0.34	0.38

Note: Data provided for standard (S) and conservation (C) crop rotation and tillage method. Case study Dairy 2 does not manage arable land and is not converted. *see section 5.3 in Niedermayr et al. (2021) and the sources cited there for more details on this indicator.

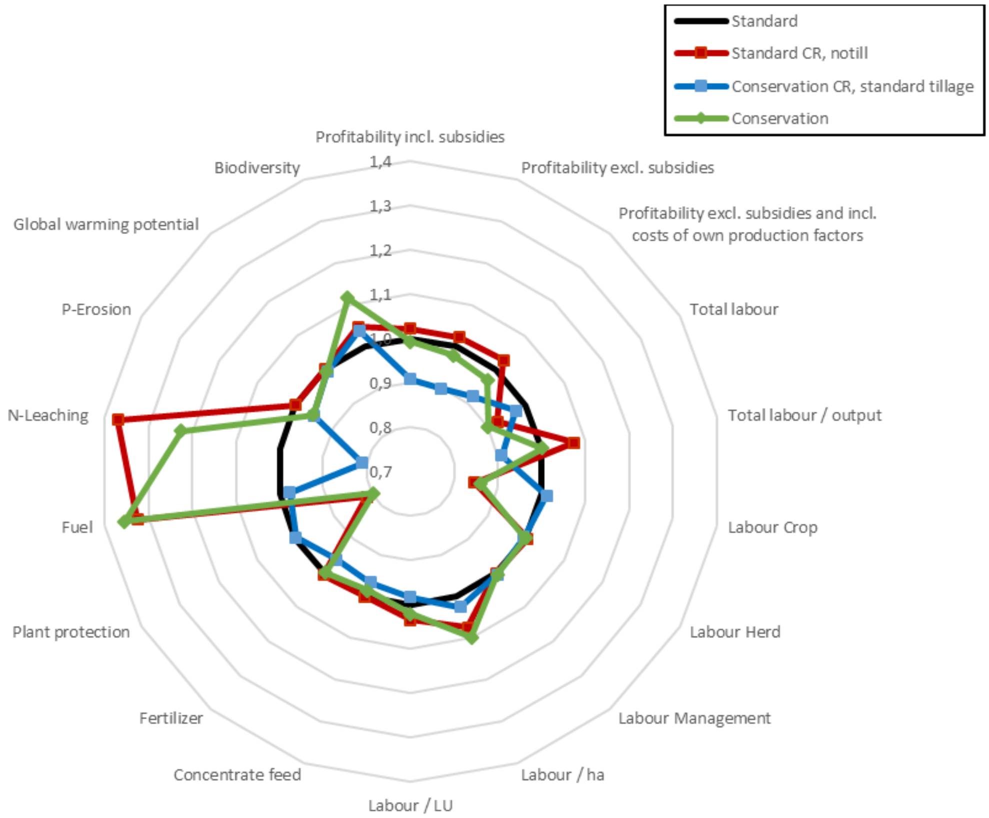
5.1.3 Results

With regard to technical-economic performance, the three profit indicators in Figure 16, relating to average profitability, show similar results. C*onservation* agriculture is on average slightly less profitable than *Standard* farming. This reflects two countervailing effects. On the one hand, changing the cropping program under *Conservation CR, till* reveals profits losses from stronger restrictions, for example on maximum rotational shares results and increased catch crop acreages under Conservation Agriculture. On the other hand, at unchanged cropping program, reduced tillage is more profitable, mainly driven by lower labour and resource requirements of machine operations. These cost savings from reduced tillage can, however, not offset the adverse economic effects of changes in the crop rotation under Conversation Agriculture.

The performance of Conservation Agriculture in the social/labour related dimension is less conclusive (Figure 16). While labour requirements in farm management and livestock production remain as expected mostly unaffected, labour requirements in crop production considerably decrease with the conversion to Conservation Agriculture. This decrease is mainly due to the changes in tillage management, as reduced tillage practices require less field passes. Depending on the case study, changes in the cropping program at unchanged tillage can decrease or increase labour requirements in crop production. As livestock production and farm size are kept unchanged, total farm labour needs per hectare and livestock unit decrease with conversion to Conservation Agriculture, reflecting both changes in tillage management and in crop rotation. When labour requirements are normalised by the total monetary output of the farm, results indicate that solely switching to reduced tillage practices at unchanged cropping program are more productive in the use of labour input. In contrast, labour productivity decreases with the conversion of the crop rotation, but maintaining ploughing, as considerably less revenue is generated. When converting fully to Conservation Agriculture, beneficial effects from reduced tillage are offset by changes in the cropping program, resulting in Standard farming and Conservation Agriculture being equally productive in terms of their labour use.

From an environmental point of view, no clear conclusion can be drawn as results as well as drivers of the farm performance differ for each indicator (Figure 16). Expenditures on nitrogen (N) fertilisers mainly reflect mainly changes in the crop program, assuming that yield levels are not affected by changes in tillage management (KTBL, 2019a). For most farms, N-demand remains constant or even decreases with changes in the crop program. Where decreases occur, they are mainly driven by higher shares of legumes providing N by mineralising their residues and an overall lower demand for N as fewer crops with high N needs are grown. On the dairy farms, changes in crop rotation, however, result in an increase in N-demand due to less fodder produced on arable lands leading to an intensification in grassland management. N-leaching is considerably affected by changes in tillage practices. The implementation of reduced tillage practices decreases the risk of leaching, among others as ploughing provokes N mineralisation in months with low N-demand. The conversion of the crop rotation to Conservation Agriculture increases N-leaching on most farms. Here, changes in crop rotation shift fertilisation to months with higher risk of leaching. Overall, the conversion to Conservation Agriculture decreases N-leaching. Similar to N-leaching, P-erosion increases with the conversion of the crop rotation while changes in tillage management have only minor effects. This results in higher risk of P-erosion under Conservation Agriculture. Expenditures on plant protection are considerably higher under Conservation Agriculture, mainly driven by changes in tillage management. Reduced tillage is associated with increased application of pesticides, for example as the avoidance of mechanical weeding is compensated by an increase in herbicide use. The impact of the conversion of the crop rotation is limited. The implementation of reduced tillage practices further leads to a considerable reduction in fuel requirements, while changes in crop rotation again only have a minor impact.

Expenditures on purchased concentrates and GWP are only affected to a small extent. The performance slightly decreases with the conversion to Conservation Agriculture due to changes in the crop rotation. Finally, Conservation Agriculture performs better regarding biodiversity. Here, both the conversion of crop rotation and tillage system have beneficial effects, resulting in a considerably increase in biodiversity performance under Conservation Agriculture.



Note: Values denote average differences relative to standard farming. Relative differences are calculated for each farm and the average is determined across the farms. The labour indicators: total labour, labour crop, herd and management; as well as all the environmental indicators except for biodiversity are inverted such that higher values represent better performance.

Figure 16: Integrative performance assessment of German case study farms with bio-economic model FarmDyn.

5.1.4 Discussion and conclusion

The sustainable performance of Conservation Agriculture is assessed by a stepwise conversion of eight typical case study farms in Germany. The minimisation of soil disturbance is associated with an increase in economic performance for all case study farms, mainly achieved by considerable cost savings with respect to labour and fuel consumptions (Gay et al., 2009). In fact, despite the lack of public payments and price premiums, more than 39% of the arable land in Germany is already managed with reduced tillage practices (Mal et al., 2015). However, full conversion to Conservation Agriculture which require e.g. switch to no-till practices including direct seeding and changes in the cropping program, are less frequent (Mal et al., 2015). The low share reflects declines in profitability due to the required diversification of crop rotations and significant capital investments for special machinery. Furthermore, during a transition period, performance losses might occur, and additional training might be needed (Gay et al., 2009; Mitchell et al., 2016).

The results indicate that impacts of Conservation Agriculture on environmental performance are not straightforward. Switching to Conservation Agriculture is associated with considerable improvements of some environmental indicators, especially in terms of N-leaching, fuel consumption and biodiversity, but it requires greater use of chemicals for weed control (Gay et al., 2009). In addition, the results of many environmental performance indicators vary widely among the case study farms and farm types, such that no clear policy recommendations can be drawn, asking for a more in-depth analysis.

Finally, Conservation Agriculture is associated with considerably lower labour requirements in crop production. Given the limited availability of skilled workers on the German labour market and restricted capacity of family labour, the reduced workloads of Conservation Agriculture could be seen as a major strength.

The farm performance is assessed using the bio-economic farm scale model FarmDyn. Such models are valuable tools to analyse technical innovations and (ex-ante) policy changes, as they describe in detail farm management and investment decisions (Britz et al., 2012; Janssen and van Ittersum, 2007). By assessing economic, environmental as well as social/labour related performance indicators and their trade-offs, they provide relevant information for policy design and on underlying drivers of differences in performance. However, bio-economic farm scale models rely on detailed data input. Limited data availability at farm and regional level renders it hard to up-scale from single farm case study level to higher scales (Britz et al., 2012). Bio-physical processes and interaction between farm management and the environment are for example strongly dependent on location factors (e.g. soil type, climate, accessibility) (Britz et al., 2012), information not available in existing data bases where farm data are not geo-referenced. In the present study it was therefore necessary to select typical farms based on a farm typology for NRW. In this context, average values, for example for farm size and livestock density (feed autonomy (own feed)) as well as average crop shares, were applied and linked to spatially referenced data, e.g. on crop yields and intensity of grassland use. This may result in important information not being considered (e.g. link to on-farm management practices) and case studies not representing existing farms. In the trade-off between a greater resolution and higher costs of collecting more data (Britz et al., 2012), case study related data laboratories could provide an important basis for future modelling.

5.2 Integration of provision and consumption of public goods and ecosystem services in the measurement of farm performance

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5.2.1 Introduction

Agroecosystems are arguably one of the most important ecosystems to sustain human wellbeing, both for the provisioning of food and energy materials i.e., productive- and non-productive benefits such as recreation, regulation of natural hazards and carbon sequestration (CICES, 2018; Van Zanten et al., 2014). These productive and non-productive benefits are also referred to as ecosystem services (ESs). ESs can be defined as the direct or indirect contribution of ecosystems to human well-being. ESs are formalised under the Ecosystem Service Cascade model (Potschin and Haines-Young, 2011), which links ecological structures and processes through ES with human wellbeing (Figure 17). The Cascade model postulates that an ES may only be considered a service if human beneficiaries can be identified, thus asserting that the derivation of benefits and values from ESs is a social construct dependent on the demand derived from contextual characteristics. However, the biophysical structures and functions that supply ESs also suggest an underlying ecological dimension to the model. Thus, the Cascade model can be expanded to explicitly incorporate ecological and socio-economic dimensions such that it may be interpreted as a social-ecological system in which humans are a part of – rather than separate from – nature (Barredo et al., 2015; Doré et al., 2011; Folke, 2007; Potschin and Haines-Young, 2011).

Under the principles of a social-ecological system, the ecological and socio-economic dimensions may respectively be equated to the principles of supply of and demand for ESs (Van Zanten et al., 2014) (Figure 17). Here, ES supply is spatially and temporally explicit (Potschin and Haines-Young, 2011; Van Zanten et al., 2014). Certain services may only be supplied at certain spatial scales (e.g. on- vs off-farm services in the case of agroecosystems) or during certain times of the year (e.g. crop yield). Likewise, demand for ESs will differ across different geographic regions, between different end-users, as well as through time.

We have illustrated above how ESs link the ecological and socio-economic dimensions of the Cascade model in one direction, however, the two dimensions can also be linked in the opposite direction (socio-economic to ecological) through drivers of change (Figure 17). Drivers of change are defined as "any natural or human-induced factors that directly or indirectly cause change in an ecosystem" (Barredo et al., 2015). When considering agroecosystems, these drivers of change include, amongst others, the farm management practices (FMPs) adopted by farmers. FMPs form part of what is referred to as cropping/livestock-pasture systems, which may be defined as the temporal sequence of crops and management practices in individual fields (Rega et al., 2018). At a higher level, the combination of various principal FMPs on a particular farm make up a farming system (Rega et al., 2018).

FMPs may either enhance ecosystem functioning and subsequently ES supply through supporting soil health and biodiversity, or they may degrade ecosystem functioning by exploiting ESs (Zhang et al., 2007). The type of FMPs implemented therefore determine whether ESs supplied to the agroecosystems are beneficial or detrimental to ecosystem functioning, and thus indirectly influences the ability of agroecosystem themselves to supply ESs back to the socio-economic dimension (Zhang et al., 2007). Through well-planned and regulated FMPs we thus can manage agroecosystems to ensure long-term environmental sustainability (Bateman et al., 2009; Pretty, 2008; Pretty and Bharucha, 2014; Nicholls et al., 2017).

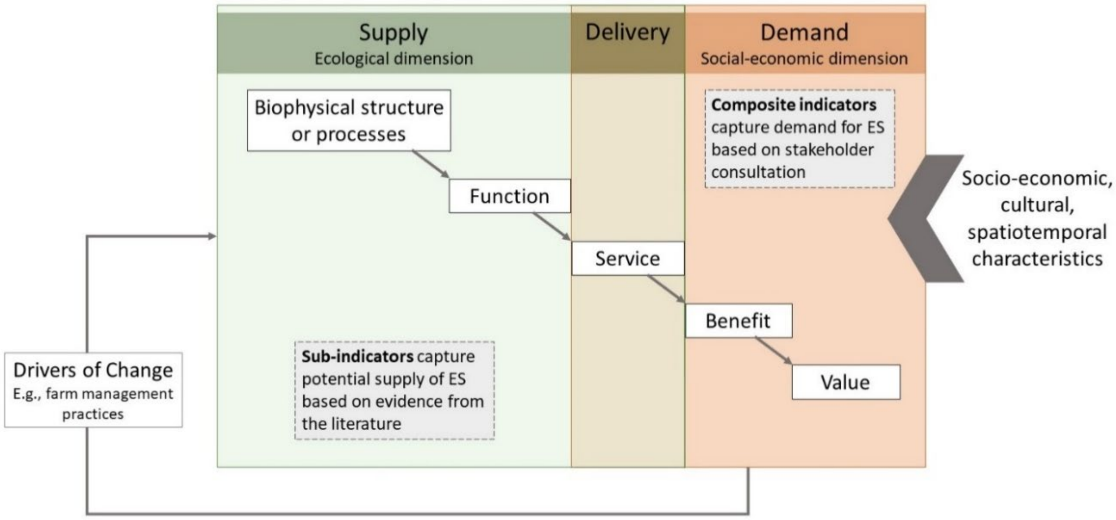


Figure 17: Adapted illustration of the Ecosystem Service Cascade model, embedded within a socio-ecological system, incorporating concepts of Barredo et al., (2015), Potschin and Haines-Young, (2011) *and* Van Zanten et al., (2014).

So far, we have mainly described the link between FMPs and ESs in determining environmental sustainability in agroecosystems. However, we acknowledge that FMPs in agroecosystems are rarely applied in isolation (Kragt and Robertson, 2014; Lautenbach et al., 2010; Zhou et al., 2019). Their combined application is mainly dedicated by farm(er)'s goals and can thus be used to classify farms into farming systems. Evaluating the environmental performance of farming systems rather than individual FMPs has the added benefit of allowing for matches and mismatches in potential ES supply and demand to be evaluated. As such, we supplement the work done in the present deliverable with a secondary environmental performance indicator for the farming systems (identified in Rega et al., 2021) based on the ESs concept.

5.2.2 Methodology

In this section we present a holistic approach to evaluating overall sustainability of farming systems at farm level using indicator composition in three distinct stages. First, we link farm management practices to the potential supply of ESs using secondary data collected during a Rapid evidence assessment (REA). In a second step, we incorporate demand for ESs with the indicators quantifying this linkage to obtain an individual performance indicator per FMP. Performance is quantified for 26 FMPs based on their impact across 17 ESs and the relative demand for each ES in a given case study area. Therefore, we obtain a distinct performance for each FMP dependent on the case study area. Lastly, we aggregate the individual FMP indicators into an overall farming system indicator, quantifying the environmental performance of a given farming system in a given case study area. An overview of case study areas and their corresponding NUTS code as well as the typical farm type in each can be found in Table 12. The full list of FMPs and farming systems considered can be found in Table 13.

Table 12:. List of case study areas and their corresponding NUTS code, as well as the typical farm type in each.

Country	Case study area	NUTS code	Farm type
Austria	Salzburg-Umgebung	AT323	Dairy
	Steyr-Kirchdorf	AT314	Dairy
France	Auvergne	FRK1	Dairy and beef cattle
	Brittany	FRH0	Dairy and beef cattle
	Sarthe	FRG04	Dairy and beef cattle
Greece	Crete	EL43	Fruits and vegetables
Belgium	Hageland-Haspengouw	BE22	Arable
England	High Weald	UKJ2	Arable and horticulture
	North Kent	UKJ4	Arable, horticulture and livestock
Poland	Lubelskie	PL81	Pig and poultry
	Podlaskie	PL84	Pig and poultry
Italy	Ravenna	ITDH7	Arable, fruits and vegetables
Romania	Suceava	RO215	Dairy and mixed crop-livestock
Scotland	Eastern Scotland	UKM2	Arable
	Highlands	UKM6	Beef cattle and sheep
Sweden	Northern Sweden	SE3	Arable, dairy and beef cattle
	Southern Sweden	SE2	Arable, dairy and beef cattle

Table 13. Categorisation of FMPs into farming systems. X indicates FMP is often associated with, but does not form a core part of, the farming system. XX indicates FMP forms a core part of the farming system.

FMP	Agroecological	Organic	Low-input	Integrated	Conservation	Conventional
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		

Figure 18 illustrates the aggregation process visually, while each step of the aggregation process is described in more detail in the next three sub-sections below.

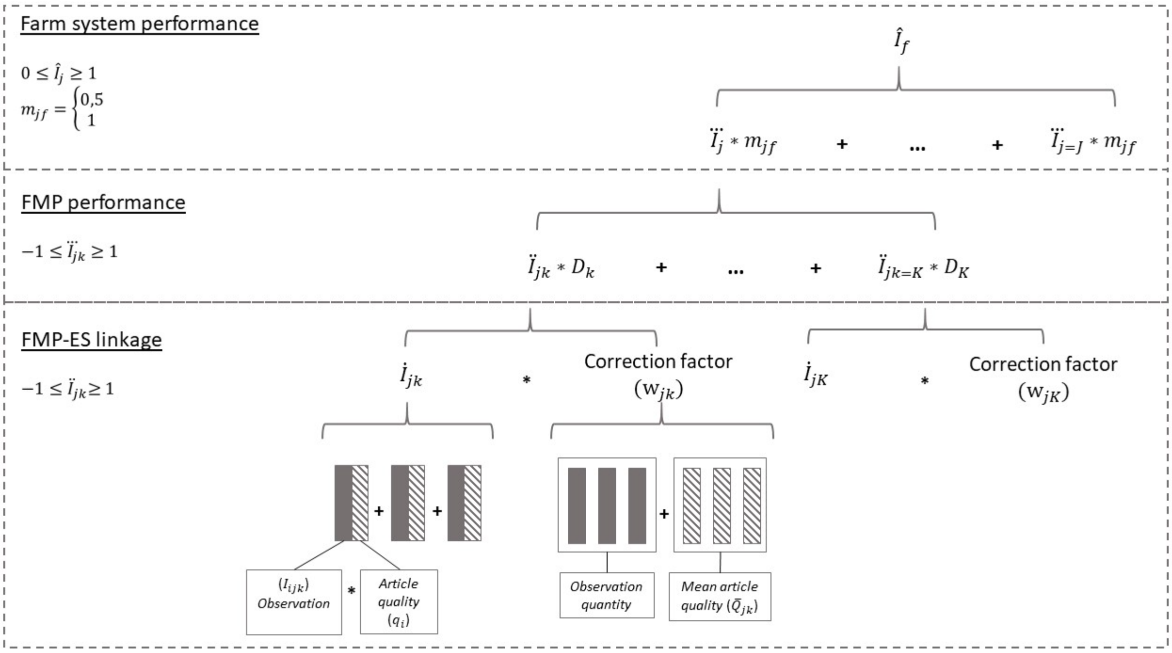


Figure 18: Visual representation of the agri-environmental performance (AEP) assessment framework. AEP performance indicators linking FMPs to ESs ($\ddot{I}_{jk}$) are composed for management practice j linked to ES k through a weighted aggregation of intermediate indicators $\dot{I}_{jk}$ (the sum product across multiple observations (I_{ijk}) and their respective article quality score (q_i)) and the respective correction factor w_{jk}. AEP performance indicators in turn are weighted with the respective ES weights D_k and incorporated into a weighted geometric aggregation to construct the composite AEP indicator ($\ddot{I}_j$) for management practice j. Lastly, composite AEP indicators for management practice j are weighted (m_{jf}) against their relative importance in farming system f to then be incorporated in a weighted addition to obtain the overall farming system AEP ($\hat{I}_f$) for farming system f.

5.2.2.1 Sub-indicators: quantifying ES supply

In order to estimate the impact of ecological FMPs on potential ESs supply in European agroecosystems, we calculate AEP indicators per FMP-ES combination. AEP indicators are calculated through the aggregation of existing evidence in the secondary literature derived from a REA. The full REA procedure is described in more detail in (Van Ruymbeke et al., 2021). Briefly, calculating AEP indicators per FMP-ES consistent of the following four steps. First, a sample was taken from the academic literature for a set of FMPs (Table 17) selected based on results listed in (Rega et al., 2018) combined with input about eight European countries. In a second step, a search string was composed and run in WebOfScience; inclusion criteria were used to screen the resulting articles. Of the initial 2,228 articles obtained by the search string, a final corpus of 95 articles was used in indicator calculations.

Third, expert-mediated qualitative data for the link between an FMP and the supply of an ES was extracted into a database. Here, the link between an FMP and an ES was expressed as 1 (negative impact), 2 (inconclusive impact) or 3 (positive impact). Finally, using the expert-mediated qualitative observations, a weighted arithmetic mean was calculated at farm level, in which observations were weighted against the quality of the article from which they were derived. In order to internalise a measure of confidence within the AEP indicators, indicator output was corrected for the quantity and quality of the underlying evidence. The full process of AEP indicator composition is illustrated visually in Figure 21. A total of 132 AEP indicators were composed at farm level.

Formally, the AEP indicator is calculated as follows:

$$\ddot{I}_{jk} = \left(\dot{I}_{jk} * w_{jk}\right) - \left(2 * w_{jk}\right) = \left(\left(\frac{\sum_{n=1}^{N_{jk}} I_{ijk} q_i}{\sum_{n=1}^{N_{jk}} q_i}\right) w_{jk}\right) - (2 * w_{jk}) \qquad (1)$$

Where $\ddot{I}_{jk}$ is the AEP indicator calculated for FMP j linked to ES k. I_{ijk} is observation i linking FMP j to ES k (which takes the value of 1, 2 or 3), q_i is the article quality associated with observation i, and w_{jk} is the correction factor specific to the interaction between FMP j and ES k (calculated according to equation 2). Normalisation of the AEP indicator to a scale of -1 to +1 is achieved by subtracting $\left(2 * w_{jk}\right)$.

$$w_{jk} = \bar{Q}_{jk} * (1 - r) + \frac{P\left(N_{jk}^{obs}\right) - 0.5}{0.5} * r \qquad (2)$$

Equation 2 describes how the correction factor (w_{jk}) is calculated for each $\ddot{I}_{jk}$ linking FMP j to ES k. This is calculated based on the mean article quality $\bar{Q}_{jk}$ across $\ddot{I}_{jk}$, the probability $P\left(N_{jk}^{obs}\right)$ associated with the number of observations which go into the composition of $\ddot{I}_{jk}$, as well as a constant r which reflects the trade-off made between the number of observations (N_{jk}^{obs}) and the mean article quality ($\bar{Q}_{jk}$). r may take a value between 0 and 1, where 0 reflects full importance being placed on evidence quality (neglecting evidence quantity), 1 reflects full importance being placed on evidence quantity (neglecting evidence quality), and any value in between reflects a trade-off between the two. We set $r = 0.1$, thereby assuming that quality of evidence ($\bar{Q}_{jk}$) is more influential in determining level of confidence in the AEP indicator than quantity of evidence (N_{jk}^{obs}).

5.2.2.2 Composite indicators: incorporating ES demand

Following the linkage of FMPs to potential ES supply, a composite AEP indicator ($\ddot{\ddot{I}}_j$) was calculated for management practice j as a weighted geometric mean of the $\ddot{I}_{jk}$ derived for management practice j and ES k and WE_k, the case study-specific and scale-specific weights for ES k, divided by the sum of WE_k, for ES $k = 1 \ldots K$:

$$\ddot{\ddot{I}}_j = \exp\left(\frac{\sum_{k=1}^{K} WE_k \ln(\ddot{I}_{jk} + 2)}{\sum_{k=1}^{K} WE_k}\right) - 2 \qquad (3)$$

The demand for ESs is captured in equation 3 by the ES-specific weight (WE_k). Each weight is attributed to an ES for an individual LIFT case study area at farm and territorial level independently. The full set of weights for each case study area at each spatial level is listed in Table 14 in the results section.

The link between FMPs and ESs was quantified in step 1 of this aggregation framework for European agroecosystems as a whole. As such, the potential supply of ESs incorporated with demand for ESs in step 2 remains constant across the considered case study areas. For a detailed description of the calculation of the FMP-ES linkages, as well as the resulting indicators, we refer the reader to (Van Ruymbeke et al., 2021).

5.2.2.3 Farming system performance

FMPs are rarely applied in isolation. Their combined application is mainly dictated by a farm(ers) goals and can thus be used to classify farms into farming systems (Rega et al., 2018). Therefore, we aggregate the composite AEP indicators to perform a crude estimation of AEP of farming systems. In a previous literature review carried out in D1.1 (Rega et al., 2018) the most common management practices adopted within five different farming systems were identified: Agroecology, Organic farming, Low-Input farming, Integrated/Circular farming and Conservation Agriculture. We use this categorisation of FMPs into farming systems to estimate the overall AEP per farming system. As the underlying composite AEP indicators may include both positive and negative AEP indicators, the trade-offs/synergies for potential ES supply resulting from the co-implementation of FMPs are inherently incorporated by adopting a simple additive aggregation method for this exercise. In order to enable comparisons to be made between AEP of farming systems within case study area at each spatial level, AEP estimates are normalised using min-max normalisation (Oecd and JRC, 2008).

The AEP of farming system f ($\hat{I}_f$) is calculated as follows:

$$\hat{I}_f = \sum_{j=1}^{J} \ddot{I}_j * m_{jf} \qquad m_{jf} = \begin{cases} 0.5 \\ 1 \end{cases} \tag{3}$$

Where a weighted sum is taken of the composite AEP indicators ($\ddot{I}$) for the management practices $j = 1 \ldots J$, weighted with a FMP- (j) and farming system-specific (f) weight, which can take the value of $m_{jf} = 1$ if management practice j is a core part of farming system f, and $m_{jf} = 0.5$ if management practice j is frequently applied under farming system f but is not used to define said farming system. These composite indicators can also be used to supplement the spider web diagrams of the LIFT farm sustainability assessment with further information regarding environmental performance of the considered farming systems (farming approaches).

5.2.3 Results and discussion

Demand for ESs was quantified through stakeholder and expert consultation in each case study area separately. The number of stakeholders/experts engaged in the demand-elicitation exercise ranged from one (Sarthe, France), to ten (Lubelskie and Podlaskie, Poland). The average demand for each ES in each case study area is listed in Table 14. Demand ranges from 0 (ES is not considered important at all) to 1 (ES is considered most important). Reflecting the relative importance of each ES within a given case study area at farm level, ES demand is influenced by the socio-economic, ecological, geographic as well as stakeholder/expert characteristics of the case study area. From Table 14 we observe that in 12 of the 17 case study areas production is the most important ES at farm level. In those case study areas where production is not the highest demanded ES, ESs related to maintaining soil health (decontamination and fixing processes and soil formation and composition) and reducing diseases/pests receive the highest demand.

Table 14. Full set of weights (reflecting ES demand) for considered LIFT case study areas at farm level.

Ecosystem service	Sweden		Scotland, UK		Poland		Romania	Italy	England, UK		Belgium	Greece	Austria		France		
	North	South	Highlands	Eastern Scotland	Podlaskie	Lubelskie	Suceava	Ravenna	North Kent	High Weald	Hageland-Haspengouw	Crete	Salzburg-Umgebung	Steyr-Kirchdorf	Auvergne	Sarthe	Brittany
Biodiversity	0.00	0.17	0.87	0.30	0.08	0.21	0.49	0.07	0.13	0.18	0.45	0.92	0.25	0.33	0.16	0.88	0.40
Carbon sequestration	0.00	0.13	0.78	0.20	0.44	0.03	0.49	0.07	0.13	0.03	0.41	0.50	0.05	0.00	0.17	0.59	0.40
Cultural and heritage value	0.33	0.17	0.70	0.30	0.18	0.00	0.47	0.03	0.05	0.16	0.19	0.55	0.30	0.18	0.17	0.00	0.20
Decontamination and fixing processes	0.00	0.00	0.13	0.30	1.00	0.95	0.19	0.11	0.08	0.03	0.16	0.21	0.00	0.00	0.00	0.00	0.00
Disease and pest control	0.17	0.33	0.30	0.50	0.75	0.76	1.00	0.53	0.33	0.39	0.36	1.00	0.13	0.10	0.16	0.12	0.27
Erosion regulation	0.00	0.00	0.22	0.10	0.19	0.22	0.29	0.24	0.14	0.28	0.33	0.76	0.00	0.15	0.05	0.06	0.27
Fire protection	0.00	0.00	0.04	0.00	0.04	0.11	0.03	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.02	0.00	0.00
Ground water provisioning	0.33	0.17	0.09	0.10	0.49	0.54	0.33	0.40	0.13	0.20	0.19	0.45	0.00	0.05	0.10	0.59	0.40
Habitat creation/ protection	0.33	0.27	0.78	0.30	0.00	0.05	0.32	0.07	0.12	0.21	0.24	0.74	0.13	0.10	0.11	0.88	0.33
Pollination	0.00	0.10	0.26	0.50	0.31	0.20	0.56	0.24	0.18	0.40	0.29	0.74	0.00	0.05	0.10	0.06	0.20
Production	1.00	1.00	1.00	1.00	0.44	0.55	0.87	1.00	1.00	1.00	1.00	0.82	1.00	1.00	1.00	0.29	1.00
Recreation and tourism	0.67	0.33	0.78	0.20	0.23	0.08	0.58	0.12	0.05	0.14	0.21	0.63	0.13	0.26	0.18	0.12	0.20
Regional climate regulation	0.33	0.33	0.35	0.10	0.15	0.09	0.15	0.24	0.02	0.16	0.15	0.53	0.05	0.00	0.02	0.12	0.00
Regulation of freshwater quality	0.00	0.00	0.30	0.50	0.78	0.88	0.40	0.20	0.15	0.17	0.32	0.32	0.13	0.08	0.16	0.29	0.67
Regulation of natural hazards	0.17	0.17	0.30	0.30	0.18	0.21	0.00	0.40	0.05	0.14	0.18	0.53	0.13	0.05	0.02	0.88	0.13
Smell reduction	0.00	0.00	0.00	0.00	0.13	0.20	0.18	0.00	0.00	0.04	0.00	0.00	0.05	0.00	0.04	0.00	0.27
Soil formation and composition	0.00	0.17	0.30	0.30	0.70	1.00	0.32	0.29	0.12	0.49	0.36	0.34	0.17	0.21	0.17	1.00	0.80

Prior to calculating farming system performance in a given case study area, ES demand (Table 14) was used in the assessment of overall FMP performance in each case study area. Results hereof are available upon request from the authors. Table 15 lists the performance of the six considered farming systems in the LIFT typology across the 17 case study areas included in this analysis. Results are shown normalised ($\hat{\imath}^N$) and non-normalised ($\hat{\imath}$) for easier comparison between farming systems per case study area. From Table 15 we see that across all case study areas, agroecology is the best performing farming system in terms of environmental performance based on ES potential supply and demand. Likewise, standard farming is the worst performing farming system across all 17 case study areas.

Table 15. Farming system performance per case study area at farm level. $\hat{I}$ illustrates the non-normalised performance indicator, and $\hat{I}^N$ illustrates the normalised performance indicator based on min-max normalisation within each case study area.

Country	Case study	Agroecology		Conservation		Standard		Integrated		Low-Input		Organic	
		$\hat{\imath}$	$\hat{\imath}^N$	$\hat{\imath}$	$\hat{\imath}^N$	$\hat{\imath}$	$\hat{\imath}^N$	$\hat{\imath}$	$\hat{\imath}^N$	$\hat{\imath}$	$\hat{\imath}^N$	$\hat{\imath}$	$\hat{\imath}^N$
Austria	Steyr-Kirchdorf	2.11	1.00	0.88	0.32	0.31	0	1.06	0.41	0.77	0.25	1.31	0.55
	Salzburg-Umgebung	2.27	1.00	0.90	0.29	0.35	0	1.11	0.40	0.75	0.21	1.34	0.52
France	Auvergne	2.18	1.00	0.86	0.28	0.34	0	1.06	0.39	0.71	0.20	1.33	0.54
	Brittany	1.64	1.00	0.95	0.48	0.30	0	0.94	0.48	0.59	0.22	1.15	0.63
	Sarthe	0.89	0.99	0.76	0.81	0.17	0	0.67	0.68	0.37	0.27	0.68	0.69
Greece	Crete	1.08	1.00	0.54	0.42	0.14	0	0.62	0.51	0.47	0.35	0.75	0.65
Belgium	Hageland-Haspengouw	1.85	1.00	0.82	0.35	0.28	0	0.96	0.43	0.71	0.28	1.31	0.66
England, UK	High Weald	1.87	1.00	0.80	0.34	0.26	0	0.97	0.44	0.78	0.32	1.27	0.63
	North Kent	2.41	1.00	0.88	0.26	0.34	0	1.16	0.40	0.91	0.27	1.56	0.59
Italy	Ravenna	1.97	1.00	0.88	0.34	0.32	0	1.00	0.41	0.67	0.21	1.28	0.58
Poland	Lubleskie	1.82	1.00	1.13	0.54	0.32	0	1.06	0.49	0.80	0.32	1.31	0.66
	Podlaskie	1.79	1.00	1.03	0.49	0.30	0	1.02	0.48	0.80	0.34	1.29	0.66
Romania	Suceava	1.42	1.00	0.66	0.38	0.19	0	0.77	0.47	0.57	0.31	0.99	0.65
Scotland, UK	Eastern Scotland	1.73	1.00	0.77	0.35	0.25	0	0.90	0.44	0.63	0.26	1.15	0.61
	Highlands	1.19	1.00	0.55	0.38	0.16	0	0.67	0.50	0.46	0.29	0.76	0.58
Sweden	Northern Sweden	1.38	1.00	0.45	0.20	0.22	0	0.66	0.38	0.34	0.10	0.77	0.47
	Southern Sweden	1.58	1.00	0.62	0.28	0.25	0	0.78	0.40	0.47	0.16	0.95	0.53

Combining the environmental performance of farming systems quantified in Table 15 for the Austrian case study areas with the LIFT farm survey-based sustainability performance indicators depicted in Figure 19 (right panel B), we notice some particular differences. First, the performance indicators calculated using the LIFT large-scale farmer survey evaluate performance for the two case study areas combined, while the indicators listed in Table 15 consider the case study areas separately. Second, the farming systems considered in Figure 19 (right panel B) are slightly different from those considered in Table 15. This is because in the LIFT farm survey-indicator composition process, certain farming systems were combined to account for small sample sizes. This process is further explained in previous chapters of the deliverable. Despite this, the calculation process for supplementary environmental indicator proposed here is flexible to these differences. In this way we are able to combine underlying FMPs to match the novel farming systems put forward by the LIFT farm-survey indicators. Similarly, we are able to combine the indicators calculated for the different case study areas to better match the results in Figure 19 (right panel B). In Table 16 we list the environmental performance of the combined farming systems derived from the LIFT farm-survey indicator calculation, as well as the performance of the remaining farming systems for a selection of combined case study areas.

Table 16: Farming system performance for the combined farming systems derived from the LIFT farm-survey performance indicators for the combination of case study areas in Austria and France, for the country level in Greece, and for the regional level of Flanders in Belgium.

Farming system[14]	Austria	France	Greece	Flanders
Agroecology	2.19	1.85	1.97	1.85
Conservation	0.89	0.82	0.88	0.82
Standard	0.33	0.28	0.32	0.28
Integrated	1.08	0.96	1	0.96
Low-Input	0.76	0.71	0.67	0.71
Organic	1.32	1.31	1.28	1.31
Ecological combination	-	0.77	-	-
Integrated/circular AND organic	1.04	-	-	-
Organic (++)	0.95	-	-	-
Organic combination	-	-	0.65	-
Low-input AND integrated/circular	-	-	-	0.83

From Figure 19 (right panel B) we can see that standard farming is the worst performing farming system along all but one of the environmental indicators. Comparing this to the results listed in Table 16 we can see that here too, Standard farming is the worst performing farming system overall. Comparing the environmental performance between the different farming systems in Figure 19 (right panel B) we see that the best performing farming systems vary, depending on the indicator looked at. In this sense, Table 16 gives us slightly more insights, as here we can see that overall, Organic (or what is called Organic + in Figure 19 (right panel B)) is the best performing ecological farming system from those considered in Figure 19 (right panel B), followed by Integrated/Circular AND Organic, and Organic (++). Similar comparisons can be made between the spider diagrams composed for the remaining case study areas in section 4.2 and the results listed in Table 16.

In Figure 19 (left panel A) we also illustrate the sustainability performance indicators calculated for the Flemish case study area. However, as opposed to the indicators calculated for the other case study areas, these have been calculated based on FADN data. As described above, this means that performance is evaluated at the regional or country level – in the case of Belgium this is at the regional level of Flanders – but not at the case study level. As such we focus on the LIFT farm-survey indicators in this section. However, we include the example of Flanders to illustrate that the environmental indicators proposed here can also be used to supplement FADN-based performance indicators. In Figure 19 (left panel A) we see that Standard farming is the worst performing farming system across all considered environmental indicators. Comparing this to the results of the supplementary environmental indicators listed in Table 16 we see that here too, Standard farming is the worst performing farming system in Flanders. In Figure 19 (left panel A) we also see that Low-Input AND

[14] The exact farming systems of FMPs which have been combined to form the combined farming systems in Table 15 are described in chapter 4.2 of this deliverable.

Integrated/Circular is the best performing farming system along all environmental indicators. However, the analyses listed in Table 16 show that Integrated/Circular is the better performing farming system of the two. These opposing results highlight the importance of incorporating a second environmental indicator in the analyses proposed in this deliverable. Particularly because the indicators calculated based on both the LIFT large-scale farmer survey data and the FADN data quantify environmental performance based on the use of external inputs. However, there are many other factors related to FMPs and farming systems which determine environmental performance. Thus, by supplementing the analysis with an environmental indicator quantifying environmental performance based on ESs, we are able to introduce some of the ecological information that may otherwise be lost by only considering LIFT large-scale farmer survey or FADN data.

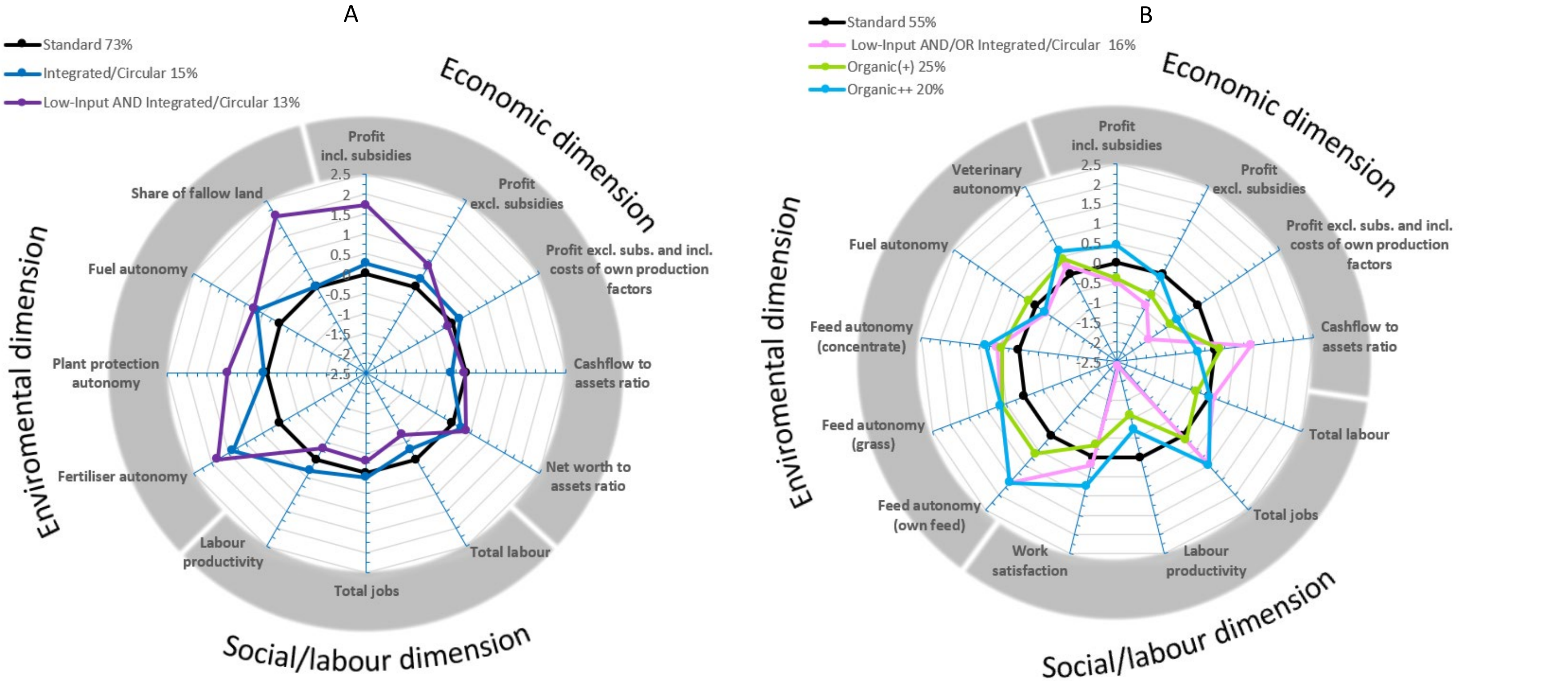


Figure 19. Spider diagrams illustrating the performance of farming systems across 12 FADN indicators related to the social, economic and environmental sustainability dimensions in the A) Flemish case study area (Flanders) for Standard, Integrated/Circular, as well as Low-Input AND Integrated/Circular farming systems, and in the B) Austrian case study areas combined for Standard, Low-Input AND/OR Integrated/Circular, Organic (+) and Organic ++ farming systems.

5.3 Employment effects and private social indicators

5.3.1 Analysis on the LIFT large-scale farmer survey data

Stuart Henderson (UNIKENT, UK), Laure Latruffe (INRAE, France)

5.3.1.1 Material and method

Data from the LIFT large-scale farmer survey were used to study the link between the level of employment and the working conditions on farm, for different farming systems. We focused on French dairy and beef cattle farms. The sample used contains 146 farms, including 96 specialist dairy farms, 42 specialist cattle farms and 8 mixed dairy-beef farms.

The total number of jobs on the farm was used as the proxy for the level of employment. The working conditions were considered from the point of view of workload, more specifically with the number of hours worked. The average was calculated over the whole labour force of the farm.

We explored the correlation between average farm labour hours of each farm compared with its corresponding total number of farm jobs. This allows to explore whether farm workers are being overworked or, in opposite of the spectrum, not having enough work. We also assessed the correlation between the number of weeks of vacation, and the total number of farm jobs.

We firstly oppose two farming systems, namely organic farms (certified organic farms, or farms in conversion to organic farming and receiving an agri-environmental payment for that) and non-organic i.e. conventional farms. Secondly, we apply the LIFT typology protocol (Rega et al., 2021) to compare ecological farming systems to the Standard farming benchmark. Farms were separated using the LIFT survey-protocol, with a cut-off at 2.4 in the low-input calculation of the protocol where >2.4 denotes an ecological (low-input) farm and <2.4 a standard farm. This results in 71 Standard farms and 75 ecological (Low-Input) farms. Table 17 compares averages of various characteristics between Standard and Low-Input farms.

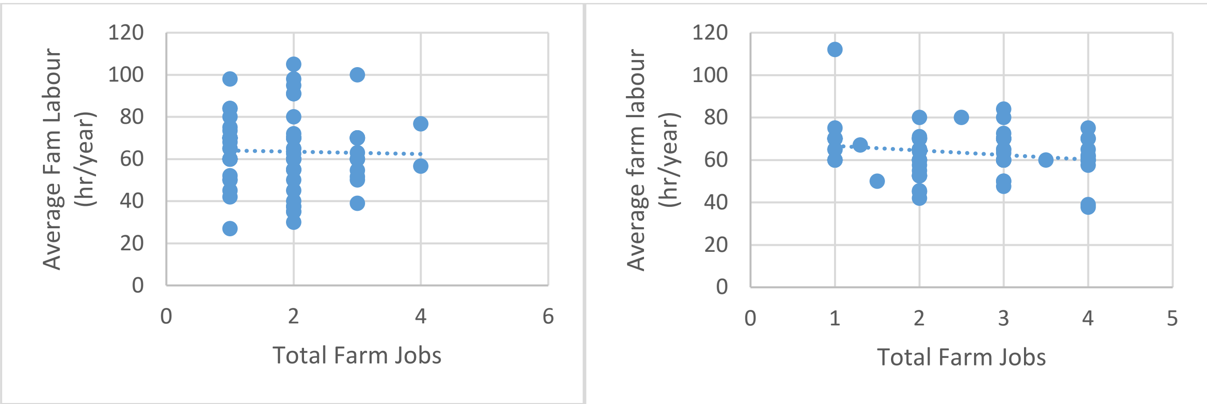
Table 17: Averages comparing standard and ecological farms across different variables (French dairy or/and beef cattle farms, data from the LIFT large-scale farmer survey)

Variable	Standard farms	Low-Input farms
Utilised Agricultural Area (ha)	119.4	103.3
Herd size (Livestock Units for cattle)	66.3	91.1
Average family labour per family member (hours)	53.5	50.7
Average family labour per farm (hours)	4,937	4,643
Average hired labour per farm (hours)	1,481	5,660
Average total labour per farm (hours)	6,446	10,477
Average total family jobs	1.9	1.8
Average total jobs	4.1	10.4
Average family vacation per farm (weeks)	3.8	1.8
Average family vacation per job (weeks)	1.2	0.6

In this sample Standard farms are bigger in terms of their land area than Low-Input farms. As seen in Table 17 there are slightly more working hours and jobs for family labour on Standard farms (4,937 hours and 1.9 job) than on Low-Input farms (4,643 hours and 1.8 job), however there is also additional vacation on Standard farms than on Low-Input farms (1.2 vs 0.6 weeks). The contrasting difference between both farming systems relates to hired labour. On Low-Input farms there is almost three times as much hired labour hours than on Standard farms, leading to a strong difference in terms of total jobs (4.1 for Standard farms, 10.4 for Low-Input farms).

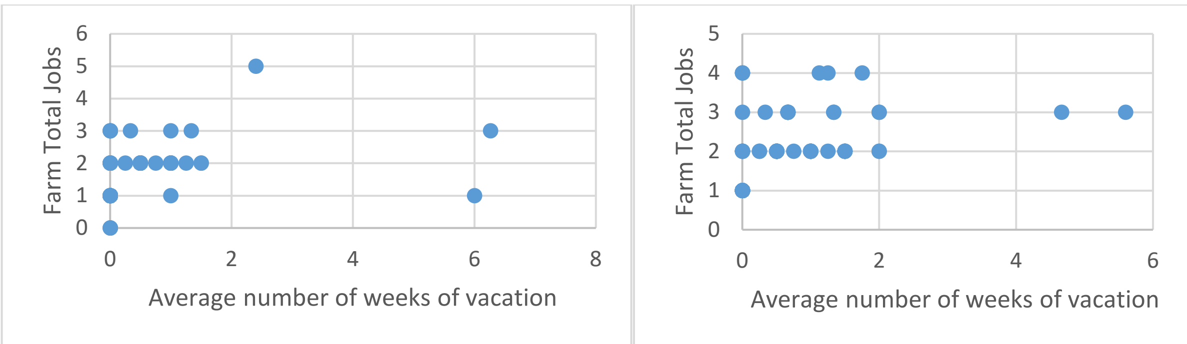
5.3.1.2 Results for organic vs. conventional farms

Figure 20 shows firstly that there is more variation in the number of hours worked on average on an organic farm by each individual (Figure 20, left panel) compared with the conventional farms (Figure 20, right panel). Secondly, we can observe a higher average number of hours worked per individual on the conventional farms. Thirdly, there is more of a downward trend on conventional farms perhaps indicating that there may be fewer individuals on these farms to share a large amount of the workload.



Organic farms *Conventional farms*

Figure 20. Link between the average farm labour spent on farm with the total number of jobs on the farm – French dairy and cattle farms, data from the LIFT large-scale farmer survey



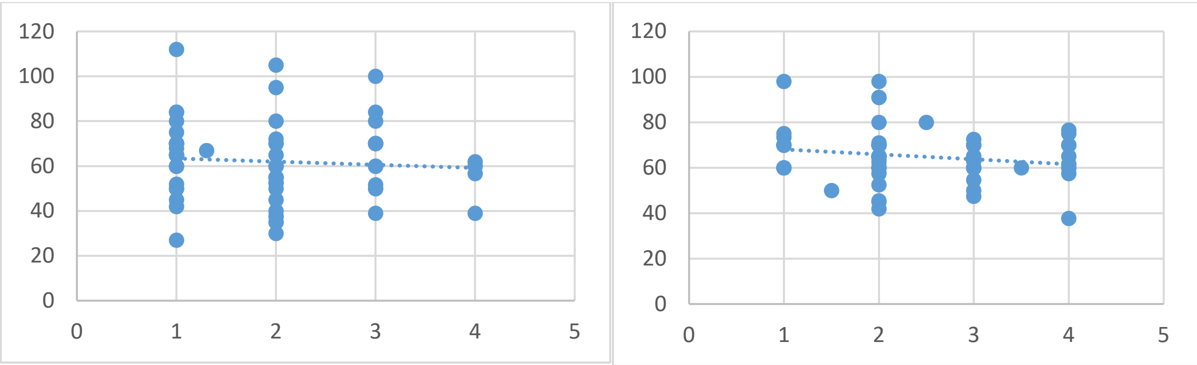
Organic farms *Conventional farms*

Figure 21. Link between the total number of jobs on the farm and the number of weeks of vacation – French dairy and cattle farms together, data from the LIFT large-scale farmer survey

Figure 21 explores the correlation between average number of weeks of vacation taken per family members on farms and comparing conventional (right panel) with organic farms (left panel). In contrast to the previous charts, these show that there seems to be more jobs and more weeks of vacation per family member on conventional farms.

5.3.1.3 Results for Low-Input vs. Standard farms

The patterns for Low-input farms and Standard farms (Figure 22) are similar to the ones above comparing organic farms and conventional farms.



Low-input farms *Standard farms*

Figure 22. Link between the total number of jobs on the farm (vertical axis) and the number of weeks of vacation (horizontal axis) – French dairy and cattle farms, data from the LIFT large-scale farmer survey

We conclude from these two comparisons that there is more variation in the number of hours worked on average on an ecological farm compared to a Standard or Conventional farm. In terms of absolute levels, we can see that on Standard or Conventional farms there is a higher average number of hours worked per individual but also a higher number of weeks of vacation.

5.3.2 Analysis on the data from the specific LIFT survey to farmers on working conditions

Nathalie Hostiou, Jacques Veslot (all INRAE, France)

5.3.2.1 Introduction

Due to an important increase of apparent labour productivity over the last decades, working conditions on farms are evolving with pressures on work for farming production systems. With a generation of farmers soon to retire, the farming sector is facing an additional challenge, namely, how to ensure that a new generation of farmers will step into their shoes (Coopmans et al., 2020). In Europe, just 7.5% of farmers are under 35 years of age, while 30% are over 65 (Council of the European Union, 2014). A major obstacle to ensuring continuity is the perceived lack of attractiveness of farming as a profession (Coopmans et al., 2020). Despite this, social performance is the pillar of sustainability that is the most often neglected, compared to the evaluation of environmental and economic performances of farming systems. Working conditions in ecological farms can differ in comparison to more conventional farming practices. The adoption of ecological practices promises to be an opportunity to obtain worthy and fulfilling employment and working conditions (Gliessman, 2007). But contrasting results can exist within dimensions contributing to working conditions (Duval et al., 2021).

In Hostiou et al. (2021), main results from a comparative analysis of 5 European cases studies, for livestock and crops farms, highlighted differences in working conditions across areas. For example, the working conditions in Ireland and Crete differed significantly from those in the other study areas. Farmers in Crete and Ireland worked shorter hours but faced more difficulties when replacing workers. Farmers in Crete had less time away from the farm, and perceived a higher level of stress. These differences in working conditions in Ireland and Crete, compared to the other case study areas are probably due to contextual factors, such as the predominant agricultural systems (e.g. permanent crops in Crete compared to livestock farming in Ireland) and the availability of off-farm employment. It should be stressed that the use of organic practices is only one of the many factors affecting working conditions. The two main factors explaining the variability observed in farmers' working conditions are contextual, namely the case study area and the production system. Here, in order to better identify relations between working conditions and the uptake of ecological practices, we carried out an analysis on working conditions for a more homogeneous sample, namely the specialist dairy farms in four European case studies.

The main objectives of this study are: (i) to describe farmers' and farm workers' working conditions in dairy farms characterised by different degrees of ecological approaches in European case study areas; (ii) to identify relations between working conditions, the degree of uptake of ecological approaches and the workforce composition (gender, family vs hired workers).

5.3.2.2 Material and methods

5.3.2.2.1 Data collection of indicators on on-farm working conditions

As described in Hostiou et al. (2021), a set of indicators to be collected on on-farm working conditions was selected in a two-step approach: (i) a theoretical basis from the literature on social performance and working conditions and (ii) and expert knowledge.

Data collection related to indicators was based on the collection of primary data during interviews with dairy farmers in four case studies: Brittany in France, Puy-de-Dôme in France, Salzburg und Umgebung area in Austria and Steyr-Kirchdorf in Austria.

Indicators on on-farm working conditions were collected for different types of workers: the farm manager, the family workers and all workers together (family and hired workers) (Table 18) based on the interview with the farm manager. The interviews were carried out in 2018 and 2019.

Information on farm characteristics (for example the degree of ecological approaches) and workforce composition was also collected (Table 19 and Table 20).

Table 18. Description of the indicators on on-farm working conditions (category, label of the variable, types of workers considered, formula and units)

Indicator	Category	Label of the variable	Units	Types of workers considered	Formulae (see Tzouramani et al., 2019 and Hostiou et al., 2021)
Mean working hours for the family workers	Work duration	duration_mean_family	hours/week	family workers	Sum of Q15_7 / (Q15 + 1)
Total working hours for the family workers per Livestock Unit	Work duration	duration_total_family_per LSU	hours/week	family workers	Sum of Q15_7 / LU
Rate of peak period * Capability to finish the work	Work intensity	intensity_peak_index	No unit (proportion of peak periods multiplied by an ordinal indicator of the capability to finish (with 4 levels: Yes, always; Most of the time; Sometimes; Rarely/seldom; No, never) rescaled into a scalar between 1 and 2.	all workers	(QA1 * QA2 / 52) * QA4
Work at night	Work intensity	intensity_night_work	Binary: No/Yes	all workers	QA15
Farm manager sole decision maker	Decision making	organisation_decision_sole	Binary: No/Yes	Farm manager	Q15SQ5 with 1
Specialisation of workers	Work organisation	organisation_specialisation	Categorical with 4 levels: No/Few/Most/All	all workers	QA5
Difficulty to replace a worker in case of leave	Work organisation	organisation_replacement	Categorical with 3 levels: Not difficult (very easy, easy)/Quite difficult/Very difficult	all workers	QA7
Holidays of the family workers	Quality at work	quality_holidays_family	Mean number of weeks per year	family workers	Sum of Q15_8 / (Q15 + 1)
Free days (weekend and/or day off)	Quality at work	quality_freedays	Binary: No/Yes	all workers	QA9
Work flexibility (ability to take hours off during working hours for absences)	Quality at work	quality_flexibility	Binary: No/Yes (Yes = Yes for both answers to QA16 and QA17 questions)	all workers	QA16 and QA17

Complexity of work organisation	Work complexity	complexity_organisation	Ordinal (sum of binary answers to questions QA18, with coefficient -1 for the last question) rescaled from 0 to 1.	all workers	Sum of QA18 with -1
Complexity in operating system	Work complexity	complexity_operating	Binary: No/Yes	all workers	QA19
Being a farmer	Self-identity and attitudes	identity_farmer	3 variables with 5 levels from Strongly disagree to Strongly agree: questions of the LIFT large-scale farmer survey questionnaire (Tzouramani et al., 2019) were considered, each one was used as a variable to build this indicator. Each of these variables was expressed on a scale from 1 (strongly agree) to 5 (strongly disagree). The sum of the three variables is converted into ordinal (which gives an index from 0 to 15).	Farm manager	Q49_1 + Q49_2 + Q49_3
Prioritising environment	Self-identity and attitudes	identity_environment	3 variables with 5 levels from Strongly disagree to Strongly agree: 3 questions of the LIFT large-scale farmer survey questionnaire (Tzouramani et al., 2019) were considered, each one was used as a variable to build this indicator. Each of these variables was expressed on a scale from 1 (strongly agree) to 5 (strongly disagree). The sum of the three variables is converted into ordinal (which gives an index from 0 to 15).	Farm manager	Q49_4 + Q49_5 + Q49_6
Level of stress	Stress	stress_level	Ordinal from 0 to 10	Farm manager	QA22
Mean Satisfaction Level (with his/her working conditions)	Satisfaction	satisfaction_mean	Average of the 5 ordinal satisfaction components	Farm manager	QA24 : QA28
Satisfaction with daily work	Satisfaction	satisfaction_daily_work	Ordinal from 1 to 5	Farm manager	QA24
Satisfaction with life balance	Satisfaction	satisfaction_life_balance	Ordinal from 1 to 5	Farm manager	QA25
Satisfaction with being farmer	Satisfaction	satisfaction_being_farmer	Ordinal from 1 to 5	Farm manager	QA26
Satisfaction with decision making	Satisfaction	satisfaction_decision_making	Ordinal from 1 to 5	Farm manager	QA27

Satisfaction with life quality	Satisfaction	satisfaction_life_quality	Ordinal from 1 to 5	Farm manager	QA28
Agricultural relations of the farmer	Social relations	relations_agriculture	Binary: No/Yes	Farm manager	QA29
Village/rural relations of the farmer	Social relations	relations_rural	Binary: No/Yes	Farm manager	QA30
Food chain relations of the farmer	Social relations	relations_value_chain	Binary: No/Yes	Farm manager	QA31
Social relations of the farmer	Social relations	social_relations	Binary: No/Yes	Farm manager	QA29 + QA30 + QA31

Table 19. Description of indicators on farm characteristics selected for the comparative analysis on working conditions

Indicator	Category	Label of the variable	Units	Types of workers considered	Formulae with question code in questionnaire
Livestock Unit (LSU)	Farm size	size_LSU	Integer (number of Livestock units)	farm	Q31 > LSU
Total Utilised Agricultural Area (UAA)	Farm size	size_UAA	Integer (number of ha)	farm	Q11_sqTOT
Country	Farm location	country	Categorical with 2 values	farm	Q1_1
Region	Farm location	region	Categorical with 4 values	farm	Q1_2
Organic / Not organic	Degree of uptake of ecological practices	ecological_organic	Binary: 0 (not organic) / 1 (organic)	farm	Q9_2A
Maize silage per LSU	Degree of uptake of ecological practices	ecological_maize_silage_perLU	Integer (ha/LSU)	farm	Q69_3A / LSU
No silage / Haymilk	Degree of uptake of ecological practices	ecological_no_silage	binary: 0=silage; 1=haymilk	farm	"TSG Haymilk" (Q9_3) or No maize/grass silage
LSU / UAA (livestock farms)	Degree of uptake of ecological practices	loading_LSU_perUAA	Integer (LSU/UAA)	farm	LSU / Q11_sqTOT

Table 20. Description of indicators on workforce composition selected for the comparative analysis

Indicator	Category	Label of the variable	Units	Types of workers considered	Formulae with question code in questionnaire
Management structure	Farm type	management_structure	Categorical with 3 values (Individual / Partnership / Company)	farm	Q6
Number of family workers	Workforce composition	workforce_nbfam	Integer (number)	family workers	Q15+1
Proportion of family workforce in the total workforce	Workforce composition	workforce_propfam	Percentage	family workers	Q15/(Q15+Q16)

Proportion of men in the family workers	Workforce composition	workforce_sexratio	Percentage	family workers	Average of Q15_1
Age of the family workers (mean per family)	Workforce composition	workforce_age	Integer (number of years)	family workers	Average of Q15_3
Education level of the family workers (mean per family)	Workforce composition	workforce_education	Average of education levels across family members converted into ordinal from 1 (No schooling) to 7 (University – non-agricultural)	family workers	Average of Q15_2
Experience of the family workers (mean per family)	Workforce composition	workforce_experience	Integer (number of years)	family workers	Average of Q15_4
Proportion of men in farm managers	Farmer	farmer_sex	Binary: 0 (Female) / 1 (Male)	Farm manager	Q15_1A
Age of farm manager	Farmer	farmer_age	Integer (number of years)	Farm manager	Q15_3A
Experience of the farm manager	Farmer	farmer_experience	Integer (number of years)	Farm manager	Q15_4A
Education level of the farm manager	Farmer	farmer_education	Categorical with 7 levels: 1 (No schooling), 2 (Primary school), 3 (Middle or secondary school), 4 (High school or sixth form college – agricultural), 5 (High school or sixth form college – non-agricultural), 6 (University – agricultural), 7 (University – non-agricultural)	Farm manager	Q15_2A

5.3.2.2.2 Data analysis

The analysis was carried out for a sample of 99 farms: 37 in Salzburg und Umgebung area in Austria (AT_SA), 42 in Steyr-Kirchdorf in Austria (AT_SK), 11 in Brittany in France (FR_BR), and 9 in Puy-de-Dôme in France (FR_PD) (Table 21).

As the samples of farms surveyed were built on different selection criteria between case study areas, resulting in unbalanced data notably across ecological approaches, we did not group farms from different regions corresponding to a same type of ecological approaches. Using univariate and multivariate statistical analyses, our aim was to identify whether similar patterns existed in all or several case study areas, particularly between working conditions and ecological approaches.

The analysis has followed different steps. Descriptive statistics (mean, standard deviation) were calculated to describe the indicators for all the farms and for each case study and each ecological approach (99 farms). A principal component analysis (PCA) was carried out on normalised indicators on working conditions, using all farms with complete data (86 farms), weighted to give the same importance to each region. This multivariate analysis aims at highlighting main components in working conditions and to look at patterns in the distribution of ecological approaches along these main components.

5.3.2.2.3 Identification of four degrees of ecological approaches

Four degrees of uptake of ecological approaches adopted were identified using the following variables: organic or conventional; silage use or haymilk (certified within the EU quality scheme as TSG) (Table 21). From an environmental point of view, haymilk is associated with a less intensive usage of grassland, as grass can be cut less often, when hay is produced, compared to silage, which can be beneficial for biodiversity on grassland (Niedermayr et al., 2021). In the context of the LIFT project, conventional haymilk and organic haymilk systems thus share some similarities with low-input and integrated farming systems, as defined in Rega et al. (2018); and Rega et al. (2021), additionally to the characteristics of organic farming systems, also described in these deliverables. We differentiate four degrees of ecological approaches in the sample of dairy farms: (i) conventional farms as the most intensive and from an environmental point of view unrestricted production system, followed by (ii) conventional haymilk farms, (iii) organic farms, which comply with the standards of organic farming and (iv) organic haymilk farms, which we consider as the most ecological farming system.

Table 21. Number of farms per degree of ecological approaches and per case study area

Acronym of the case study areas	**AT_SA**	**AT_SK**	**FR_BR**	**FR_PD**	**Tot al**
Name of the case studies	Austria Salzburg und Umgebung	Austria Steyr-Kirchdorf	France Brittany	France Puy-de-Dôme	
conventional farms	8	26	6	0	40
conventional haymilk farms	10	0	1	0	11
organic farms	2	14	3	4	23
organic haymilk farms	17	2	1	5	25
Total	37	42	11	9	99

5.3.2.3 Results

5.3.2.3.1 Sample description of dairy farms

Conventional farms (with silage or haymilk farms) have a larger herd size than in the farms with other degrees of ecological approaches (Table 22). Organic haymilk farms have a lower UAA. Organic and organic haymilk farms have a lower number of livestock units per hectare than conventional and conventional haymilk farms. But standard deviations are high for all degrees of ecological approaches showing a large diversity of farm structures within a degree of ecological approaches. Differences are also observed between the case study areas. Farms in the two French case studies had larger UAA than in Austrian case studies. The number of livestock unit per hectare is very different within the case studies with a gradient from highest to lowest livestock unit per hectare (Austria Salzburg und Umgebung > Austria Steyr-Kirchdorf > France Brittany > France Puy-de-Dôme).

Table 22. Statistics (Mean and standard deviation) on farm characteristics per case study area and per degree of ecological approaches (- : no standard deviation)

Degrees of uptake of ecological approaches	Conventional			Conventional haymilk		Organic				Organic haymilk			
Case study area	AT_SA	AT_SK	FR_BR	AT_SA	FR_BR	AT_SA	AT_SK	FR_BR	FR_PD	AT_SA	AT_SK	FR_BR	FR_PD
Number of farms	8	26	6	10	1	2	14	3	4	17	2	1	5
Livestock Units (LSU)	92.69 (31.13)	72.87 (38.07)	130.33 (50.82)	76.05 (40.29)	75 (-)	67.1 (60.39)	45.94 (24.4)	98 (78.31)	55.4 (29.57)	58.94 (24.41)	39.35 (13.22)	70 (-)	43.2 (14.52)
Total UAA in ha	38.94 (13.37)	38.16 (14.11)	124.67 (39.45)	35.95 (10.65)	70 (-)	41.5 (33.23)	33.06 (18.17)	113.67 (78.59)	112 (60.59)	31.46 (9.68)	32.5 (3.54)	92 (-)	86 (38.14)
LSU / ha UAA	2.43 (0.5)	1.84 (0.64)	1.03 (0.17)	2.07 (0.67)	1.07 (-)	1.52 (0.24)	1.52 (0.54)	0.81 (0.12)	0.52 (0.21)	1.85 (0.37)	1.24 (0.54)	0.76 (-)	0.54 (0.21)

Most of the dairy farms, in the four degrees of ecological approaches, are managed by individual farmers (Table 23). There are more partnership management farms in France, particularly in Brittany. Workforce in mainly composed by family workers in all case studies. Conventional farms and organic farms have more family workers (3.42 and 3.57 respectively) than conventional haymilk and organic haymilk farms (2.55 and 2.64 respectively). There are fewer family workers in both French areas than in both Austrian areas.

There are more permanent hired workers in the total workforce in conventional and conventional haymilk farms in France Brittany.

Family workers and farm managers are quite old. Farm managers in conventional farms are younger than in farms with other degrees of ecological approaches in both Austrian case studies and in France Brittany.

Family workers in haymilk organic farms in Austria have a higher level of education. The level of education of family workers is lower in France Puy-de-Dôme.

For all the four degrees of ecological approaches, Austrian family workers have more years of experience than French farmers. Austrian and French Brittany farm managers have more years of experience in organic and organic haymilk than in conventional farms.

Family workers are composed mainly of men in farms of the four degrees of ecological approaches. Family women workers are more numerous and represent 50% or more of the family workforce in certain case study areas: in conventional farms (52% of the family workforce), and in organic haymilk farms (50%) in Austria Salzburg, in conventional haymilk farms in France Brittany (50%), in organic farms in France Puy-de-Dôme (54%). Farm managers are mainly men in the four degrees of ecological approaches. Women farm managers are more numerous in conventional haymilk farms (50%) and in organic haymilk farms (50%) in Austria Steyr-Kirchdorf. There are fewer women farm managers in conventional farms.

Table 23. Statistics (Mean and standard deviation) on workforce composition per case study area and per degree of ecological approaches (- : no standard deviation)

Degrees of uptake of ecological approaches	Conventional			Conventional haymilk		Organic				Organic haymilk			
Case study area	AT_SA	AT_SK	FR_BR	AT_SA	FR_BR	AT_SA	AT_SK	FR_BR	FR_PD	AT_SA	AT_SK	FR_BR	FR_PD
Number of farms	8	26	6	10	1	2	14	3	4	17	2	1	5
Management structure	Individual = 7 / Partnership = 1	Individual = 26	Individual = 1 / Partnership = 4 / Company = 1	Individual = 9 / Partnership = 1	Partnership = 1	Individual = 2	Individual = 14	Individual = 1 / Partnership = 2	Individual = 2 / Partnership = 2	Individual = 17	Individual = 2	Partnership = 1	Individual = 3 / Partnership = 1 / Company = 1
Number of family workers	2.88 (0.64)	3.88 (0.82)	2.17 (1.17)	2.6 (0.84)	2 (-)	3.5 (0.71)	4 (1.41)	2.67 (2.08)	2.75 (1.26)	2.82 (1.01)	4 (0)	2 (-)	1.6 (0.55)
Proportion of family workforce in the total workforce	1 (0)	0.96 (0.12)	0.89 (0.17)	1 (0)	0.8 (-)	1 (0)	0.94 (0.12)	0.92 (0.13)	0.92 (0.17)	0.93 (0.18)	1 (0)	1 (-)	0.9 (0.22)
Proportion of men in the family workforce	0.48 (0.14)	0.57 (0.15)	0.75 (0.27)	0.63 (0.15)	0.5 (-)	0.58 (0.12)	0.59 (0.13)	0.77 (0.25)	0.46 (0.32)	0.5 (0.11)	0.62 (0.18)	1 (-)	0.7 (0.27)
Age of the family workers (mean for the family) (years)	45.41 (2.35)	48.43 (7.4)	48.18 (7.76)	39.98 (9.5)	38 (-)	45.5 (4.95)	47.52 (6.17)	46.6 (11.66)	41.77 (8.98)	45.9 (7.47)	49 (12.37)	49.5 (-)	47.4 (6.65)
Education level of the family workers (mean per family)[1]	3.81 (0.5)	3.6 (0.57)	4.81 (0.91)	3.94 (0.66)	4.5 (-)	4.42 (0.12)	4.26 (0.76)	4.8 (1.06)	3.62 (0.48)	3.87 (0.59)	4 (0.71)	5.5 (-)	3 (0.71)
Experience of the family workers (mean per family)	28.57 (2.39)	31.3 (7.47)	23.92 (10.52)	23.22 (9.77)	5.5 (-)	27.08 (4.83)	30.28 (5.46)	21.1 (13.21)	17 (12.73)	29.02 (8.98)	31.38 (10.08)	26.5 (-)	27.75 (5.38)
Proportion of men in farm managers	1 (0)	0.85 (0.37)	0.83 (0.41)	0.5 (0.53)	1 (-)	1 (0)	0.79 (0.43)	1 (0)	0.75 (0.5)	0.76 (0.44)	0.5 (0.71)	1 (-)	1 (0)
Age of the farm manager (years)	36.88 (12.3)	42.69 (10.98)	45.17 (11.55)	39.1 (12.74)	37 (-)	46.5 (13.44)	45.07 (9.58)	49.33 (13.28)	40.5 (15.42)	42.12 (9.64)	48 (5.66)	51 (-)	47.6 (7.2)
Experience of farm manager (years)	20.38 (12.78)	25.88 (10.27)	19.33 (14.36)	23 (13.09)	10 (-)	30.5 (13.44)	27.57 (10.89)	25.67 (17.1)	17 (12.73)	25.76 (9.38)	32 (5.66)	30 (-)	27.75 (5.38)
Education level of the farm manager[1]	4 (0)	3.92 (0.63)	5.17 (1.33)	4.1 (1.45)	4 (-)	4 (0)	4.36 (0.93)	4.67 (1.15)	3.5 (0.58)	4.06 (0.56)	4 (0)	6 (-)	3 (0.82)

[1]For clarity reason, farmer and workforce education levels are expressed in tables as an average of education level classes considered as ordinal.

5.3.2.3.2 Comparison of on-farm working conditions for the four degrees of ecological approaches in the four case study areas: results of univariate statistical analyses

5.3.2.3.2.1 Work duration and work intensity

Work duration for the family workers (expressed in number of hours worked per week on average) is higher in conventional farms and in conventional haymilk farms than in organic dairy farms. But differences are very important across the 4 case studies (Figure 23). Work duration for the family workers is higher in organic dairy farms in France Puy-de-Dôme (72.6 hours per week on average), due to transformation and direct selling of cheese, than in the other case studies. Work duration in dairy farms in Austria Salzburg und Umgebung is higher than in Austria Steyr-Kirchdorf for all different degrees of ecological approaches.

Work efficiency (number of hours worked by the family workers per livestock unit) is better in conventional farms than in organic farms in both Austrian case studies.

There is no relation between the degree of ecological approaches and work at night but differences are identified across case studies: farmers in both French case studies work more at night than in Austria.

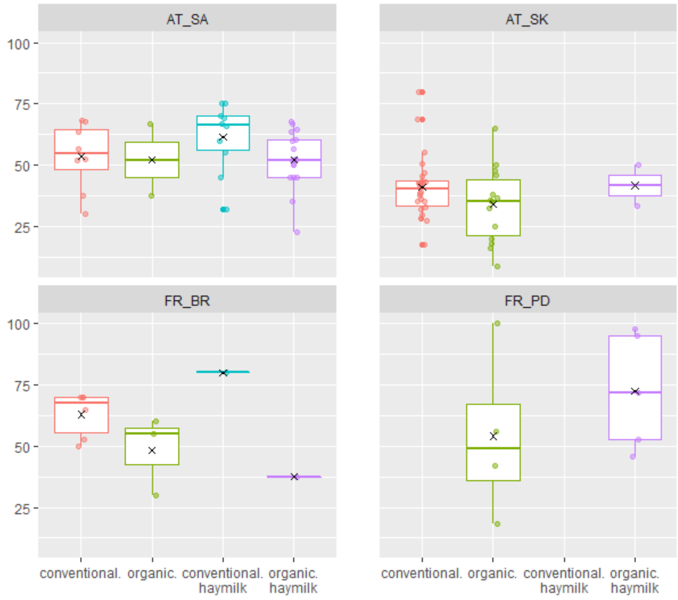


Figure 23. Mean working hours for the family workers (hours per week) according to the degree of ecological approaches in the 4 case study areas

5.3.2.3.2.2 Work organisation

There is no strict relation between the degree of ecological approaches and the difficulty to replace workers in case of leave (for expected absences such as vacations or meetings for example and for unexpected absences such as illness for example). However, it seems that farmers express more difficulty to replace a worker in case of absences in organic farms in Austria Salzburg und Umgebung and in France Brittany.

There is no strict relation between the degree of ecological approaches and the level of specialisation of workers: both in conventional and in organic farms, workers can be specialised on certain tasks or versatile (they carry out all types of tasks).

5.3.2.3.2.3 Quality at work

There is no strict relation between the degree of ecological approaches and indicators related to quality at work: number of holidays (defined as more than 3 days in a row) for the family workers, number of free days (defined as weekends or day off in the week) for the family workers and work flexibility (defined as the ability to take hours off during working hours for expected/anticipated absences and for unexpected/unforeseen absences).

Relations between some indicators of quality at work and the degree of ecological approaches were observed in Austria Salzburg und Umgebung and in France Brittany. In Austria Salzburg und Umgebung farmers in conventional farms and in conventional haymilk farms have less ability to take hours off during working hours for expected or unexpected absences than in organic and organic haymilk farms. In France Brittany family workers in conventional farms (haymilk or not) have more free days (weekends or day off in the week) than in organic farms (haymilk or not).

5.3.2.3.2.4 Work complexity

Farmers in organic and organic haymilk farms in all the case study areas indicated that their work is more complex following the adoption of ecological practices due to changes needed to observe and to monitor the herd, the crops and the farm (Figure 24).

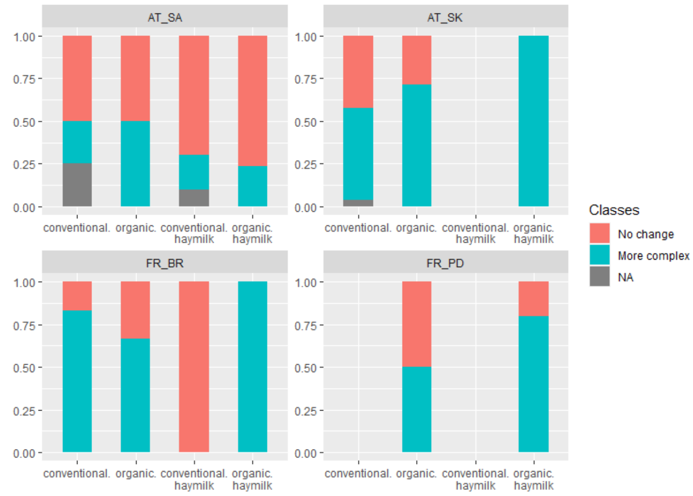


Figure 24. Complexity in operating system indicated by the farm manager according to the degrees of ecological approaches in the 4 case study areas

5.3.2.3.2.5 Self-identity and attitudes

In all case studies, farmers in organic farms (haymilk or not) have a different representation of their job than in conventional farms (Figure 25): the former agree less with the three statements “Being a farmer is an important reflection of who I am”, “What happens to farmers as a whole will have an effect on what happens in my life”, “I have a strong sense of belonging to the farming community”. Their self-identity seems to be different and related to other representations than in conventional farms. However, farmers in organic farms and in organic haymilk farms in Austria Salzburg und Umgebung, in France Brittany and in France Puy-de-Dôme, say that to prioritise and to preserve the environment is an important part of who they are (Figure 26). This relation was not observed in Austria Steyr-Kirchdorf.

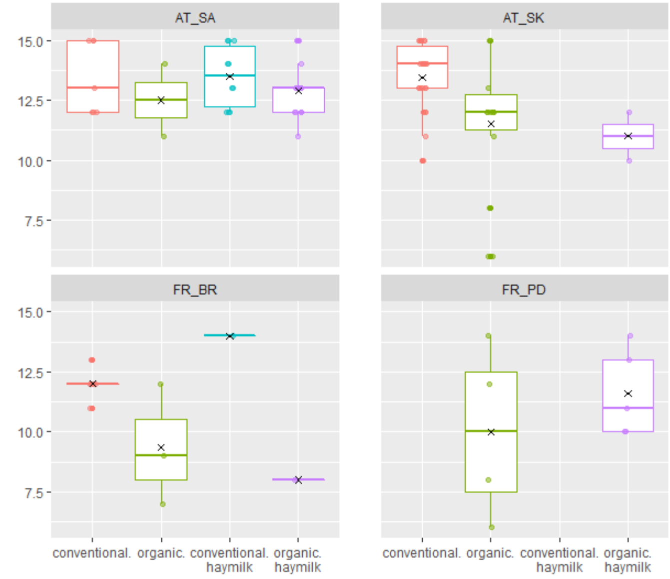


Figure 25. Being a farmer (score between 0 and 15; calculated as a sum of scores 0 to 5 for each of the 3 statements related to this indicator) according to the degree of ecological approaches in the 4 case study areas

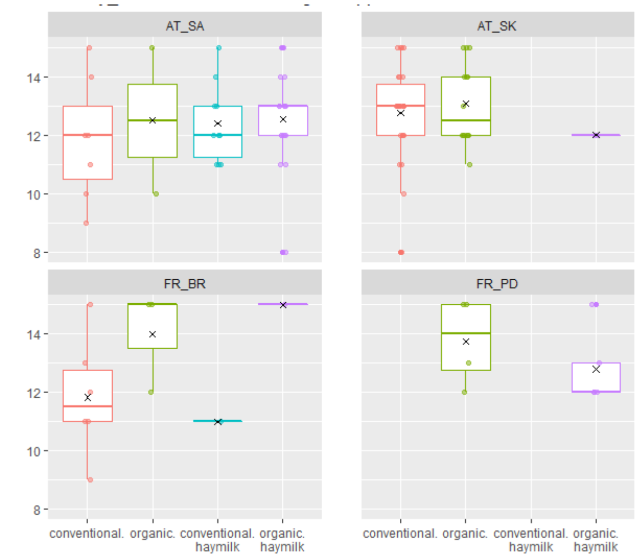


Figure 26. Prioritising environment (score between 0 and 15; calculated as a sum of scores 0 to 5 for each of the 3 statements related to this indicator) according to the degree of ecological approaches in the 4 case study areas

5.3.2.3.2.6 Stress and satisfaction at work

Although it seems that the average level of satisfaction perceived by farm managers in conventional farms is lower than in other farms in all case studies (Figure 27), there is no strict relation between the degree of ecological approaches and the level of stress.

Differences between case studies are very important. The level of stress perceived by farm managers is lower in France Puy-de-Dôme in comparison to the three other case studies. In Austria Salzburg und

Umgebung the level of satisfaction expressed by farm managers in organic haymilk farms varies from 1 (low level of satisfaction) to 5 (high level of satisfaction). In comparison, in Austria Steyr-Kirchdorf, the level of satisfaction is less variable for organic haymilk farms (4 to 4.5). Differences within a same degree of ecological approaches are also observed. For example in Austria Steyr-Kirchdorf, the level of stress perceived by farmers in conventional farms varies from 0 (no stress) to 9 (high level of stress). A high variation (between 3 and 8) is also noticed for organic farms in Austria Steyr-Kirchdorf.

When analysing more precisely certain components of the level of satisfaction, for example the level of satisfaction from being a farmer (Figure 28), farm managers in organic farms indicated a higher level of satisfaction with their job than farm managers in conventional farms.

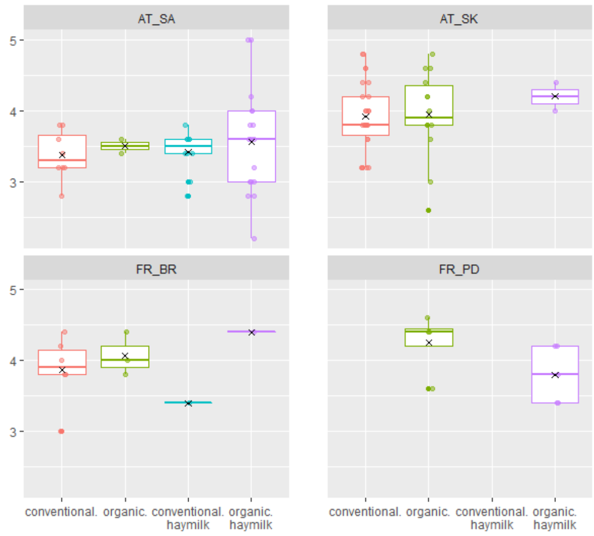


Figure 27. Level of mean satisfaction indicated by farm managers (scale from 1 – not satisfied at all, to 5 – very satisfied) according to the degree of ecological approaches in the 4 case study areas

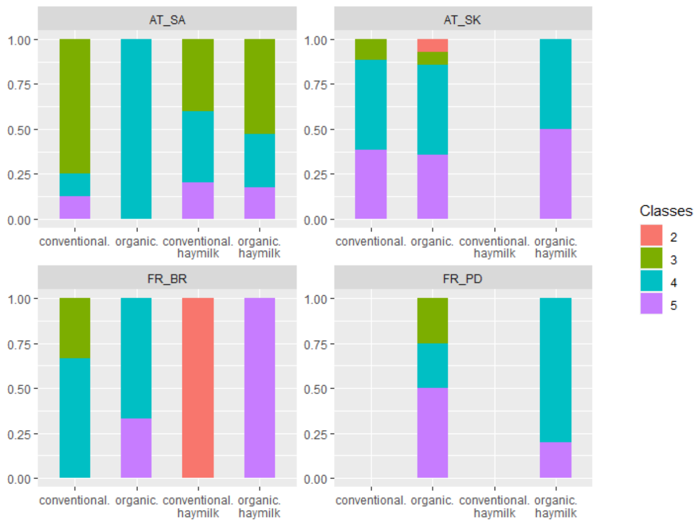


Figure 28. Proportion of farm managers according to the level of satisfaction from being a farmer (scale from 2 – unsatisfied, to 5 – very satisfied) according to the degree of ecological approaches in the 4 case study areas

5.3.2.3.2.7 Social relations of the farmers

There is no strict relation between the degree of ecological approaches and the social relations in which farmers are involved. Differences are rather noticed between case studies: farmers (for the different degrees of ecological approaches) in both Austrian case study areas participate more in the local community relating to agricultural activities (e.g., participation in local festivals, local farmers' market, local farming fairs, hosting open day events in the farm) and in village/rural area events (e.g., voluntary work for associations, church, school, family, local politics) than in both French cases study areas.

5.3.2.3.3 Analysis of working conditions for degrees of ecological approaches and workforce composition: multivariate analysis

5.3.2.3.3.1 Characterisation of main components

The visualisation of variables on the first factorial plan (Figure 29) shows a first axis that opposes mainly mean satisfaction level (negative values) to difficulty to replace workers in case of leave, then mean stress level and finally mean working hours for family workers, with a strong contribution of mean satisfaction level. The second axis is positively correlated with the indicators of social relations, particularly those related to agricultural activities and rural relations, and with farmer identity. To summarise, the first axis can be interpreted as a gradient towards lower mean satisfaction levels and the second axis as a gradient towards greater engagement in the agricultural and local community.

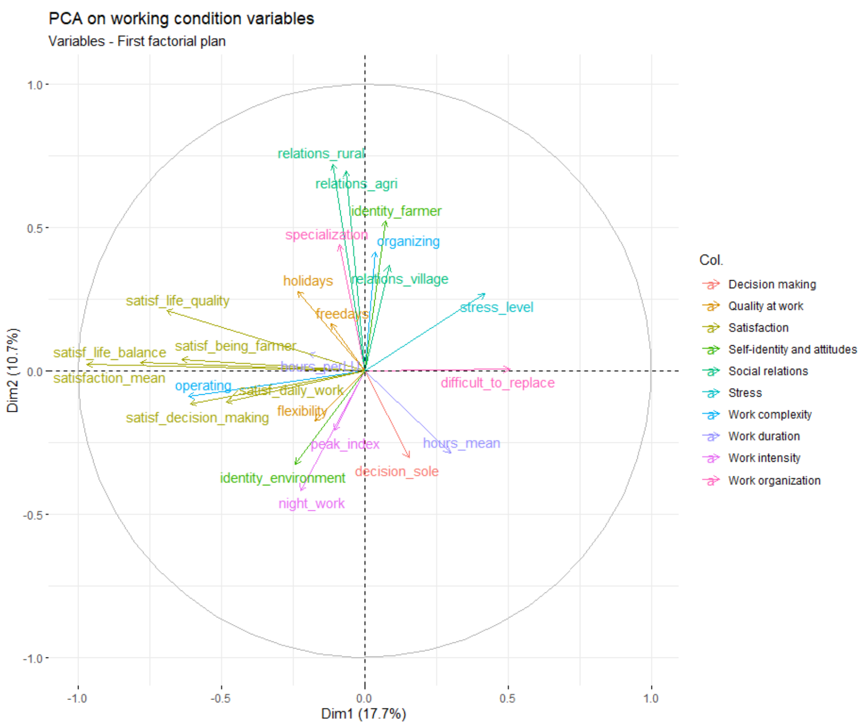


Figure 29. PCA on working condition indicators – First factorial plan (biplot)

The second factorial plan (Figure 30) is not as well defined as the first one. The third axis is negatively correlated with indicators of work quality: holidays, free days (week-ends and day off during the week) and flexibility (e.g. ability to take hours off during working hours for absences) (negative values), and positively with satisfaction in daily work, farmer making his/her decision alone and difficulty to replace a worker in case of leave (positive values). The fourth axis is negatively correlated to work complexity and work intensity (negative values). To summarise, the third axis can be interpreted as a gradient towards lower free time, and the fourth axis as a gradient towards lower workload.

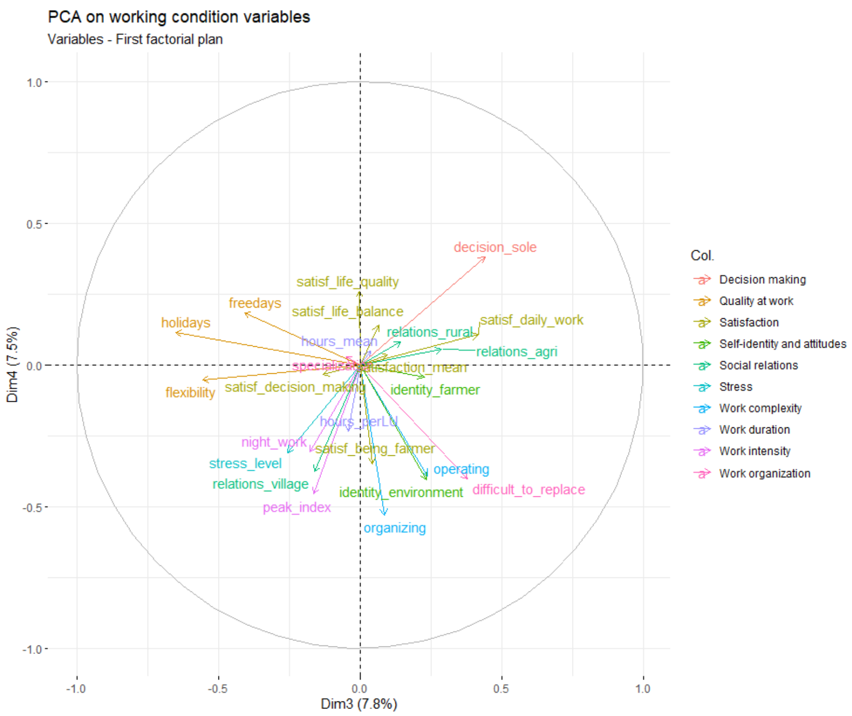


Figure 30. PCA on working condition indicators – Second factorial plan (biplot)

5.3.2.3.3.2 Relation between degrees of ecological approaches and working conditions indicators

When projecting the indicator of ecological approaches (organic/haymilk) on the two first factorial plans (Figure 31), only very subtle differences can be noticed. Organic dairy farms are slightly shifted towards negative values on the second axis, thus towards lower values of farmer identity and social relations in agriculture (Figure 31 Panel A), and towards positive values on the third axis, that is towards less free time (i.e. less flexibility, fewer holidays and free days) (Figure 31 Panel C). Haymilk farms are only slightly shifted towards positive values on the first axis, which means towards lower satisfaction levels, and higher stress levels (Figure 31 Panel B). These results mean that on average organic dairy farmers seem to be less likely to identify as a farmer and to be less involved in classical agricultural relationships. Then, on average, organic dairy farmers – or a part of them – are characterised by less free time. Farmers in dairy haymilk farms, on average, seem to be broadly less satisfied and/or more stressed with their working conditions, maybe due to the complexity of managing hay crops and the burden of drought.

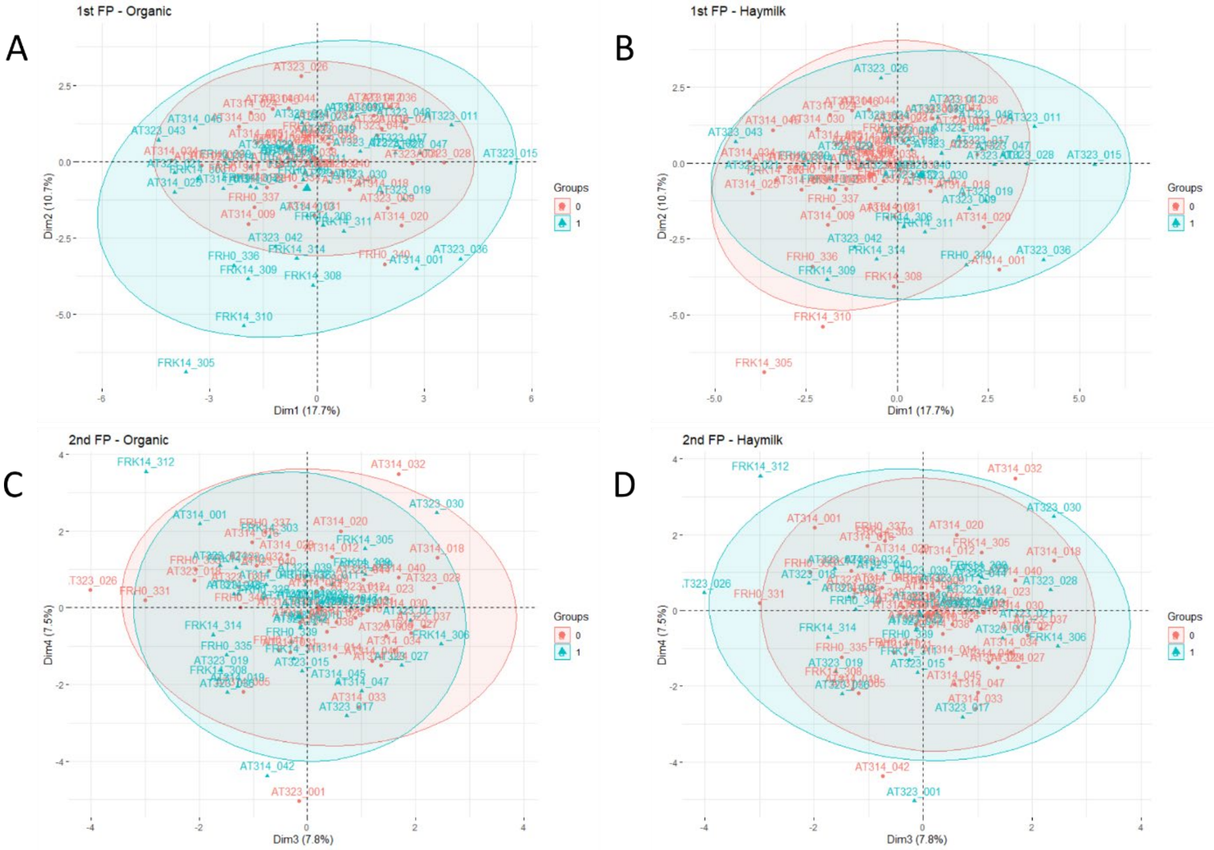


Figure 31. Projection of indicators of organic farms and haymilk farms on the two first factorial plans (FP)

When looking at individual scores (Figure 32), these patterns of working conditions are mostly due to differences between case study areas, and whether specific degrees of ecological approaches are present within one or several regions. First of all, lower scores on the second axis for organic farms (i.e. lower values of farmer identity and social relations) are mostly due to very low value in France Puy-de-Dôme farms. These lower scores on the second axis can also be shown within regions, particularly with lower values in organic farms in Austria Steyr-Kirchdorf and in organic haymilk farms in Austria Salzburg und Umgebung compared to conventional farms (Figure 32 Panel B). On the third axis (i.e. less free time), beyond strong differences between case study areas, results show significantly lower values in organic farms in Austria Steyr-Kirchdorf compared to conventional farms (Figure 32 Panel C). Finally, higher scores on the first axis can be shown for haymilk farms within France Puy-de-Dôme regions, and to a lesser extent in Austria Salzburg und Umgebung, especially for conventional farms (Figure 32 Panel A).

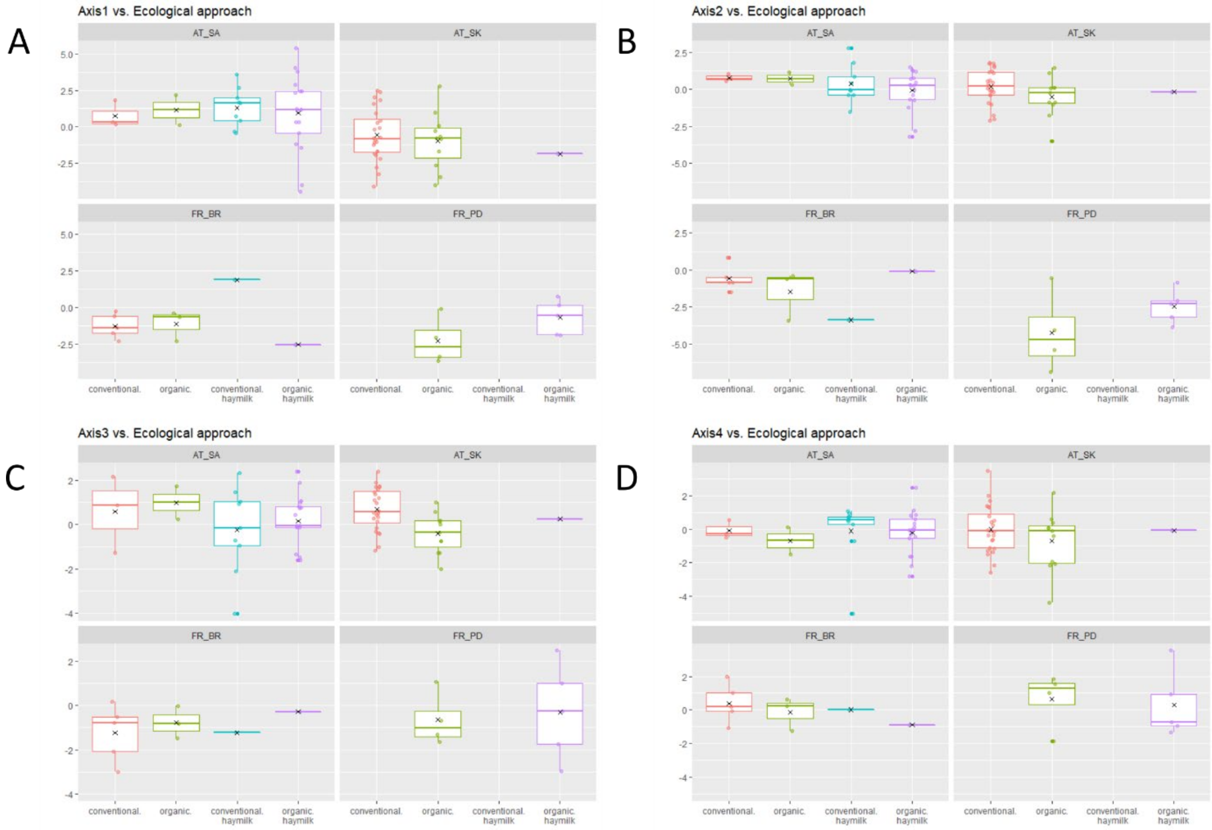


Figure 32. PCA scores vs. degree of ecological approaches for the 4 first axes

5.3.2.3.3.3 Relation between workforce composition (gender and hired workers) and working conditions indicators

Similar representations are highlighted for some indicators of the workforce composition, such as the gender of the farmer (gender), the number of family workers strictly higher than 2 or not (more than 2 family workers), and the presence of hired workers or not (hired). Results show slightly lower scores for women farm managers on the first (Figure 33) and the fourth axes (Figure 33 Panel D), meaning respectively, on average, slightly higher levels of satisfaction and more workload. Results also show higher scores for smaller family workforce (fewer than 2 workers) on the first (Figure 33 Panel B) and the third axes (Figure 33 Panel E), meaning firstly lower levels of satisfaction or more stress, and secondly less free time. Finally, lower scores on the first axis for farms with hired workers are noticed (Figure 33 Panel C), meaning higher satisfaction levels in the farm's hired workers, on average. Although subtle, these patterns can be also found within most regions (Figure 34). For example, lower levels on the first axis (meaning higher satisfaction levels) can be noticed for farms managed by women within all regions, and especially in Austria Steyr-Kirchdorf and France Puy-de-Dôme regions (Figure 34 Panel A).

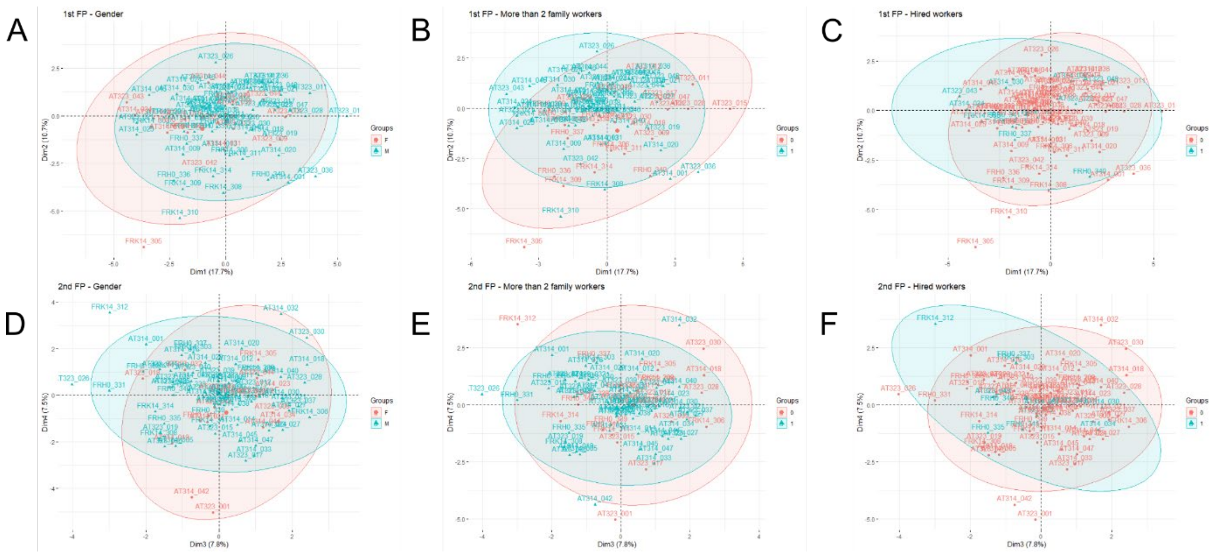


Figure 33. Projection of indicators of farmer's gender (A&D) (women in blue, men in red), workforce with more than two family workers (B&E) (more than 2 family workers, fewer than 2 family workers in red), and farms with hired workers (C&F) (workforce with hired workers in blue, workforce without hired workers in red) on the two first factorial plans (FP)

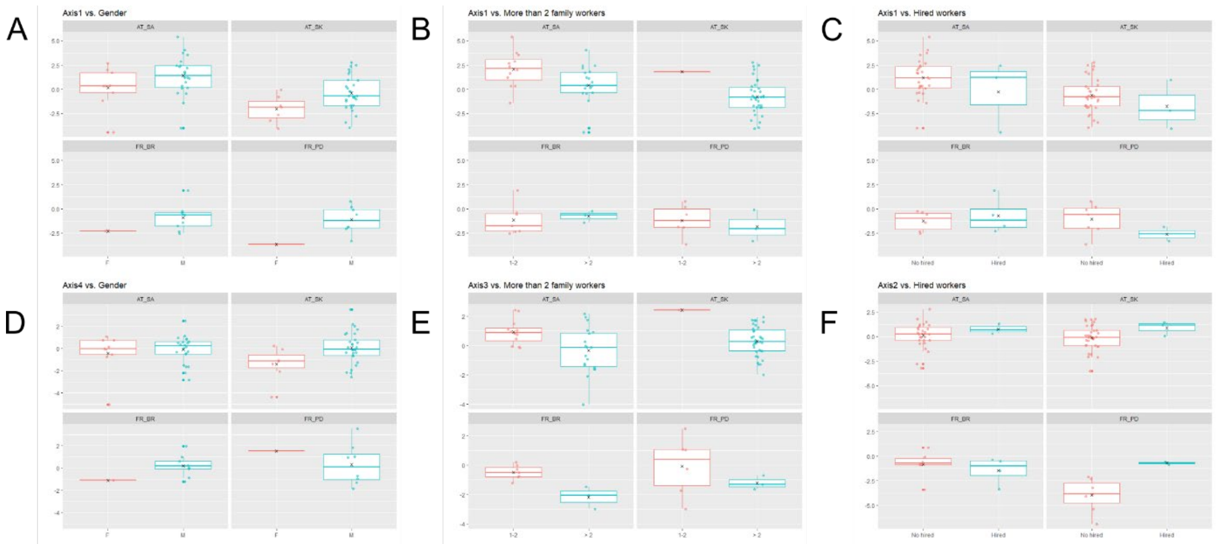


Figure 34. PCA scores vs. farmer's gender (A = Axis1 & D = Axis 4) (women in blue, men in red), workforce with more than two family workers (B = Axis 1 & E = Axis 3) (more than 2 family workers, fewer than 2 family workers in red) and farms with hired workers (C = Axis 1 & F = Axis 2) (workforce with hired workers in blue, workforce without hired workers in red) on the two first factorial plans (FP)

5.3.2.4 Discussion and conclusion

Our results show no strong relation between the degree of uptake of ecological approaches and our indicators of on-farm working conditions in dairy farms. However, relations between some indicators of on-farm working conditions and the degree of ecological approaches were highlighted. In conventional dairy farms, on average, we show that the average work duration for the family workforce is higher and that farmers indicated lower satisfaction with their working conditions. In organic farms, on average, farmers felt that work organisation was more complex with the implementation of ecological practices (for example more tasks to perform at a specific moment in time, more interactions between the different farm activities, difficulties to anticipate, etc.) and that to pilot the system was also more complex (farmers had to change the way they observe their system and their monitoring habits). This result, i.e. a more complex work in ecological dairy farms, is consistent with previous studies (Duval et al., 2021). Dairy organic farmers also considered their work as less flexible due to less free time (less holidays, days off and ability to take hours off during working hours for absences). On average organic farmers seemed to be less likely to identify as a farmer as indicated in the survey used in this study. Their self-identity seems to be different and relates to other representations than in conventional farms. But at the same time, organic farmers indicated higher levels of satisfaction to be a farmer, which is consistent with previous studies (Bouttes et al., 2020; Duval et al., 2021). Ecological farming affects on-farm working conditions but it is not the only factor in the myriad of influences on the working conditions on farm (Hostiou et al., 2020).

Differences of on-farm working conditions in dairy farms were also shown between case study areas. For example, in dairy farms in France Puy-de-Dôme, work duration is higher than in the other case studies, and farmers perceive lower levels of stress. In both French case study areas, dairy farmers said having more work at night than in both Austrian case study areas. We can conclude that on-farm working conditions on dairy farms also depend of the case study area due to production systems, practices, etc.

Working conditions also depend on the workforce composition. Women, as farm manager, indicated higher levels of satisfaction with their work but at the same time more workload. We also showed that in dairy farms with fewer than two family workers, workers indicated lower levels of satisfaction or more stress, and less free time. This result is consistent with previous studies highlighting a relation between the number of workers, farmers' expectations and their working conditions: farmers working alone or within small associations/partnerships (couple for example) have less ability to take free time in comparison with larger associations (Solano et al., 2006; Cournut et Hostiou, 2010; Béguin et al., 2021). In dairy farms hiring workers, higher satisfaction levels were noticed as shown by Béguin et al. (2021) too. These results show that workforce composition (gender, number of workers, presence of hired workers) is important to consider in order to understand and accompany the transformations of on-farm working conditions and the changes induced by the adoption of ecological practices.

6 Discussion, conclusions and policy recommendations

In light of the ambitions of the EU to achieve an ecological transition of its agricultural sector it is crucial to assess and continuously monitor (i) the uptake of main ecological approaches by farms and (ii) its associated effects on farm performance considering all sustainability dimensions.

Given these needs, here we developed a novel indicator system, namely the LIFT sustainability performance assessment, which combines the LIFT farm typology and farm performance indicators, covering all performance dimensions (economic, environmental, social/labour) jointly. Based on this indicator system, we carried out a farm sustainability performance assessment with the two main data sources in LIFT, namely FADN data and LIFT large-scale farmer survey data. These analyses covered the main farm types present in the EU (dairy farms, beef cattle farms, sheep and cattle farms, granivore farms, cereal, oilseed and protein crop farms, other field crop farms, orchards - fruits crop farms) and were executed in several countries (Austria, France, Romania, Ireland, Scotland, Poland, Hungary, United Kingdom, Italy). Additionally, we organised in-depth analyses of further specific aspects, namely (i) the extension of the developed indicator framework to bio-economic models, (ii) the integration of the consumption and provision of ecosystem services into the developed indicator system through composite agri-environmental performance (AEP) indicators derived from the body of secondary literature and region-specific stakeholder input and (iii) the analysis of farmers' social conditions in the context of an ecological transition.

6.1 Summary and discussion of results

In this section we provide an overall summary and discussion of results of the LIFT farm sustainability performance assessments in chapter 4, as well as the further in-depth analyses carried out in chapter 5. More detailed results of the respective individual analyses can be found in the respective chapters.

6.1.1 Farm sustainability performance assessment results

Our overall results show that ecological farming approaches tend to perform better than Standard farming in the environmental sustainability dimension. We also find that an increasing degree of uptake of ecological approaches, proxied by combinations of ecological farming approaches, is often related to a further increase in environmental performance. Our analyses make clear that environmental performance is shaped by farm types, in particular the differences between livestock and non-livestock farms are important: livestock farms adopting ecological approaches tend to have higher feed autonomy (i.e. are less dependent on external feed sources), lower veterinary expenses (i.e. a higher veterinary autonomy), while differences regarding fuel autonomy are less pronounced. This points towards a certain trade-off: if farms produce more of their own feed instead of buying it on input markets, this is associated with higher fuel usage to produce the feed on their agricultural land. However, since farms can also externalise the associated field work partially or fully to contractors, this higher fuel usage does not necessarily manifest in higher fuel expenses. For arable and permanent crop farms such trade-offs are less pronounced. Indeed, certain farm management practices associated with ecological approaches in the LIFT farm typology, for example no tillage, might even reduce fuel consumption if climatic and soil conditions are favourable for mechanical weed management (see also results in section 5.1 for the stepwise adoption of Conservation Agriculture based on bio-economic modelling). For the other environmental performance indicators, reflecting fertiliser and plant protection intensity as well as the presence of fallow land, there is an overall positive tendency: farms adopting ecological farming approaches have on average lower expenses for fertilisers and plant protection and a higher share of fallow land from their total UAA. Nevertheless, as clearly pointed out throughout the deliverable, the indicators measuring environmental performance are limited by the underlying data and we consequently had to rely on proxies (e.g. using expenses instead of input quantities in many cases).

With respect to the economic sustainability dimension, results are less clear. Economic performance, specifically profitability of ecological approaches, tends to be higher for some ecological approaches in specific countries regions, but in this context, it is crucial to consider the impacts of public payments and of opportunity costs of own production factors. Farms which have adopted ecological farming approaches tend to be less productive in their use of land and labour (Niedermayr et al., 2021), hinting towards less productive technologies associated with ecological approaches, a result which is confirmed by literature e.g. for organic farming (Lakner and Breustedt, 2017) or pasture-based vs. zero grazing dairy farming systems (Schulte et al., 2018). The uptake of ecological approaches also affects liquidity and financial stability of farms. Here, the uptake of ecological approaches does not seem to be associated with particular drawbacks. Farms having adopted ecological approaches tend to have a similar net worth to assets ratio and also a similar or in some cases even higher cashflow to assets ratio compared to Standard farming. However, since both indicators are ratios with total assets in the denominator, asset structure of farms may distort results. For example, if farms do not keep up with new or replacement investments into assets, they might appear as performing better in the short run due to overall lower total assets, even though they may not be viable in the long run. However, such effects are hard to disentangle in cross-sectional analyses and would require monitoring over multiple years.

As regards social/labour performance, results are also less clear. The indicators reveal differences in farm size, labour demand (total labour input and paid jobs) and labour productivity between ecological farming approaches and Standard farming. For the first two performance indicators, which also reflect farm size, there is no clear overall tendency. In some cases ecological farming approaches require less (e.g. Austrian dairy farms in section 4.1.1) or more (e.g. Italian specialist orchard – fruits farms in section 4.1.9) labour input than Standard farms, but in many cases there are no significant differences. Furthermore, it is not possible to assess solely based on those two indicators, whether the depicted labour demand reflects differences in overall farm sizes, differences in labour productivity or both. However, if total labour input is normalised by revenues, the resulting indicator reveals that in most cases, ecological farming approaches have on average lower labour productivity. This means they need more labour than Standard farms to generate a comparable monetary output (not considering public payments).

6.1.2 Results of further in-depth analyses

The in-depth analyses covered in chapter 5 provide further insights regarding specific aspects of major importance in the context of an assessment of farm sustainability performance of ecological farming.

The analysis in section 5.1 shows how the bio-economic model FarmDyn can be used to analyse a stepwise conversion to Conservation Agriculture for arable farms, dairy farms, beef farms and pig fattening farms in Germany. The detailed modelling of the conversion process in combination with more detailed performance indicators, in particular regarding environmental and labour-related performance, provides nuanced results and allows to model causal effects associated with such a transition.

The analysis in section 5.2 investigates the integration of supply of and demand for ecosystem services into the LIFT farm sustainability performance assessment. Specifically, a system is developed, where the spider web approach presented in chapter 3 can be supplemented with further composite environmental indicators, reflecting overall supply and region-specific demand of ecosystem services, associated with the different farming approaches. The results from the analysis show that such an extension enriches the spider web diagrams with additional information.

The third section (5.3) shows a detailed analysis of farmer's private social sustainability and employment in the context of an increasing uptake of ecological approaches, applied to specialist dairy farms and to dairy or cattle farms in French and Austrian European case studies. Results indicate that ecological farming affects on-farm working conditions, but it is not the only factor in the myriad of influences on the working conditions on farms. The study of the relation between workload or vacation, on the one hand, and the level of employment, on the other hand, shows that there is more variation in the number of hours worked on average on an organic farm or a Low-Input farm compared to a Standard farm or Conventional farms.

6.2 Limitations, possible extensions and policy recommendations

6.2.1 Limitations and possible extensions of the LIFT farm sustainability performance assessment

We based our methodological approach presented in chapter 3 on comparatively simple indicators, which can be calculated on basis of already existing FADN data or LIFT large-scale farmer survey data and do not require further data sources or modelling. Such a pragmatic approach has its merits (see also Frater and Franks (2013)). One main advantage is that the LIFT farm sustainability performance assessment developed here is well suited for large-scale and long-term exploratory monitoring and comparatively easy to apply for policy makers and researchers. It provides also useful information for stakeholders such as farm extension services or farmers themselves, which is however less detailed compared to other farm level sustainability assessment tools.

The presented approach can be extended to include even better indicators regarding environmental and social sustainability dimensions as soon as the FADN to FSDN transition will take place. However, a crucial aspect in this context are costs of collecting additional data in FSDN. Vrolijk and Poppe (2021) recently estimated costs of expanding the FADN data in the context of its transition to FSDN for a range of further variables related to environmental and social aspects. Their results show that additional costs would vary to a considerable degree between countries, as some countries already collect additional data on farm sustainability for national purposes. Also, in order to limit costs, they propose to decrease overall sample size slightly and in turn collect additional data only for a sub-sample. In this context it needs to be noted that FADN data is already limited by its sampling nature (Kelly et al., 2018). Firstly, smaller, non-commercial farms are underrepresented in the sample. Secondly, environmental performance is to a large extent not farm-specific, but depends on the presence, distribution and interaction of farms at the territorial level (see Matthews et al., (2022) and Van Ruymbeke et al., (2022) for more information on this topic). Thirdly, in terms of both environmental and private social performance, the sampling criteria in FADN do not consider the distribution of information regarding these performance dimensions in the farm population, meaning that FADN is potentially not representative regarding these aspects. As soon as further data becomes available in the new FSDN, the current results could be re-examined, using improved environmental indicators, either means-based indicators based on input quantities instead of expenses or even outcome-based indicators, reflecting actual environmental outcomes like biodiversity. In this context, the cross-sectional analyses presented in this deliverable could also be extended to a longitudinal monitoring over several years, which would be a very beneficial avenue for further research.

Another aspect for future research is the further development of the LIFT farm sustainability performance assessment from the current exploratory stage towards causal inference. In principle, there are different ways to accomplish this. The developed approach can for example be extended to bio-economic modelling, as presented in section 5.1. This is of particular interest, if policy makers are interested in the effects of policies which have not yet been implemented (ex-ante assessments). A potential limitation of such models is whether results based on such modelled farms can be generalised to a larger, more heterogenous farm population. Another way to move more towards causal inference is to expand the presented indicator system by applying further statistical tests and econometric methods (e.g. matching) to control for sample selection bias due to e.g. structural differences like natural site conditions or farm size between farming approaches before carrying out the farm sustainability performance assessment. Such methods were for example applied and discussed in Niedermayr et al. (2021) and could be used in further research to supplement the LIFT farm sustainability performance assessment. A further avenue for future research is to extend the LIFT farm sustainability performance assessment on a broader scale with the additional composite indicators of farm environmental performance developed in section 5.2, supplementing the spider web diagrams with additional information. This could be done based on FADN data or farm survey data.

Finally, social/labour performance remains a very crucial topic for further research in the context of an ecological transition of EU agriculture. This is underlined by the results in section 5.3, showing that ecological farming affects on-farm working conditions, but it is not the only factor in the myriad of influences on the working conditions on farms. Even when looking at specific farm types – in our case it was the example of dairy farms – there are still substantial differences between different contexts (e.g. countries/regions, adopted practices or other framework conditions). Another aspect of major relevance is a clear framing of the social sustainability dimension, which has been found to be also rather heterogenous in the scientific literature (Janker and Mann, 2020).

6.2.2 Policy recommendations

Based on these findings as well as limitations and possible extensions of our approach, we formulate the following policy recommendations:

Firstly, it is important to consider trade-offs and synergies within and between farm sustainability dimensions, in the context of an ecological transition of EU agriculture. In this deliverable, our analyses show some overall trends. We see mostly positive environmental effects and potentially negative effects on labour productivity associated with ecological approaches, while in terms of economic effects profitability is strongly linked to public payments and ownership structure of production factors (own land vs. rented land, unpaid family labour vs. paid labour, equity vs. debts). In order to encourage an ecological transition of EU farms and associated positive environmental effects, it is thus of importance to provide adequate public support to farms and encourage the development and improvement of market-based tools like public certification schemes in order to foster marketing possibilities and price-premiums for products with clear ecological benefits. Also, policy makers need to consider current trends and potential future developments in the farming sector, especially structural change, in order to ensure long-term economic viability of more ecological farms. Our results also highlight that in many cases the effects of an increasing uptake of ecological approaches are heterogenous and need to be investigated further. In response, policy measures, supporting this transition, also need to be flexible enough, so that they can be tailored to properly address region-specific needs of farms.

Secondly, solid, evidence-based policy requires sound and relevant data. The FSDN is certainly a step in the right direction, but representativeness of the underlying sample with respect to environmental, social/labour and to some extent also economic criteria needs to be improved in order to provide an accurate picture of EU agriculture based on the FSDN sample. In this context, we see the collection of further sustainability data (FSDN) only for a sub-sample of FADN farms as problematic, since our analyses based on FADN data already show that sample size can be relatively quickly a limiting factor in farm level sustainability assessments for individual farm types at the country level, especially if further econometric methods have to be applied to correct for potential sample selection bias.

Finally, besides large-scale monitoring, investigating farm sustainability performance of ecological approaches to farming in the EU should be also investigated in more detail at regional level, e.g. via living labs, operating in a regional context and integrating concurrent research and innovation processes and stakeholders to develop practical solutions for problems at the local level.

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9 Appendix

Table 24: FADN type of farming (TF8) classification of farms

TF8	Description of TF8	Grouping of TF on the basis of principal types of farming
1	Field crops	15. Specialist cereals, oilseeds and protein crops 16. General field cropping 61. Mixed cropping
2	Horticulture	21. Specialist horticulture indoor 22. Specialist horticulture outdoor 23. Other horticulture
3	Wine	35. Specialist vineyards
4	Other permanent crops	36. Specialist fruit and citrus fruit 37. Specialist olives 38. Various permanent crops combined
5	Milk	45. Specialist dairying
6	Other grazing livestock	46. Specialist cattle – rearing and fattening 47. Cattle – dairying, rearing and fattening combined 48. Sheep, goats and other grazing livestock
7	Granivores	51. Specialist pigs 52. Specialist poultry 53. Various granivores combined
8	Mixed	73. Mixed livestock, mainly grazing livestock 74. Mixed livestock, mainly granivores 83. Field crops – grazing livestock combined 84. Various crops and livestock combined

Table 25: Eurostat coefficients to calculate the number of livestock units

Type of livestock	**Code from the LIFT large-scale farmer survey questionnaire**	**Eurostat coefficient**
Dairy cows	Q31A_1	1
Cull dairy cows	Q31A_2	0.8
Calves for fattening	Q31A_3	0.7
Suckler cows	Q31A_4	0.8
Other cattle	Q31A_5	0.8
Goats (breeding females)	Q31A_6	0.1
Other goats	Q31A_7	0.1
Ewes	Q31A_8	0.1
Other sheep	Q31A_9	0.1
Breeding sows	Q31A_10	0.5
Other pigs	Q31A_11	0.3
Laying hens	Q31A_12	0.014
Other chicken	Q31A_13	0.030
Other poultry	Q31A_14	0.030