A REVIEW OF FARM LEVEL INDICATORS OF SUSTAINABILITY WITH A FOCUS ON CAP AND FADN

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ABOUT THE FLINT PROJECT

FLINT Farm Level Indicators for New Topics in Policy Evaluation.

PROJECT SUMMARY

Given the continual evolution of the CAP and the current reform that is on-going, it is now both timely and relevant to take stock of current evaluation practices and specifically focus on which indicators that are or can be employed to aid our understanding of the relative success of policy targeting. This is the means by which “to obtain an in-depth picture of the impact of the CAP at farm level”, in order “to better align the [CAP post-2013] policy to the objectives and targets of the Europe 2020 Framework”. Two precise examples are given in the tender specification document – innovation and resource efficiency – but the list by extension also covers agricultural (economic) viability and environmental sustainability. The logical platform from which to develop the suite of indicators, as proposed in FLINT, is the EU Farm Accountancy Data Network (FADN), which is the existing data infrastructure for the CAP.

FLINT will first consider existing policy measures and accompanying methodologies, such as agrienvironmental indicators per se or the Common Monitoring and Evaluation Framework (CMEF) covering the CAP as a whole; in this sense the contribution of other sources, such as the OECD, or other initiatives, such as EU strategies or MS schemes, which are related to farm-level practice and outcomes, must also be taken into account. Following the analysis of policy evaluation needs, FLINT will review the data and indicators currently available through FADN sources and will identify gaps and deficiencies in the current data availability.

The stock of variables available in the various Member State FADN datasets varies and the capacity/willingness of the various countries to collect additional data is also variable. Hence a pilot in numerous countries with different data collection methods and coming from different starting points is required. Such a pilot can only be tested effectively through on-farm data collection on farms. This pilot will provide invaluable information about the operational structure and time-frame required to collect such data and develop such indicators.

The value-added of the newly developed indicators will be tested in the analysis of a number of policy analysis scenarios. Hence, FLINT will make a contribution to enhancing the policy analysis capabilities for the CAP policy assessment, useful for the Commission within an operational perspective covering the entire EU.

The objective of FLINT is to establish a tested data-infrastructure with up to date farm level indicators for the monitoring and evaluation of the CAP and contribute to a better targeting of CAP and other related policy measures.

Specifically the objectives of FLINT are to:

1. Assess current and future policy evaluation needs
2. Review the data available to facilitate policy evaluation and identify any data gaps
3. Pilot the collection of additional farm level data through the FADN under 3 different data
4. collection administrative environments.
5. Test the farm level indicators for policy evaluations
6. Make recommendations about the future data collection in the EU

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AES	Agri-Environmental Scheme
AFI	Agri-Environmental Footprint Index
AHS	Animal Health Strategy
AWU	Annual Working Unit
C	Carbon
CAP	Common Agricultural Policy
CH_4	Methane
CO_2	Carbon dioxide
CSS	Countryside Stewardship Scheme
DLG	Deutsche Landwirtschaftsgesellschaft
DPSIR	Driving-force/Pressure/State/Impact/Response
EDAPPA	Évaluation de la Durabilité pour l'Accompagnement des Porteurs de Projet Agricole
EEA	European Environment Agency
EEC	European Economic Community
EICD	European Interpolated Climate Data
EIP	European Innovation Partnerships
ESDB	European Soil Database
EU	European Union
FAO	Food and Agriculture Organisation
FADN	Farm Accountancy Data Network
FBI	Farmland Birds Index
FBS	Farm Busines Survey
FLINT	Farm Level Indicators for New Topics in Policy Evaluation
FSRA	Farm Safety Risk Assessment
FSS	Farm Safety Statement
GHG	GreenHouse Gases
GIS	Geographic Information System
HNV	High Nature Value
ICT	Information and Communications Technology
IDEA	Indicateurs de Durabilité des Exploitations Agricoles
IFOAM	International Federation of Organic Agriculture Movements
IOAs	Input Output Accounting systems
INPACT	INitiatives Pour une Agriculture Citoyenne et Territoriale

IPCC	Intergovernmental Panel on Climate Change
K	Potassium
KUL	Kriterien Umweltverträglicher Landbewirtschaftung
KSNL	KriterienSystem Nachhaltige Landwirtschaft
LAG	Local Action Group
LCA	Life Cycle Analysis
LPIS	Land Parcel Identification System
MAVT	Multi Attribute Value Theory
MCA	Multi-Criteria Analysis
MCDM	Multicriteria Decision Making Model
MESMIS	Marco para la Evaluación de Sistemas de Manejo de recursos naturales incorporando Indicadores de Sustentabilidad
MWD	Mean Weight Diameter
N	Nitrogen
NACAH	National Assessment Catalogue for Animal Husbandry
NFS	National Farm Survey
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
OECD	Organisation for Economic Co-operation and Development
P	Phosphorus
PLAGE	Plateforme d'évaluation Agri-Environnementale
PSR	Pressure/State/Response
R&D	Research and Development
RDP	Rural Development Programme
RISE	Response-Inducing Sustainability Evaluation
SAFA	Sustainability Assessment of Food and Agriculture systems
SDAS	Sustainable Dairy Assurance Scheme
SDI	Sustainable Development Indicators
SEAMLESS	System for Environmental and Agricultural Modelling; Linking European Science and Society
SIA	Sustainable Impact Assessment
SIRIS	Système d'Intégration des Risques par Interaction des Scores
SROI	Social Return on Investment
TFP	Total Factor Productivity
UAA	Utilised Agricultural Area
UCD	University College Dublin

EXECUTIVE SUMMARY

The agricultural sector has a strong role to play in achieving the goal of 'Sustainable growth: promoting a more resource efficient, greener and more competitive economy' listed in the Europe 2020 strategy. From a policy perspective, the Common Agricultural Policy (CAP) is likely to be a driver of sustainability as it has progressively introduced more environmental and social concerns within the various CAP reforms.

In this context, we provide here a review of sustainable indicators for agriculture. Not only do we review the international literature, but we also provide a synthesis of several national initiatives of farm sustainability assessment in the nine partner countries of the FLINT project: Finland, France, Germany, Greece, Hungary, Ireland, the Netherlands, Poland, and Spain.

Although no consensus has yet been reached in terms of the operational meaning of sustainability, we consider here that sustainable development aims at preserving or enlarging our capital stock which includes the economic capital, the social capital and the natural capital. The review particularly focuses on indicators at the farm level. The farm level is a relevant scale at which to assess sustainability, as farm management decisions may directly impact farm sustainability. Further, the farm level approach increases the spatial accuracy, which is highlighted as a main challenge in other quantification approaches. Finally, the farm is the legal unit for legislation purposes and the economic unit that receives payments for externalities within the CAP framework and as such is the level at which most policies are directed.

The typology of sustainability indicators generally follows the three sustainability pillars: environmental indicators; economic indicators; social indicators. The literature review shows that the environmental pillar has undergone an 'indicator explosion', due to the multitude of themes covered (e.g. greenhouse gas emissions, biodiversity, water quality, resource efficiency, soil conservation...) and the attention given by society to this dimension of sustainability. Due to the complexity of environmental issues, many of these indicators are composite in nature, leading to uncertainty over whether individual or composite indicators are preferable. By contrast, economic indicators relate to a relatively small number of themes (profitability, productivity, autonomy, resilience) and were not generally developed as indicators measuring economic sustainability. Social indicators cover two types of themes: sustainability relating to the farm community (such as well-being and health) and sustainability relating to society as a whole (such as the quality of life in rural areas). The measurement of these indicators is challenging as they are often qualitative and subjective. Thus, any methodology used to measure them should be fully clear and transparent.

Careful attention should be given to the selection of indicators, since the data measured will influence the outcome of that indicator and therefore the outcome of the analysis. Selection should be made keeping in mind that sustainability assessments should be validated, credible and reproducible. Several selection criteria are provided in the literature, such as representativeness, transferability, adaptability, and measurability at an acceptable cost. In addition, the literature recommends using a set of indicators that can jointly provide an answer rather than one single indicator.

The national initiatives in the nine countries partners of the FLINT project are diverse in relation to the aims, methods and data utilised. Three main aims are covered: farm decision support; comparison of farms; evaluation of policies. Various methods are used such as decision support systems or multicriteria decision making. In relation to data, few initiatives use the European-wide Farm Accountancy Data Network (FADN) data. Where FADN data are used, they are often complemented with additional data collected from farmer surveys or from stakeholders in the value chain. Overall, the national initiatives provide ideas for original and relevant indicators for themes that are not currently covered by FADN, and give some feedback about the difficulties of implementing sustainability assessments using FADN data.

In this report, recommendations are made for the FLINT project in view of selecting indicators that can facilitate policy analysis, in terms of indicator design, involvement of stakeholders and in particular, convincing farmers and authorities of the benefits of data collection and the dissemination of results.

1 INTRODUCTION

Growing environmental concerns have prompted governments to promote sustainable choices and actions in the economy, allowing the preservation, or preventing the deterioration of the environment whilst also maintaining competitiveness. In the European Union (EU) the European Commission has for example included three priorities in its Europe 2020 strategy, one of them being 'Sustainable growth: promoting a more resource efficient, greener and more competitive economy' (European Commission, 2010a)

The agricultural sector has a strong role to play in achieving this goal. The Common Agricultural Policy (CAP), originally strongly focused on food security the 'optimum utilisation of the factors of production' (Westbury *et al*., 2011) and a fair standard of living for farmers, has progressively introduced more environmental concerns within the various CAP reforms. This led to the adoption of a strategy for integrating the environmental dimension into the CAP by the European Council in Helsinki (December 1999). This Integration Strategy stressed the key role of Member States in the implementation of integration measures and asked for the development of appropriate agri-environmental indicators to monitor such integration. The greening of the CAP continues within its 2013 reform.

Although receiving less attention, social concerns are also being integrated. In their report about the provision of public goods by agriculture, Cooper *et al*. (2009) identify rural vitality and farm animal welfare and health as social public goods. The authors stress the importance of social vitality, with agriculture contributing to the achievement of a 'critical social mass [that] is important to sustain the services and infrastructure relied upon by rural populations, as well as serving as a repository of skills and knowledge which help to keep alive rural cultures and traditions'. During the preparation of the 2013 CAP reform, the European Commission also recognised the positive role of agriculture in rural areas in delivering 'multiple economic, social, environmental and territorial benefits' (European Commission, 2010b). The new CAP hence aims at promoting 'a balanced territorial development of rural areas throughout the EU by empowering people in local areas, building capacity and improving local conditions and links between rural and urban areas' (European Commission, 2010b).

As summarised by Pretty *et al*. (2010) the goal is 'no longer simply to maximise productivity but to optimise across a far more complex landscape of production, rural development, environmental, social justice and food consumption outcomes'.

Also, retail and agro-food sectors, both nationally and internationally, have increasing demands on the sustainability of agricultural production. These pressures from government and from private interests have resulted in the existence of a wide set of initiatives for the certification/labelling/monitoring of sustainable production and/or products along with an equally wide set of sustainability indicator frameworks. This multiplicity of international and national initiatives poses some important methodological issues. Such as:

- **In terms of definition:** what are the multiple objectives and concepts used in the construction of sustainable development indicators in agriculture?

The underlying question is whether all sustainability pillars are similarly considered. Sustainability indicators for the farming sector should in theory take into account the multi-functionality of agriculture.

- **In terms of operationalisation:** what is the best process for developing an indicator?

For example Boone *et al*. (2012) identify nine steps in the development of an indicator: (1) choice of goals, (2) choice of level of scale, (3) specification of conditions and functional and user demands, (4) choice of issues\themes to focus on, (5) choice of indicators, target levels and measuring techniques, (6) choice of assessment methods and aggregation, (7) choice of presentation of performance indicators, (8) choice of data sources, (9) choice of points for improvement. This complex process implies that many methodological questions are raised.

- **In terms of measurement:** is there a gap between the availability of data from farm management and accounting systems and the information needed by theoretical indicator frameworks?

The actual measurement of indicators is often difficult due to limitations on data availability, or measurements are carried out at a small scale within a pilot setting. Policy analyses and practical use require that indicators can be measured at a larger scale and a balanced trade-off can be achieved between theoretical and practical aspects.

- **In terms of harmonisation:** is there a way to harmonise of indicators across countries?

Many different initiatives exist at national level. To some extent these initiatives address the same issues, but there are subtle and less subtle differences in the definition, scope and level of detail. Harmonisation would allow for international comparison and benchmarking and more consistent policy evaluation as well as greater consistency in management decisions in international food companies.

It is in this context that the FP7 KBBE.2013.1.4-12 research project FLINT ('Farm Level Indicators for New Topics in Policy Evaluation') was placed, concerning the research theme 'Support to agricultural policy – Establishing and testing farm-level indicators'. In this project we provide a review of sustainable indicators in agriculture. Not only do we review the existing literature, but we also provide a synthesis of several national initiatives of farm sustainability assessment in the nine partner countries of the FLINT project: Finland, France, Germany, Greece, Hungary, Ireland, the Netherlands, Poland, and Spain.

The review particularly focuses on (i) indicators at the farm level, (ii) indicators that can facilitate policy analysis, (iii) the link with the European-wide Farm Accountancy Data Network (FADN). FADN 'is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy' and 'consists of an annual survey carried out by the Member States of the European Union' (European Commission, 2014). Harmonised accountancy data for a sample of farms in each Member State (about 80,000 farms EU-wide) are collected each year and stored in the European FADN database. While FADN was originally developed in the 60's to monitor farm income, the challenge is now to integrate data that can allow for the measurement of farm sustainability performance in a global context.

The report is organised as follows. Section 2 gives a broad brush picture of sustainability, the concept and its measurement. Section 3 reviews the literature on indicators grouped according to the classic categorisation based on the three sustainable development pillars (environment, economic and social), and gives a critical overview of the development of composite indicators, of the selection process of indicators and of the necessary data collection. Section 4 is devoted to the description of national initiatives in the nine EU countries listed above, according to three main aims of the development of indicators: to support farms' decisions, to compare farming systems, to evaluate policies. Section 5 proposes some specific discussion points relating to the dissemination of indicators, the multi-dimensional nature of sustainability, and the use of FADN to evaluate the CAP in terms of sustainability. Section 6 concludes and draws recommendations regarding the research on sustainability indicators (e.g. themes on which more research is needed), and regarding the FLINT project in terms of the participation of stakeholders, the dissemination of indicators, the sample to select, and the most efficient way of collecting indicators. It should be noted that, for consistency reasons, only scientific or extension initiatives are considered here; initiatives from the retail and agro-food sectors are not reviewed in this report but will be considered in FLINT Deliverable 1.4.

2 MEASURING SUSTAINABILITY

This section discusses the definition of sustainability which is a wide concept that incorporates several dimensions and objectives. The section also explains how to measure sustainability, through indicators measuring various sustainability issues at different scales.

2.1 The concept of sustainability

The concept of 'sustainable development' was introduced by the 'Brundtland report' in the late 1980's (WCED, 1987). The report attempts to reach a general consensus on the perception of the concept defining sustainable development as an 'economically viable, environmentally sound and socially acceptable development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. This concept of sustainable development spread extremely rapidly, and only two years after the publication of the Brundtland report, Pezzey (1989) recorded more than 60 different definitions of the concept.

However, the widespread adoption of the concept of sustainable development became really popular following the Rio Earth Summit in 1992 (Woodhouse *et al*., 2000), and in the meantime Toman (1992) discussed the difficulties faced in precisely defining sustainability. Indeed, some 300 definitions of the word sustainability were identified by Dobson (1996) only four years after the Rio Earth Summit.

From the above it is easily understandable that no consensus has yet been reached in terms of the operational meaning of sustainability, despite its intuitive perception (Park and Seaton, 1996). Nevertheless, one may agree with Welford's (1995 and 1996) viewpoint stressing the importance of jointly addressing three closely connected dimensions: (i) the environmental dimension, that is to be considered as an integrated part of the economy and not as a free good; (ii) equity, in terms of access to and consumption of resources between rich and poor countries and on a local and global level; and (iii) futurity, considering that endangering the ability for future generations to meet their future demand is not acceptable.

From an economic point of view, sustainable development aims at preserving or enlarging our capital stock which includes (i) the economic capital (e.g. savings, infrastructures, etc), (ii) the social capital (e.g. health, culture, education, etc), and (iii) the natural capital (e.g. air, water, landscape, biodiversity, etc) (Pingault, 2007).

Since then, 'sustainability', 'sustainable development', or 'sustainable agriculture' have often been used as catch-phrases with different interpretations by individuals, organisations or institutions to qualify actions undertaken to assess the impacts of human activities on the environment.

Nevertheless, the concept is increasingly prominent in current agricultural policy debates (Dillon *et al*., 2010). New principles have been added to its definition such as governance, solidarity, transmission capital, local knowledge (Antoine *et al*., 2001; AFNOR, 2003; Mancebo, 2006) and more recently innovation (Hennessy *et al*., 2013).

Since the last CAP reform, the principle of sustainability is integrated into the objectives of the policy (Dillon *et al*., 2010), however the application of this concept to agriculture has faced a multiplicity of definitions. Efforts have been made to produce an integrated definition of this term: the application of

the concept of sustainable development in agriculture raises interest both for the sustainability of the agricultural system itself and its contribution to sustainable development (Bockstaller *et al*., 2009a).

It thus incorporates the principal dimensions and objectives of sustainability when sustainable practices are implemented on a given agricultural system (Schaller, 1993; Vereijken, 1997; den Biggelaar and Suvedi, 2000; Gafsi *et al*., 2006).

Viewed from the perspective of the farm, the contribution to sustainable agriculture is threefold:

- the production of goods and services (economic function) ;
- the management of natural resources (ecological function) ;
- the contribution to rural dynamics (social function).

The harmonious combination of these three interconnected functions constitutes the background of sustainable agriculture. To move towards sustainability, it is necessary to progress simultaneously in all three dimensions. Besides, since these three functions are linked, the improvement (or maintenance) of the economic performance alone is meaningless if it does not come together with an improvement (or maintenance) of environmental and social performances: the economic profitability of a production system is not sufficient to compensate unbearable ecological and social costs (Vilain, 1997).

2.2 Measuring sustainability

Two types of sustainability assessment should be distinguished: *ex-post* assessment addressing an actual system on the one hand, and *ex-ante* assessment addressing a potential or virtual system on the other hand. While *ex-post* assessment should/could be used to evaluate or diagnose a given policy (provided that mechanisms through which policy influences sustainability are clearly defined and understood), *ex-ante* assessment is less frequently implemented and could be used to define optimal policies or to rank optimal options of a given policy. In the following, the focus is placed (unless noted otherwise) on *ex-post* assessment.

Assessing the sustainability of agricultural systems is a key issue for the implementation of policies and practices aimed at revealing sustainable forms of land use (Neher, 1992; Sulser *et al*., 2001; Pacini *et al*., 2003) and a key step in supporting the development of sustainable farming systems (Sadok *et al*., 2008). However, if they are to be realistic and effective, such assessments must handle the complexity/ambiguity of the concept of sustainability, whilst taking personal and subjective views concerning the relative importance of priorities into account (Dent *et al*., 1995; Park and Seaton, 1996; Andreoli and Tellarini, 2000).

The assessment of sustainability is mosly based on multi-criteria decision-aid methods (e.g. Sadok *et al*., 2008; Manos *et al*., 2013), and some approaches have resulted in prototype sustainable solutions in the field (Rossing *et al*., 1997; Zander and Kächele, 1999; Loyce *et al*., 2002; Dogliotti *et al*., 2005).

Vilain (1997) identifies two methods to guide agricultural practices towards increased sustainability: (i) the method of specifications, consisting of codifying favourable practices and reporting unsustainable practices (e.g. through charters and diagrams); and (ii) the measurement of (progress towards) sustainability using indicators.

In practice, sustainability assessment generally involves dividing the previously mentioned three dimensions of sustainability into various issues of concern (Gómez-Limón and Sanchez-Fernandez, 2010), called objectives, attributes, or themes (Alkan Olsson *et al*., 2009a; Binder *et al*., 2010; van Calker *et al*., 2005; van der Werf and Petit, 2002), and assessing these objectives using indicators (van der Werf and Petit, 2002; Bockstaller *et al*., 2009a).

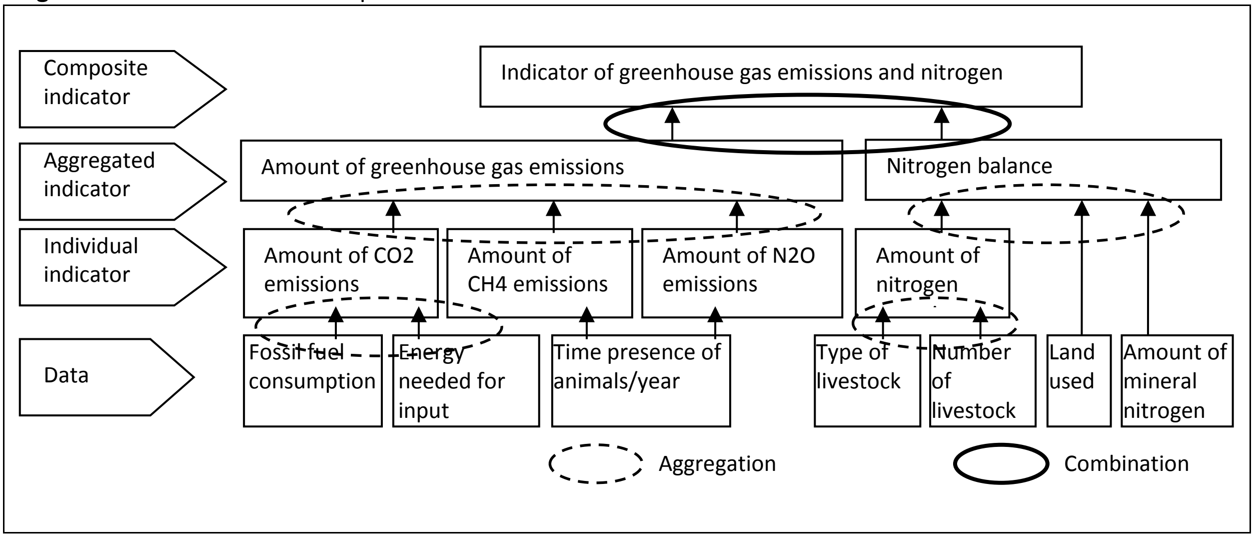
Whether of a quantitative or qualitative nature, indicators are defined as quantities of very diverse nature (data, calculations, observations, measurements), which provide information about variables

that are more difficult to gain access to, or more complex systems. Since 1997, the OECD publishes its 'Environmental Indicators for Agriculture' and defines an indicator as 'a representative measure (summary form) involving raw data on a phenomenon that is important for policy makers (OECD, 2001). Defined as such, indicators are intended to assist users in their action (decision making, building agenda, modelling, etc) providing information to policy makers and society, sharing knowledge and building consensus among stakeholders. Nevertheless, while policies obviously need indicators, the latter should be used and interpreted cautiously as they are not intended to constitute a policy *per se*.

In practice, agricultural sustainability indicators are quantifiable and measurable attributes of a system that are judged to be related to its sustainability. They are 'statistical constructs which support decision-making by revealing trends in data' (Dillon *et al*., 2014). Thus, the last fifteen years have seen an international proliferation of assessment methods based on sets of indicators to assess various issues under one or more dimensions of sustainability (over 200 identified, see Rosnoblet *et al*., 2006) or to evaluate a specific problem (Bockstaller *et al*., 2009a).

Based on this literature review, we technically define indicators as in Gras *et al*. (1989) as variables (qualitative/quantitative data observed, measured or calculated from other variables) which supply information on other variables (criteria) which are more difficult to get access to, and can be used as a benchmark to make a decision, while we understand methods as procedures for the assessment of sustainability through the definition and the calculation of indicators. Besides, placing the focus at farm level, various levels of indicators can be considered on which clarifications are necessary. While individual indicators are built from raw/input data, these individual indicators may be aggregated to form aggregated indicators. Composite indicators are then the combination of individual or/and aggregated indicators representing different dimensions of sustainability (Saisana and Tarantola, 2002; Nardo *et al*., 2005). Figure 1 illustrates these concepts.

Figure 1: From raw data to composite indicators: an illustration



Source: the authors

In concluding our remarks on measuring agricultural sustainability, we refer to Figuières *et al*. (2007) who suggest that assessing the sustainability of a given sector (e.g. agriculture) without considering the rest of the economy is not relevant. The authors also raise the issue of assessing sustainability through the analysis of single (or synthetic) scores of sustainability built on an aggregation or weighting basis, indicating that doing so means that the different components of sustainability (e.g. environmental, economic, social) are implicitly acknowledged as fully substitutable. In order to eliminate this highly questionable issue the authors recommend favouring assessment methods based on the analysis of three scores, one for each sustainability component.

2.3 Various scales of sustainability

Sustainability can be screened at different scales, such as global, local, sector-specific, individual (farm or household) and plot. The issue of scaling can also be related to spatial scales and to temporal scales. The scale through which agricultural sustainability is analysed depends on the objectives being pursued and the concerns being addressed (e.g. see Hrubovcak *et al*., 1999). For instance, issues such as global warming arise at the global level as all countries share the same atmosphere. This calls for monitoring and policy responses at this level. To that end, a wide range of international sustainability indicators exist (e.g. Millennium Development Goals Indicators, EU Sustainable Development Indicators (SDI), OECD Green Growth Indicators and agri-environmental indicators) (Cooper *et al*., 2009). These 'macro' indicators are measured at the global or national level. Other questions may arise at the 'meso' scale, such as for instance the case of water quality that must be analysed at the watershed level since the improvement of the quality of a water body cannot compensate pollution in another watershed (Pingault, 2007). Thus 'meso' indicators are defined to provide relevant information at the regional or local level.

Nevertheless, an action undertaken at a given level can help address one or more goals, sometimes defined at different levels. The calculation of nitrogen balance makes sense at the 'micro' level of the individual farm, where fertilisation strategies are defined. But the information gathered on nitrogen fertilisation can contribute both to improving the water quality at the 'meso' level and the reduction of greenhouse gas (GHG) emissions ('macro' level) (Pingault, 2007).

This makes the individual level the most important spatial unit in terms of implementation of sustainable actions, as farmers operate at this scale and management decisions can be directly implemented. Further, the farm level approach increases the spatial accuracy, which is pinpointed as a main challenge in other quantification approaches (e.g. Burkhard *et al*., 2009). Finally, the farm is the legal unit for legislation purposes and the economic unit that receives payments for externalities within the CAP framework and as such the predominant level at which most policies are directed (OECD, 2001).

The international initiative 'Sustainability Assessment of Food and Agriculture systems' (SAFA) by the Food and Agriculture Organisation (FAO) is also applied at the individual level. The initiative has developed 118 indicators of four dimensions of sustainability (good governance, environmental integrity, economic resilience and social well-being) (FAO, 2013b). They can be applied to all stakeholders in the food and agriculture supply chains, that is to say 'companies or small-scale producers, involved with the production, processing, distribution and marketing of goods' (FAO, 2013a).

Difficulties in measuring farm-level sustainability remain, (mainly due to data limitations) and some argue that precise measurement is impossible as it is site-specific and dynamic (Dillon *et al*., 2014). In relation to farm-level data at the European scale, FADN is a good starting point as data are collected on a yearly basis although some information is collected over shorter timescales (e.g. input/output prices, climatic events) or over longer timescales (e.g. changes in farm structures, farmland habitats). Besides, in its document on the common evaluation framework of rural development programmes for the period 2007-2013, the European Commission (2010c) recommends data collection at an individual (i.e. farm) level. The document also notes however, that data collected by asking farmers directly for economic information may be less robust than invoice verified data. This presents a significant challenge for the FLINT project to enrich the FADN database with good quality data on all sustainability aspects. Meanwhile, within the context of agricultural sustainability assessment Figuières *et al*. (2007) suggest that not only the farm-level should be considered but also the existing interactions among farms and their local/global environment. In addition, according to Sadok *et al*. (2008), 'knowledge and research from relevant disciplines must be integrated while handling a mixture of multiple long-term, short-term, interacting and potentially conflicting goals, depending on the scale on which sustainability is considered (farm, landscape, region, nation, group of nations or global)'.

In conclusion, there is not one static interpretation of sustainable development. Its interpretations evolve continuously depending on research progress and view as well as the focus of analysis. The distinction of economic, environmental (or ecological) and social dimensions is widely used and often

each dimension is underpinned with sub-themes and suitable indicators. The indicators used may cover the whole range from raw data (amount of nitrogen fertilizer) to composite indicators (GHG-emissions) depending on the sustainability topic at hand.

The generation of sustainability indexes, e.g. a sustainability index for each dimension, are useful to communicate the overall sustainability direction of individual indicator results, while trading off transparency and putting considerable challenges on aggregation methods. A combined presentation of both sustainability indexes and indicator results, and a transparent description of indicator calculations and aggregation methods, are therefore recommended.

Actions affecting sustainability are carried out by individuals. This speaks for a monitoring of effects at the level of the individual (e.g. the farmer). However, results from such monitoring should not be interpreted in isolation but together with 'macro' and 'meso' results from higher spatial scales, e.g. for administrative units as provided by the Common Monitoring and Evaluation Framework, and whole economy results in order to come to overall conclusions with regard to sustainability.

3 DESIGN AND SELECTION OF SUSTAINABLE FARM LEVEL INDICATORS

3.1 Typology of sustainability indicators

Diverse theoretical approaches concerning the roles, challenges and outcomes of indicators for sustainable development have developed over time. Moreno-Pires and Fidélis (2012) described the traditional opposing groups of sustainability indicators: (i) the 'technical' or 'expert-oriented' approach (e.g. Bossel, 1999; Ramos *et al*., 2004; Tasser *et al*., 2008) in which indicators are used for planning, decision making, and policy evaluation; and (ii) the 'participatory' or 'citizen-oriented' approach (e.g. Innes and Booher, 2000; Gahin *et al*., 2003; Fraser *et al*., 2006) in which impacts of sustainability indicators are viewed at the community level. The first group of indicators is considered here.

Bockstaller *et al*. (2007) identify two groups of approaches which are distinguished by their concept of sustainability: (i) the goal-oriented approach based on a set of themes and objectives addressing abiotic (air, soil, water) and biotic (species, ecosystem) environmental components, functions or impacts; and (ii) the property-oriented approach based on systemic properties e.g. adaptability, security.

Here we use the classic typology based on the three sustainability pillars: environmental indicators; economic indicators; social indicators.

3.1.1 Environmental indicators

The 'indicator explosion' (Riley, 2001) is particularly evident for the environmental dimension. For the last 20 years, a plethora of initiatives have been proposed with a very broad array of indicators (Rosnoblet *et al*., 2006). Bockstaller *et al*. (2008a) explain this in terms of 'the growing concern for environmental issues and sustainability'. Literature reviews are available for sustainability assessment methods based on indicators (van der Werf and Petit, 2002; Géniaux *et al*., 2009; Singh *et al*., 2009), for some specific themes, like pesticides (Reus *et al*., 2002; Devillers *et al*., 2005; Feola *et al*., 2011), for nitrogen (CORPEN, 2006; Buczko and Kuchenbuch, 2010) or biodiversity (Dennis *et al*., 2009; Bockstaller *et al*., 2011). Furthermore Bockstaller *et al*. (2009a) propose a review of assessment methods based on indicators. Other authors propose various classification systems of indicators. The goal of this section is to provide an overview of different indicator classifications.

3.1.1.1 Aggregation level

Girardin *et al*. (1999) distinguish <u>simple indicators</u> (indicators that are based on one measured or modelled variable), and <u>composite indicators</u> (indicators resulting from the aggregation of several variables). However, indicators based on a model output also result from an aggregation of several input variables and could be considered as composite indicators. These are defined by Nardo *et al*. (2005) as 'the mathematical combination of individual indicators that represent different dimensions of a concept. The construction of composite indicators involves stages where subjective judgement has to be made: the selection of indicators, the treatment of missing values, the choice of aggregation model, the weights of the indicators, etc'. This definition refers to different dimensions. If the definition is strictly

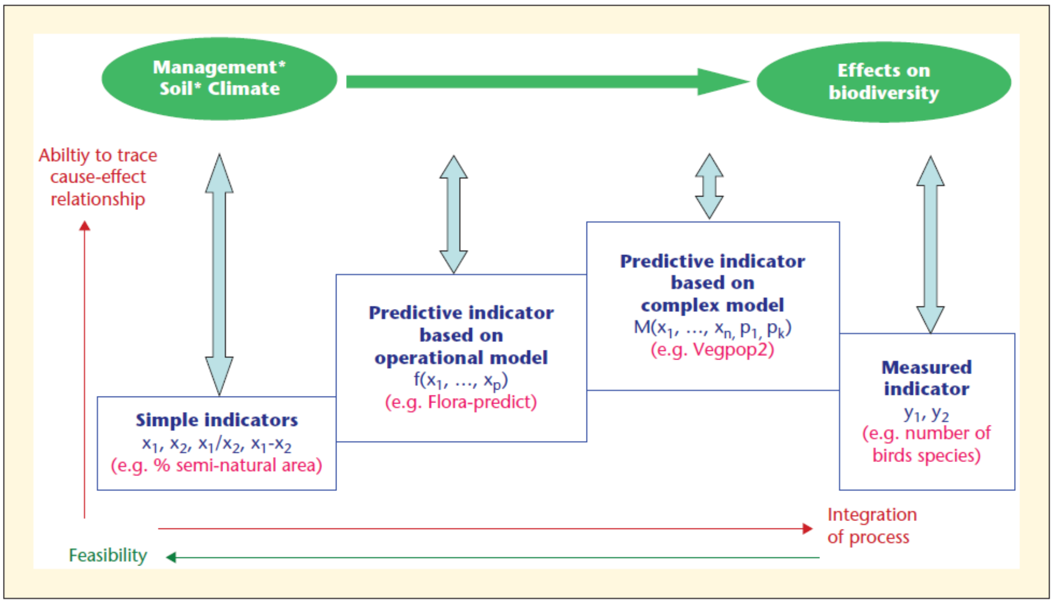
applied, it excludes indicators resulting from the arithmetical combination (addition, product) of variables of the same dimension, for example nitrogen budget or percentage of semi-natural area. Neither are impact indicators of Life Cycle Analysis (LCA) (e.g. global warming potential) strictly composite indicators. They are based on the aggregation of several emissions or resource consumption transformed by means of impact factors based on scientific data (e.g. emissions of GHG are transformed to CO_2 equivalents). As explained previously, referring to the Nardo *et al*. (2005) definition, we suggest reserving the term composite for the combination of indicators addressing different environmental themes, like water quality and biodiversity, for which a simple addition is not possible. Furthermore, composite indicators may also involve the aggregation of indicators across the three dimensions of sustainability.

3.1.1.2 Nature of the indicator

As already pointed out, there may be very different indicators within simple and composite indicators. Therefore, Bockstaller *et al*. (2011), instead of considering only the aggregation level, consider also the nature or structure of the indicator (see Figure 2): they propose three categories for environmental indicators addressing a single theme : (i) simple indicator based on a causal variable or a simple combination of variables (sum, product, ratio); (ii) predictive indicators based on model output that can be operational (with a reduced and available number of input variables) or complex (from the research point of view, without considering the number and availability of input data); and (iii) measured indicators based on field measurement or observation.

Indicators based on a single management variable or simple combination of variables (e.g. input – ouput, input/output) belong to the groups of simple indicators and result in most cases a poor predictive quality whereas measurement indicators may provide more precise information about the state or the impact, without providing information on the causes. Predictive indicators are useful for *ex-ante* assessment and to relate effect to cause.

Figure 2: Typology of indicators according to their nature



Source: Bockstaller *et al*. (2011)

Many simple indicators based on management data are available at farm level (e.g. IDEA method in France, see Zahm *et al*., 2008), and measured indicators at watershed or regional level (e.g. water quality indicators) are available. Predictive indicators such as GHG emissions and ammonia pollution are less common. This is the same for the theme of biodiversity (Bockstaller *et al*., 2011).

3.1.1.3 System boundaries

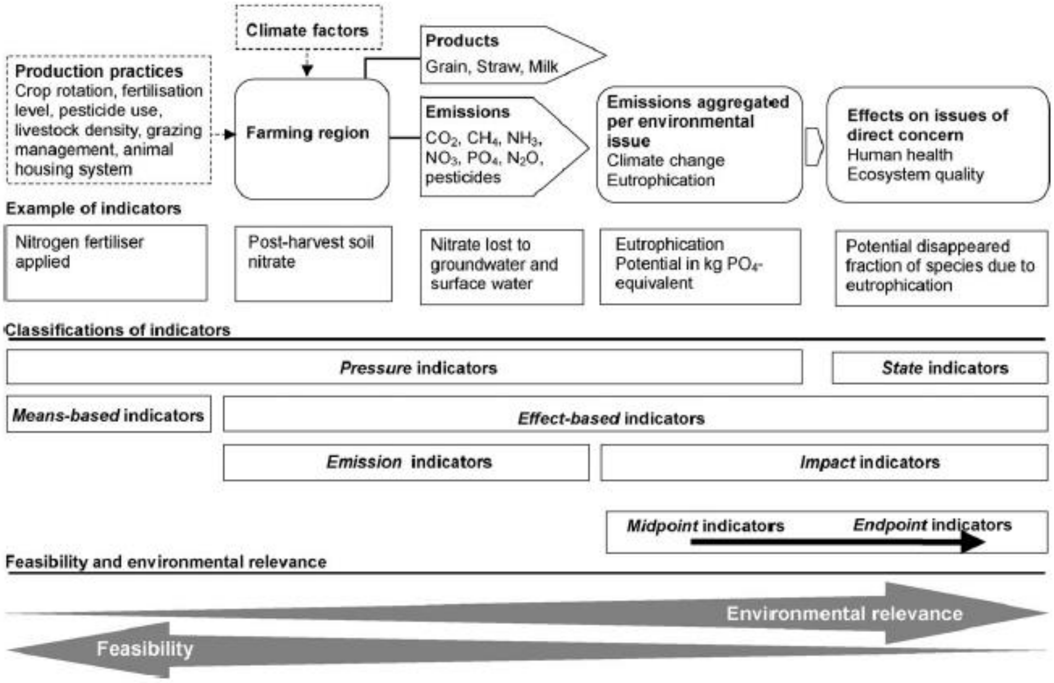
The LCA approach offers more than a simple indicator list. It can be considered as a methodological framework based on a rigorous system definition addressing not only direct impacts due to the production process, but also indirect impacts linked to the input production in the upstream cycle and impacts due to the consumption, use of product and waste management in the downstream cycle (Brentrup *et al*., 2001). Some authors make a clear separation between LCA and other methods based on indicators. On the one hand LCA may use algorithms for assessing direct impact that are used in other methods, such as nutrient budget (e.g. Halberg *et al*., 2005). On the other hand, many environmental assessment methods implement an approach close to LCA when they include assessment of indirect impacts. This is often done for the energy consumption theme (e.g. Pervanchon *et al*., 2002).

3.1.1.4 Position on the cause-effect chain

Several authors differentiate between (i) means-based indicators (van der Werf and Petit, 2002; Payraudeau and van der Werf, 2005), or action-oriented indicators (Braband *et al*., 2003) using information on farmers' practices or other causal variables; and (ii) effect-based indicators or result-oriented indicators, based on an assessment of the effect at different stages of the cause-effect chain (see Figure 3).

In relation to biodiversity, some authors distinguish between indirect (means-based) and direct (effect-based) indicators (Clergué *et al*., 2005). Referring to Hertwich *et al*. (1997), Bockstaller *et al*. (2008a) further elucidate the concept of impact shown in Figure 3 by dividing it successively into state/exposure/impact, so that impact means the final effects on human health or on the economy. In LCA, indicators of final impacts are qualified as 'endpoint impact' indicators whereas indicators related to the cause-effect chain somewhere between emissions and end-point are 'midpoint' indicators (see Figure 3) (Bare and Gloria, 2006; Goedkoop *et al*., 2009). Inspired from Figure 3, the typology of Lebacq *et al*. (2013) is based on four categories: means-based, system-state, emission and effect-based, although they recognised that system state indicators are intermediate and can be grouped with emission indicators as in Bockstaller *et al*. (2008a).

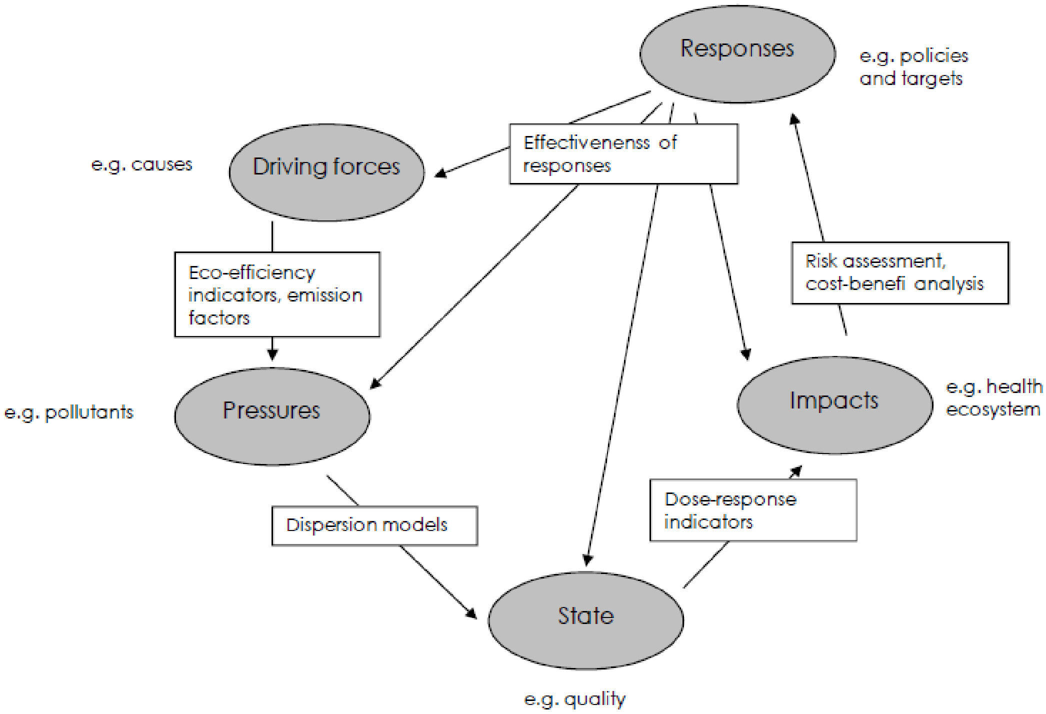
Figure 3: Examples of an indicator typology according to the cause-effect chain



Source: Payraudeau and van der Werf (2005)

The well known Pressure / State / Response (PSR) (OECD, 1999) and Driving-force / Pressure / State / Impact / Response (DPSIR) (EEA, 2005) frameworks are also inspired by this cause-effect chain (see Figure 4). They were developed to ascertain the relevance of environmental indicators for human activities and their consequences at national level. These frameworks are generalised by some authors to every scale (e.g. Maurizi and Verrel, 2002; see also an example in Géniaux *et al*., 2009), overseeing criticisms formulated by different authors (Niemeijer and de Groot, 2008a; Pissourios, 2013). One major drawback of these frameworks is the impression of linearity between pressure, state and impact given by the framework, whereas the reality is more complex and closer to a causal network than to a chain. Bockstaller *et al*. (2008a) point out the ambiguity of pressure, especially in terms of type of indicators as also shown on Figure 4. Pressure encompasses emission indicators which can be measured (e.g. nitrogen content at bottom of the root zone, measured by ceramic cup) or model output (field leaching model) as well as simple indicators based on information from farmers' management data (e.g. amount of nitrogen input).

Figure 4: The DPSIR framework of environmental indicator analysis



Source: Bottero and Ferretti (2011)

3.1.1.5 Environmental issues of concern/environmental themes

The most obvious way to classify indicators may be in terms of issues of concern, or the themes that they address. These are often organised in indicator frameworks (Alkan Olsson *et al*., 2009a). Lebacq *et al*. (2013) group environmental indicators found in the literature into ten environmental themes/topics that focus either on discernible physical aspects of the environment, or on human activities with substantial environmental impact (Pissourios, 2013) and are related to: nutrients, pesticides, non-renewable resources (i.e., energy and water), land management, emissions of GHG and acidifying substances, biodiversity, and physical, chemical, and biological soil quality.

This example encompasses two levels of the cause-effect chain: the first four themes relate to input management, while the others concern the quality of natural resources. This facilitates a reduction in the number of categories. If only themes related to the state of environment or to the impact are addressed, the number increases greatly. For example, for water quality, there are surface and groundwater themes (also marine) related to nitrates, pesticides and other pollutants (Sadok *et al*.,

2009; Goedkoop *et al*., 2009). In any case, this is only an example within a broad range of initiatives (Géniaux *et al*., 2009). However some general groups can be separated between:

(i) local and global impacts (or themes related to local or global impacts) which have consequences on the functional units used to express the indicators (Halberg *et al*., 2005);

(ii) ultimate goal, process to achieve goal and means (Alkan Olsson *et al*., 2009b); this classification of themes across sustainability dimensions considers the action chain. A policy is motivated by one or several ultimate goals (e.g. human health) requiring some process in order to achieve it (e.g. balance of environmental function) and means (e.g. protecting environmental compartment).

(iii) goal-oriented framework and system properties-oriented framework (Bockstaller *et al*., 2007). The former considers themes as goals to achieve (e.g. preserving water quality). The latter addresses themes as system properties like in the approach of Bossel (1999), (e.g. productivity, adaptability, see also López-Ridaura *et al*., 2005).

3.1.1.6 Operational utility

The DPSIR framework was developed in the context of policy evaluation. Regardless of their position in the DPSIR framework, indicators are always utilised with a specific aim (e.g. to describe the current environmental situation, or to assess the progress towards fixed goals, or to derive advice to help improve the system (see Bockstaller *et al*., 2008a). In this context, the European Environmental Agency (EEA) has developed a typology of environmental indicators, which is based on their operational utility (see Pissourios, 2013). This typology consists of four classes: (i) descriptive, (ii) performance, (iii) efficiency and (iv) policy-effectiveness indicators. Descriptive indicators are used in order to describe a specific aspect of the environmental situation and are usually presented as a time-series. Performance indicators compare the actual conditions with a specific set of reference conditions, in other words they measure the distance between the current environmental situation and the desired situation. Efficiency or eco-efficiency indicators provide an insight into the efficiency of products and processes, in terms of the resources used and the emissions and waste generated per unit of desired output. Last but not least, policy-effectiveness indicators explicitly relate the actual change in environmental variables to policy objectives.

3.1.1.7 Discussion

This review of indicator typologies reveals that any classification of indicators cannot remain one-dimensional. Several dimensions should be examined.

As in many other initiatives, data within the FLINT project may be categorised in terms of thematic areas. The availability of data may restrict the type of indicators to simple indicators, i.e. indicators based on one or a simple combination of variables of the same dimension. Predictive indicators would require more data, especially on soil and climate. Simple indicators may be aggregated using knowledge on processes to generate proxy emissions or state indicators, which can be related to environmental performance. In any case, information should be provided on the scientific soundness (e.g. predictive quality), feasibility and utility of candidate indicators. More precise criteria can be found in Niemeijer and de Groot (2008a) and Bockstaller *et al*. (2009a).

3.1.2 Economic indicators

As suggested by van Cauwenbergh *et al*. (2007), agriculture should ‘provide prosperity to the farming community’. In this context, economic sustainability is generally viewed as economic viability. Here we understand economic viability as whether a farming system can survive in the long term in a changing economic context. The change in economic context can be defined in terms of variability in output and input prices, variability in yields, changes in output outlets, and changes in public support and regulation. The concept of long term can be understood in two ways: (i) during the professional life of

the farmer, or (ii) across generations. The latter is related to the durability, i.e. the capacity of a farm to be transferred to a successor. This aspect is also sometimes considered as part of social sustainability.

The literature agrees that economic viability mainly (or only) consists of profitability and productivity. However, some authors also consider autonomy.

3.1.2.1 Profitability and productivity

Profitability is calculated by comparing revenue and cost, either as a difference or as a ratio. Sadok *et al*. (2009) and Hennessy *et al*. (2013), for example, use gross margin which is a difference between revenue and operational cost as a measure of profitability. However, farm income is also used (e.g. van Calker *et al*., 2004; Gómez-Limón and Sanchez-Fernandez, 2010; Lebacq *et al*., 2013). Hennessy *et al*. (2013) suggest also considering whether the farm has 'the capacity to remunerate family labour used on the farm at the average agricultural wage and the capacity to provide an additional five per cent on non-land assets'. Johnson *et al*. (2007) describe the relevance of net value added as economic indicator and the distribution of net value added among the relevant stakeholders (remuneration for the farmer and the paid factor costs (land, labour, capital)).

Productivity is a measure of the ability of the factors of production to generate output. It is generally measured as a partial productivity indicator which is a ratio of output to one input: for example Hennessy *et al*. (2013) calculate productivity of labour (as income per unpaid labour unit) and productivity of land (gross output per hectare). Other methods have been suggested in the management and economic literature, to account for the possibility of input substitution or output substitution: the more comprehensive measure of total factor productivity (TFP) which is a ratio of all outputs aggregated to all inputs aggregated; and the concept of technical efficiency which assesses whether a farm could increase its output without increasing its inputs (see Latruffe, 2010). In the sustainability literature, less complex indicators are used such as the indicator of economic efficiency (relating operational costs to gross output) used by Sadok *et al*. (2009).

As highlighted by Lebacq *et al*. (2013), profitability and productivity indicators are mainly quantitative indicators, and are expressed in monetary terms or as ratios. Some authors nevertheless use reference scales (such as the French IDEA method, see Vilain, 2008).

3.1.2.2 Autonomy

Autonomy is essentially a measure of one of the basic properties of every system: freedom (Bossel, 1999). For this reason, autonomy may also be seen as a social indicator. Autonomy can be viewed in terms of inputs (Lebacq *et al*., 2013). The idea behind this view is that farms that rely less on external inputs, such as feed or fertilisers, are less sensitive to input availability and price fluctuations. Autonomy is also viewed in terms of financing, in other words with regard to the pressure of debts. For example, van Cauwenbergh *et al*., (2007) discuss a solvency indicator (the ratio of optimal debt to farm equity), or Lien *et al*., (2007) discuss a qualitative indicator relating to technical insolvency, that is to say 'when the farm owner's equity falls below zero'.

Another aspect of autonomy is the diversification of income, whether farm income or household income. Farm income can be diversified by implementing non-agricultural activities on the farm such as direct sales, processing or agritourism (this is sometimes called structural diversification and is called other gainful activities in FADN), while the household income can be diversified by off-farm employment held by farmers or their families (this is called income diversification) (Meert *et al*., 2005). As early as 1982, Hill wrote that 'concern over the income of farmers has been a fundamental but ill-defined component of agricultural policy. Current income from farming is only a partial measure of the potential spending power of farmers: many have off-farm sources of income which must be taken into account when, for example, assessing poverty. A prime requirement appears to be a more precise statement of the aims of income policy and the use of income measures most appropriate to the circumstances' (Hill, 1982). O'Brien and Hennessy (2007) stressed that for many Irish farms, their sustainability was 'dependent on farmers and their spouses' ability to secure employment off the farm'.

Subsidy dependence is another aspect of autonomy. If farms are highly dependent on public support, any policy reform could put farm sustainability at risk. Several indicators are used in the sustainability literature. For example, Dillon *et al*. (2009) use direct payments as a percentage of farm gross output,

and market return calculated as family farm income minus direct payments, whereas Sadok *et al*. (2009) relate direct subsidies to margin. Vrolijk *et al*. (2010) use an indicator for the viability of farms to express the extent to which farms can cope with a reduction of direct payments. A farm is categorised based on whether a farm has a positive or negative income and cash flow.

3.1.2.3 Discussion

Compared to the literature on environmental sustainability, there is considerably less literature on economic sustainability and this has not been plagued by the indicator explosion problem. While it is common to calculate farm profitability, productivity or efficiency in management or economics literature (see e.g. Latruffe, 2010), farm profitability is less often calculated with a view to assessing sustainability and is generally part of a wider assessment of global sustainability (including not only economic sustainability but also environmental and social sustainability), and is published in non-economic journals (e.g. Thomassen *et al.*, 2009; Dolman *et al*., 2012; Dolman *et al*., 2014; van Calker *et al*., 2004; van Cauwenbergh *et al*., 2007; Sadok *et al*., 2009; Lebacq *et al*., 2013).

Economic and environmental indicators also differ in the scale of implementation. Firstly, most often economic indicators are measured at the farm level (or at crop or activity level), while many environmental indicators are measured at a smaller scale such as at plot level or at a larger scale such as at catchment level. Secondly, a larger scale such as the regional level is commonly used for economic indicators, for example when the distribution of farm income is assessed across farms in a region (e.g. Allanson, 2006). This equity assessment may however also be used to assess social sustainability (e.g. the French initiative INPACT, see Inpact, 2003).

It should be stressed here that farm income was (and still is) the first indicator of economic sustainability to be measured widely at the farm level, due to the implementation of CAP which had the primary objective of supporting farm income. FADN was created to monitor the level of farm incomes.

Another point to note is that, while the literature assessing economic sustainability uses profitability and autonomy indicators, the latter are in fact embedded in the former. Future profitability depends on external shocks and would therefore be less affected when there is a high degree of farm autonomy. Hence, autonomy indicators may be viewed as proxies for future profitability. This 'future' dimension is considered for example by Hansen and Jones (1996) and Lien *et al*. (2007), who stress that it is not possible to observe sustainability since it entails future outcomes.

In this context, and going beyond autonomy at farm level, it is the farms' adaptability or resilience that is really important. Bossel (1999) notes that adaptability is a fundamental property of a system. Lien *et al*. (2007) define resilience in farming as 'the capacity of a farm business to survive various risks and other shocks'. More generally, López-Ridaura *et al*. (2005) explain that 'the degree to which a system is sustainable will depend on its capabilities to produce, in a state of stable equilibrium, a specific combination of goods and services that satisfies a set of goals (the system is productive), without degrading its resource base (the system is stable) even when facing "normal" (the system is reliable), "extreme" and "abrupt" (the system is resilient) or "permanent" (the system is adaptable) variations in its own functioning, its environment or co-existing systems'. However in the literature, the potential of a farm to reach or to maintain a certain level of economic sustainability in the long run is very rarely accounted for. Economic sustainability should nonetheless be considered in terms of current management decisions that can ensure sustainability in the future. For example, indicators could relate to instruments that protect the farm activity from risk and uncertainty e.g. insurance, or to decisions to ensure stable sales of output (e.g. production contract, niche production with high value added). A couple of exceptions in the literature are Gómez-Limón and Sanchez-Fernandez (2010), who used the share of insured area as an indicator of economic sustainability, and the FAO SAFA initiative (FAO, 2013b) which proposes the use of safety net indicators and an indicator of risk management (although both are not explicitly defined, only guidelines are provided).

3.1.3 Social indicators

Social sustainability relates to people. Lebacq *et al*. (2013) clearly defined social sustainability based on two categories of people:

(1) social sustainability that matters at the level of the farm community; this is related to the well-being of the farmers and their families;

(2) social sustainability that matters at the level of society; this is 'related to society's demands, depending on its values and concerns'.

3.1.3.1 At the level of the farm community

Regarding the first category of social sustainability, in their review of literature Lebacq *et al*. (2013) group the indicators found into three main categories:

(i) education;

(ii) working conditions; this is measured by working time, workload (including pain), and workforce;

(iii) quality of life; this is measured by isolation and social involvement.

Other aspects of well-being are however excluded from this typology, such as the physical health of workers (e.g. van Calker *et al*., 2007), although this can be viewed as a consequence of working conditions.

For this level of social sustainability (i.e. at the farm community level), van Cauwenbergh *et al*. (2007) considered only quality of life but separated it into (i) physical well-being, whose indicators relate to labour conditions and health, and (ii) psychological well-being, which includes not only education, but also gender equality, family access to infrastructures and services, and the farmer's feeling of independence.

3.1.3.2 At the level of society

In the second category of social sustainability, similarly to above, Lebacq *et al*. (2013) group the indicators found in the literature into three main categories:

(i) multifunctionality; this includes quality of rural areas, contribution to employment and ecosystem services;

(ii) acceptable agricultural practices; this includes environmental impacts and animal welfare;

(iii) quality of products; this includes food safety and quality processes.

Van Calker *et al*. (2007) consider the contribution to the rural economy, which is less strict than the contribution to employment but could also be included in Lebacq *et al*.'s (2013) quality of rural areas. Van Cauwenbergh *et al*. (2007) add equity, as well as heritage, cultural, spiritual and aesthetic values. As underlined by Cooper *et al*. (2009), farmers keep traditions alive. Also, as mentioned above, the succession theme is sometimes included in the social sustainability dimension. For example, Gómez-Limón and Sanchez-Fernandez (2010) use the intergenerational continuity in agriculture, and Dillon *et al*. (2009) consider demographic viability.

3.1.3.3 Discussion

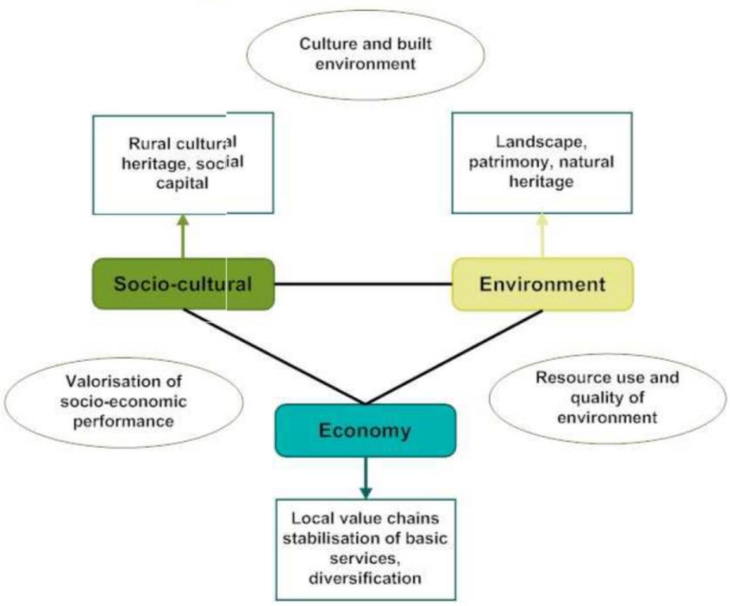
Unlike environmental and economic indicators, social indicators are often qualitative. They are difficult to quantify as they are often subjective. This difficulty gives rise to a number of steps which must be undertaken, such as the need for clear definition of specific indicators, the design of scoring systems and the interpretation of the indicator. Indicators relating to the farm community are often based on farmers' self evaluation through surveys or interviews, although many studies aim to ensure accuracy and precision in these assessments. For example, Sadok *et al*. (2009) choose to use the social indicator of physical constraints. For this, they resort to qualitative estimation based on information regarding frequency of machine vibration, repetitiveness of actions, frequency of heavy load manipulation, and allergies and noise level. In contrast, indicators relating to society may be assessed by experts (e.g. van

Calker *et al*., 2007). The indicator of quality of life in rural areas can be given as an example. As explained by Pissourios (2013), such indicators can be measured by two complementary approaches: (i) the quantitative approach which relies on collecting observable and measurable indicators that are then aggregated into a composite indicator, and (ii) the qualitative approach which is based on peoples' perceptions of the quality of their lives, i.e. measuring the quality of life that is 'psychologically experienced', and relying on interviews. The latter approach is used in Kazana and Kazaklis (2009) for Greek rural areas.

A second point to note, referring to Lebacq *et al*. (2013), is that society's demands are constantly changing, and so is the range of social indicators. This is also stressed by Lyytimäki and Rosenström (2008) who indicate that 'ecological thresholds and social transformations can produce surprises and new issues that cannot be included within existing frameworks, so those frameworks have to be constantly updated and adapted. As explained above for environmental indicators, this could explain why social indicators are also affected by the indicator explosion.

A final note is that, while environmental indicators and economic indicators can stand alone, this is not always the case for social indicators at the societal level. Agriculture contributes to the quality of life in rural areas in terms of economic contribution (e.g. the level of farm output is crucial for the viability of upward and downward industries) and environmental contribution (e.g. creation of landscape, reduction of pollution). This can be seen in Figure 5 which illustrates the case of quality of life in rural areas. It is sometimes difficult to identify the sustainability pillar to which a specific indicator belongs: for example ecosystem services may be part of environmental sustainability but also social sustainability; the suitability of the farm for succession may relate to economic as well as social sustainability. Hence, a general conclusion is that the social sustainability of farms is the dimension that would need the most thought and consideration in the future.

Figure 5: Dimensions of quality of life in rural areas



Source: Grieve *et al*. (2011)

3.2 Development of composite indicators

Many initiatives are based on lists of indicators which are organised in more or less well-structured frameworks (see van der Werf and Petit, 2002; Géniaux *et al*., 2009; Singh *et al*., 2009). However, the question of aggregation arises when the objective is to comment on the sustainability outcome of a policy, or to compare two or more policy options via a set of indicators. There is a need for a methodology to combine diverse information in an explicit, consistent and transparent way, whilst presenting it in an easily intelligible form to facilitate policy evaluation. As pointed out by Nardo *et al*. (2005), 'The construction of composite indicators involves stages where subjective judgment has to be made: the selection of indicators, the treatment of missing values, the choice of aggregation model, the weights of the indicators, etc.'. This has led to two schools within the 'indicators community': 'aggregators' insisting on this need for aggregation and 'non-aggregators' who caution about the subjectivity involved, and about the potential pitfalls in adding apples and oranges and the potential for loss of information in the aggregation process. However, several approaches are available to avoid these pitfalls (Bockstaller *et al*., 2008a and 2009b) as reviewed in the following.

3.2.1 Aggregating a set of indicator values into a single composite value

The most common and intuitive approach is to combine different sources of information into a single value, e.g. indicator scores into a global index or composite indicator. This is in many cases calculated by means of a sum or a weighted mean (Rosnoblet *et al*., 2006). Some assessment methods deliver a single score resulting from the sum of scores without an explicit standardisation of the single indicator values. This kind of approach presents several methodological flaws such as the risk of adding apples and oranges. Several possible techniques for normalisation exist: linear scaling techniques, Gaussian normalisation, distance to target, ranking by experts, categorical scales, etc. (Géniaux *et al*., 2009). Another approach is to convert all values into the same unit, monetary or physical (e.g. ecological footprint). Aggregation methods based on a common monetary unit as in cost-benefit analyses raise the issue of how to value non market goods and services such as environmental assets, water quality, biodiversity, etc. (van der Heid *et al*., 2010). The contingent method is one of the currently implemented approaches in spite of many criticisms (Venkatachalam, 2004).

3.2.2 Multi-criteria analysis

A serious drawback of using a single composite indicator is the loss of information as a result of aggregation and hidden compensation. A possible solution to these problems is multi-criteria analysis (MCA). MCA has its roots in management science and operational research and is a methodology for selecting between, or prioritising, different options described by a set of criteria (Sadok *et al*., 2008). Central to MCA is:

(i) some form of criteria or scale for selecting between, or prioritising, different options;

(ii) a table to show the performance of the different options relative to each other (see Table 1). This is based on a weighting, rating or ranking procedure by a group of experts or stakeholders (Josien *et al*., 2006). The use of weighting procedures in aggregation is also often criticised due to their subjectivity. This cannot be totally avoided but should be transparent. Andreoli *et al*. (1999) proposed guidelines to limit this problem.

(iii) statistical analysis or some alternative methods for drawing conclusions or highlighting the key findings from the MCA. Such analysis lays on a multitude of very different approaches, e.g. (i) a utility function in the case of a compensatory approach (allowing compensation between criteria) that allows 'weak sustainability' such as the Multi-Attribute Utility Theory (e.g. Foltz *et al*., 1995),

or (ii) pair-wise comparisons using outranking approaches which are mostly non compensatory (Hayashi, 1998) for the assessment of 'strong sustainability' (see later) like in Electre methods (Arondel and Girardin, 2000). In this case, the number of criteria or indicators has to be limited and the method yields a relative assessment of options (policy options, production systems, etc.).

Table 1: Example of hypothetical data on ranks and rates of environmental themes by a group of experts

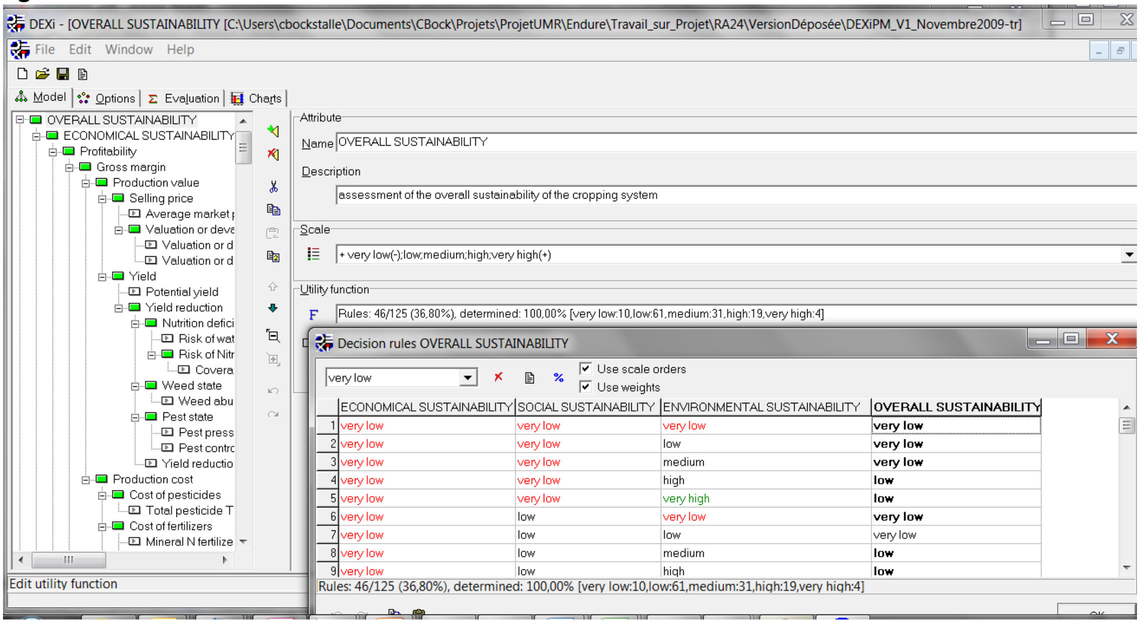
Expert	Theme	Rank (between 1 and 9)	Rate (total per expert is 100)
1	Nutrient	1	50
1	Pesticide	3	30
1	Resource management	5	20
2	Nutrient	3	35
2	Pesticide	1	40
2	Resource management	5	25
3	Nutrient	1	45
3	Pesticide	5	25
3	Resource management	3	30

Source: the authors

3.2.3 Multi-criteria assessment based on a qualitative method

Qualitative approaches can also be considered as a way to aggregate. These types of approaches lead to a conclusion in the form of a score, or of classes of a given criterion (e.g. sustainability). Technically, therefore, these approaches can be considered as hybrid (or mixed, Sadok *et al*., 2008) approaches combining qualitative and quantitative elements (organised in qualitative classes). Such approaches are based on decision rules expressed in 'if then' rules i.e. presented either as decision trees based on qualitative multi-attribute decision modelling or in the form of a dashboard (Bockstaller *et al*., 2009b). Fuzzy logic can be used to account for the uncertainty in the indicator outputs and to avoid the effect of knife-edge limit of a given class (Prato, 2005; Phillis and Andriantiatsaholiniaina, 2001). The number of criteria included in the analysis can be increased when these are structured in a hierarchical tree. The outcomes of the analysis can be influenced by changing specification of the tree (Poyhonen *et al*., 2001). Recently, the French DEXi tool developed by Bohanec *et al*. (2008) was implemented in several cases in French and European projects to assess the sustainability of cropping systems (Sadok *et al*., 2009; Pelzer *et al*., 2012, see Figure 6). However, sensitivity of such decision trees has to be considered seriously (Carpani *et al*., 2012). Another aggregation method, SIRIS, was developed to avoid subjectivity in the construction of aggregation rules in decision trees (Aurousseau, 2004). More recently, the CONTRA method was developed to combine advantages of fuzzy decision trees, DEXi, and SIRIS (Kauffer, 2013).

Figure 6: Overview of DEXiPM based on the DEXi tool



Note: a partial view of an example of aggregation rules (utility function) is given in the table.
Source: Pelzer *et al*. (2012)

3.2.4 Discussion

This review of aggregation methods highlights several possibilities to avoid methodological flaws while subjectivity cannot be totally avoided but should be transparent. A mixed approach based on a decision tree offers several advantages. In any case, Bockstaller *et al*. (2008a) advise the use of a combination of non-aggregated indicators to analyse the results, highlighting strong and weak points, extreme situations, and aggregated indicators to compare options and systems. The implementation in the FLINT project will however depend on the needs of the stakeholders. Is there a need to provide a global view on farm sustainability? In any case, mixed approaches based on decision trees offer interesting possibilities. They could also be used to combine different simple indicators based on management data and, if available, farm level environmental data (e.g. share of area with slope, share of drained area, etc.) to assess an environmental theme. For example in the case of nitrate leaching, knowledge on the processes requires not only an indicator about nutrient surplus but also an assessment of the management of soil cover during the winter drainage period.

3.3 Selection criteria

Lebacq *et al*. (2013) grouped the approaches to assess sustainability into three categories: (i) the method-based approach, where the assessment is done with an existing method; (ii) the objective-driven approach, consisting of the whole process of developing a method and collecting the data needed; and (iii) the data-driven approach, where indicators are selected and calculated from existing data. In terms of the method-based approach, guidelines to choose a method have been proposed in the literature (e.g. van der Werf and Petit, 2002; Galan *et al*., 2007; van der Werf *et al*., 2007; Bockstaller *et al*., 2009a). The FLINT project relies on a mixture of data-driven approaches (using existing FADN data) and objective-driven approaches (new indicators are selected and additional data are collected). In this frame, indicators should be cautiously chosen. The literature suggests various criteria for the selection.

3.3.1 Selection of an indicator

As underlined by Lebacq *et al*. (2013), the choice of an indicator is decisive as it influences conclusions. Thus, it is equally decisive to use a selection procedure that is well-defined, robust and transparent, so that the assessment is validated, credible and reproducible (Niemeijer and de Groot, 2008a; Dale and Beyeler, 2001). Therefore, careful choices have to be made before launching the process of sustainability assessment. For example, in the case of agri-environment schemes (AES), Mauchline *et al*. (2012) report that 'two evaluation methodologies applied to the same scheme produce two different overall conclusions when conducted by a multi-disciplinary team (Carey *et al*., 2003) compared with an ecologist alone (Carey *et al*., 2005). A similar discrepancy is found for single issue analysis compared to "combined effect" analysis of AES agreements (Primdahl *et al*., 2003)'.

Lebacq *et al*. (2013) describe two main steps in the selection of indicators.

(1) Contextualisation of the assessment

This crucial step has various titles in the literature, e.g. the 'pre-modelling phase' (Alkan Olssson, 2009a) or the step of 'preliminary choices and assumptions' (Bockstaller *et al*., 2008a). During this first stage, many aspects need to be clarified and decided: (i) the purpose of the assessment in terms of precise objectives and end-users; (ii) the system boundaries in terms of issues/themes of concern, scope, time and spatial scales and the involvement and role of stakeholders in the assessment.

(2) Comparison of indicators

Comparisons are based on various criteria which need to be precisely defined in advance. Due to the multiplicity of methodologies, authors may not have the same understanding of some criteria (Bockstaller *et al*., 2009a). Lebacq *et al*. (2013) listed three main criteria: (i) relevance; this is related to the appropriateness of the indicator to the context and scale, and also includes a quality/accuracy aspect; (ii) practicability, which consists of measurability, quantification and compatibility of the data with the aggregation method selected, and transferability to other farm types; (iii) end user value; this relates to the appropriateness of the indicator to stakeholders' expectations in terms of clarity, comprehension, and policy relevance.

Rice (2003) proposes additional criteria that can guide the selection of indicators: (i) representativeness, with the author questioning 'Can the dynamics of the indicator be taken to reflect more than the dynamics of the specific times and places where the data were collected?'; this is related to the transferability aspect mentioned by Lebacq *et al*. (2013); (ii) availability of historic data, so that the performance of an indicator can be evaluated; (iii) theoretical basis, in particular 'the consistency of an indicator with ecological theory, but also the degree to which the diversity of professional views all accept the theoretical arguments'. This historic dimension is also reported by Niemeijer and de Groot (2008a) as it can give information on the reliability of the indicators.

The criteria described above are 'ideal' criteria. However, one aspect that should not be forgotten is the operational capacity of an indicator in terms of cost. As explained by Pingault (2007), data should be available at an acceptable cost, and the cost related to the design and calculation of the indicator should also be tolerable. More generally, the author suggests considering the implementation cost, the cost of using the indicator, and the cost of adapting it to changes in the context. The author reports that this cost aspect was mentioned by OECD as early as 1997 in its first report on environmental indicators for agriculture. In relation to this Rice (2003) explained that for indicators of environmental health, 'desirable situations are when the indicator can be calculated from data that [are] already being provided by existing monitoring programmes, and are in the public domain. It is also desirable that the tools needed to take the measurements are widely available, inexpensive to use, and of known and consistent accuracy and precision'. In their literature review, Niemeijer and de Groot (2008a) also report the financial and practical dimensions, notably the cost-benefit aspect and the possibility of developing the indicator with available resources and time.

3.3.2 Indicator *vs*. set of indicators

Several authors have highlight the need to consider indicators as a set instead of individual indicators (e.g. Lyytimäki and Rosenström, 2008; Niemeijer and de Groot 2008a; Lebacq *et al*., 2013). Niemeijer and de Groot (2008a and 2008b), referring to environmental sustainability, stress that indicators have to be selected 'on the basis of how they jointly provide an answer to our environmental questions'. They recommend considering causal networks and the various causal chains that are inter-related within the networks. On tillage farms in Spain, Gómez-Limón and Reig Martínez (2013) demonstrate the usefulness of analysing several indicators in conjunction with each other, in order to obtain more robust results.

In building a casual network Niemeijer and de Groot (2008a) suggest that first of all, the domain of interest and the boundaries of the system should be defined, then the indicators are identified, and finally the indicators are mapped on a directional graph. On this graph, indicators should be organised in categories, and connected with arrows that can show the cause-effect directions. The selection of indicators should be done by identifying key nodes. However, the authors note that 'It may in some cases be better to select an indicator that scores a little lower in terms of the individual evaluation criteria ... but is a corner stone in our logical inference of cause and effects'.

Lebacq *et al*. (2013) indicate three criteria for selecting a set of indicators: (i) parsimony, that is to say that indicators should be few and not redundant; (ii) consistency, that is to say that all necessary indicators are in the set; and (iii) sufficiency, that is to say that the set is exhaustive in the sense that it embraces all sustainability objectives. The parsimony criterion is however questionable: a big number of indicators could be a good starting point to avoid wrong conclusions that could arise from using few indicators or when the goal of the assessment is to assess weak and strong points of a system. This whittling down from an initially large indicator list is the approach adopted within the FLINT project.

3.4 Data collection: desirability, feasibility, gaps

Data collection can be a major constraint in sustainability assessments. For example Lebacq *et al*. (2013) illustrate this with environmental themes: while, for example, simple farm-gate nutrient budgets usually ignore field-barn interactions and controllable inputs, such as deposition or biological N-fixation (Watson *et al.*, 2002) and therefore require relatively few data, the calculation of GHG-emissions necessitates a large amount of often production-system specific information which makes the data collection much more complicated. Lebacq *et al*. (2013) underline that most economic indicators can be calculated since monetary information is often recorded, while social indicators often require additional qualitative information. Sometimes proxies are used, but this may not accurately reflect the objective. This results in an imbalance between the dimensions of sustainability covered by the literature and frameworks. While the economic dimension is largely covered, the multiplicity of themes in the environmental dimension and the subjectivity in the social dimension result in lower coverage of these two dimensions. Lebacq *et al*. (2013) recommend that future research relying on data collection should cover topics that have not been widely investigated so far, in particular social and socio-economic indicators.

Overall, the development and use of indicators for such new topics will not happen instantly but needs an accumulation of experiences to become a routine. For example, preparing accounts (i.e. the current basis of the FADN) is already a relatively complicated task. In Germany, for example, farmers or their employees attend trainings (e.g. in winter schools organized by the farmers' unions) to learn the basics of accounting or the farmers consult bookkeeping offices for preparing the accounts. For FADN farms, the existing accounts have to be converted into FADN format (either by the farmers themselves or by bookkeepers, this is usually an embedded feature of the financial software products used) and then submitted to the responsible agricultural authorities which employ plausbility checks on the data using

the software tool 'winplausi'[1]. Usually an intensive communication process between authority staff and farmers/bookkeepers follows, in which the often numerous errors are corrected until a sufficient data quality is reached. Specific trainings take place each year in which farmers and bookkeepers are trained in understanding the checks embedded in 'winplausi' in order to reduce the occurrence of errors. Based on these experiences it can be concluded that for new indicators, similar pendants (auditors, trainings, software) for environmental, social, innovation or animal welfare topics would be needed to ensure adequate data quality. This is also supported by experiences with self-reporting of environmental data in Germany (Breitschuh *et al*., 2004) which show that intensive effort is required by the control authority to obtain error free data (e.g. KUL system with 20 environmental indicators: only 10% error free data after the first round; 'Environmental monitoring Thuringia' with six indicators: only 50% error-free data), so that direct farm contact is always recommended (Breitschuh *et al*., 2004).

At the same time the documentation and reporting requirements of farmers have already increased for various reasons, e.g. the need for improved business planning, compliance with various laws, regulations and measures at national and EU-scale along with increased safety and quality demands regarding agricultural products from the processing and sale industries. A variety of tools has been developed by software companies seeking to efficiently support agricultural businesses with these tasks, e.g. facilitating data collection and documentation, planning, optimisation, control, reporting, and data exchange, between different tools and with tax and agricultural institutions (Zapf *et al*., 2009). Given the variety of tools, often technical compatibility problems occur or the tools are not sufficiently maintained by the farmers to facilitate an easy electronic data exchange, but this would be desirable to create a win-win situation in which all stakeholders benefit.

In conclusion, farm data for new sustainability topics and related potential FADN indicators should be reliable, reproducible, controllable/checkable and require low additional costs and time efforts, e.g. through the use of already existing farm documentation (e.g. farm management software, invoices for purchases and sales, agricultural subsidy application forms, and Land Parcel Identification System (LPIS) field data) based on electronic data exchange. If, in addition to the existing on-farm data, new data collection activities become necessary, they should be assessed in terms of their benefit-cost ratios. Compromises have to be made involving the quantity of information collected, i.e. proxy *vs*. true indicators, and collection at one point in time *vs*. on a continuous basis. The majority of the collected information should be quantitative and documented, while estimated or qualitative assessments should be kept to a minimum. In addition, plausibility checks should be developed to allow for early detection of errors.

[1] http://www.bmelv-statistik.de/de/testbetriebsnetz/plausibilitaetspruefung-der-landwirtschaftlichen-testbetriebe-winplausi/

4 USES OF SUSTAINABILITY INDICATORS AT FARM LEVEL: NATIONAL INITIATIVES

In addition to reviewing the international literature, this report identifies a selection of national initiatives developed in nine EU countries, which are partners of the FLINT project: Finland, France, Germany, Greece, Hungary, Ireland, the Netherlands, Poland, and Spain. The literature review provides theoretical knowledge while the description national initiatives provides an illustration of the concepts and gives insights from practical applications which add and complement the international literature.

We organise the national initiatives into three types of uses:

(1) indicators used for farm decision support (internal monitoring) which are based on the specific characteristics and issues of each farm. These indicators are used to guide decisions regarding the techno-economic systems;

(2) indicators used for comparing farms and for benchmarking (inter-comparison) (although we acknowledge that benchmarking can also be used for farm decision support);

(3) indicators used for policy evaluation, which can bring information on the impact and efficiency of policies in order to justify their creation or improve their implementation.

Table 2 lists the national initiatives in each of the three categories.

Table 2: Classification of the national initiatives according to their use of indicators

Farm decision support	**Farm comparison**	**Policy evaluation**
Ex-ante analysis • Foley *et al*. (2011) (IR) • Terrier *et al*. (2010) (FR) *Current on-farm management identification* • INTIA S.A. (2014) (ES) *Ex-post analysis* • AgriClimateChange (2013) (DE, ES, FR) • Agro-Transfert Ressources et	Benchmarking of farms' performance **Global performance** • Arandia *et al*. (2011) (ES) • Batalla *et al*. (2013) (ES) • Carbon Navigator (2014) (IR) • Dantsis *et al*. (2010) (GR) • Feret (2004) (FR) • Foley *et al*. (2011) (IR) • Fourrié *et al*. (2013) (FR) • Galan *et al*. (2007) (FR) • Molnar (2008) (HU) • Pervanchon (2004a) (FR) • Pervanchon (2004b) (FR)	Measuring the impact of policies • Bergschmidt and Schrader (2009) (DE) • Casey and Holden (2005a) (IR) • Casey and Holden (2005b) (IR) • Kovács *et al*. (2013) (HU) • Manos *et al*. (2011) (GR) • Manos *et al*. (2013) (GR) • Mauchline *et al*. (2012) (DE, FI, GR, HU, IR) • Pesti and Keszthelyi (2009) (HU) • Primdahl *et al*. (2003) (DE, ES, FR, GR) • Tzanopoulos *et al*. (2011) (GR)

Territoires (2009) (FR) • Aguilar *et al*. (2013) (ES) • Fortun-Lamothe (2012) (FR) • Kool *et al*. (2010) (NL) • Kramer *et al*. (2006) (NL) • Ripoll-Bosch *et al*. (2012) (ES) • Zafiriou *et al*. (2012) (GR)	• Zahm *et al*. (2008) (FR) **Social performance** • Fourrié *et al*. (2013) (FR) • Mollenhorst *et al*. (2006) (NL) • Tömpe (2008) (HU) • Zegar and Wrzaszcz (2012) (PL) **Economic performance** • Dillon *et al*. (2008) (IR) • Ehrmann (2008) (DE) • Molnar (2008) (HU) • Ryan at al. (2014) (IR) • Thomassen *et al*. (2009) (NL) • Wrzaszcz (2012 and 2014) (PL) • Zegar and Wrzaszcz (2012) (PL) **Environmental performance** • Fourrié *et al*. (2013) (FR) • Kool *et al*. (2010) (NL) • Sintori *et al*. (2013) (GR) • Zafiriou *et al*. (2012) (GR) Certification of farms • Breitschuh (2008) (DE) • DLG e.V. (undated) (DE) • Ministère de l'Agriculture (2014) (FR) Factors influencing the performance of farms • Dolman *et al*. (2012) (NL) • Dolman *et al*. (2014) (NL) • Ligda *et al*. (2013) (GR) • Ripoll-Bosch *et al*. (2012) (ES) • Sintori *et al*. (2013) (GR) • Wrzaszcz (2012, 2013 and 2014) (PL) • Zegar (2013) (PL)	• Westbury *et al*. (2011) (IR) • Wisman and Blokland (2013) • Zalidis *et al*. (2004) (GR)

Note: Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), Ireland (IR), the Netherlands (NL), Poland (PL), and Spain (ES).
Source: the authors

4.1 Sustainability indicators to support farms' decision

Farmers undertake agricultural activities with specific production goals or business plans. In the past such objectives have generally been relatively simple ones based almost exclusively on profit (or utility) maximisation. More recently, it has been recognised that the situation is more complex. Farmers must balance objectives that relate to a wide range of issues such as food safety and environmental sustainability, in addition to maximising income levels. Farmers need to take into account considerations related to the environmental impact of their activities and the need to limit production levels so as not to exceed quotas or market capacity. A range of decision support methodologies, including those based on indicators, have been studied as a means of assisting farmers to judge whether a certain development contributes to movement in 'the right direction' rather than serving as a precisely defined benchmark (Ryan *et al*., 2014). Indicator-based assessment methods support farmers' decisions by identifying constraining practices that hamper the achievement of sustainable farmer's goals (Rais *et al*., 1997). As a consequence, a large part of indictor-based assessments are implemented by farmers and will thus theoretically lead to direct changes in actions and decision outcomes (Johnson, 1998; Hezri, 2004).

The next section considers some approaches that were used before (*ex-ante*), during or after (*ex post*) the implementation of farm based policies to assist/support in identifying practices, systems or strategies which could help reach the environmental, economic or, to a lesser degree, social objectives (Thorne and Dijkman, 2001).

4.1.1 *Ex-ante* analysis for project development support

The rapid emergence of new challenges shaping agricultural sustainability and the unpredictability of the driving forces behind them, make it necessary to find alternative ways to assess farm systems. These fluctuations make it necessary to develop fast *ex-ante* (i.e., 'before-the-event') sustainability evaluation frameworks that can assess a large body of options and rapidly identify alternative systems without the need for deep assessments of all the possible options (Sadok *et al*., 2009; European Commission, 2005; van Ittersum *et al*., 2008; Meynard, 2008).

4.1.1.1 Qualitative analysis

Tools usually implemented at the initial stage (*ex-ante* analysis) generally focus on the evaluation of the economic viability or durability of the agricultural project and take little account of the environmental and socio-territorial dimensions (Terrier *et al*., 2010). In light of this reality, the EDAPPA methodology has been developed in France to evaluate the overall sustainability of agricultural projects, their adequacy to fulfil the project initiator's objectives and the surrounding environment through the collection of 110 indicators, distributed over 31 groups of indicators within the classical three sustainability pillars (Gasselin *et al*., 2013). EDAPPA was not designed as an instrument of certification conditioning the access to funding in comparison with tools usually used in agricultural settlement process, but as a basis for discussion between extension services and project initiators. As a consequence, EDAPPA designers have adopted a qualitative assessment which judges the response of indicators to different themes of sustainability in relation to a goal expressed by the project initiator (see Table 3 for the example of one of the 31 groups fof indicators). Thus it does not produce standards and does not include a reference positioning the project on a sustainable scale.

EDAPPA helps assess an agricultural project in the light of 10 transversal themes (i.e. Technical and economic feasibility, Territorial anchoring, Quality of life, Autonomy, Adaptability, Maintenance of production support, Revitalisation of rural areas, Food security and sovereignty, Natural resources, and Energy and non-renewable resources) supporting a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis conducted on each group of indicators.

This enables to assess a project through the classical lens of sustainibility pillars, but also at different scales through the lens of more global objectives represented by the transversal themes.

A large element of the EDAPPA indicators is inspired by French *ex-post* methods which constitute the majority of assessments of the sustainability of farm systems (Peschard at al., 2004). However, all *ex-post* indicators are not applicable in the case of EDAPPA, e.g. nitrogen balance to measure fertilisation. Since EDAPPA was designed for *ex-ante* assessment, it is not possible to get enough accurate fertilisation data to calculate this balance (Terrier *et al*., 2010). Indicators are mainly determined from farmers' response to oriented questions such as 'what are your motivations for settling down in agriculture? How do you prepare your settlement? Is this settlement choice a rupture or a continuity (indicator A1-1)?' (see Table 3).

4.1.1.2 Simulation models

Some studies focus on GHG emissions associated with alternative production systems (Casey and Holden, 2006; Edwards-Jones *et al*., 2009; Beauchemin *et al*., 2010; Pelletier *et al*., 2010; Veysset *et al*., 2010; White *et al*., 2010). This is done *ex ante* in Foley *et al*. (2011), by using simulation models which determine the effect of varying management practices on GHG emissions from pastoral beef production systems in Ireland using the Greenhouse gas Emissions Model (BEEFGEM) modelling direct and indirect emissions.

Most of the tools which evaluate the sustainability of farming practices use normalised indicators. These tools have a specific application domain in which these standards/norms have a meaning, and in other areas they lose relevance. With *ex-ante* analyses, sustainability is viewed in terms of specificity of territories and characteristics of the farm project without using rates, thresholds, limits or aggregation system that are defined for specific agro-socio-economic contexts (Terrier *et al*., 2010).

Table 3: Example of indicator's evaluation in the French framework EDAPPA (example for the group of indicators A1)

A1	**Initial motivations of the project in its activities and location**							
	Indicators		***Restricted sustainability***				***Extended sustainability (territory, country)***	
			Internal to activities system		External to activities system			
Description as mentioned by the project initiators (farmers' opinion)	A1-1	Life choices in light of the past of the project initiator	*Birth of a child. Delphine's wages disappointed her; she wants something else, more autonomy. Old dream of life in nature, in the mountain. Delphine's position had separated them and when she quitted, it was the opportunity to launch their project.*					
	A1-2	Motivations for a potential pluriactivity						
	A1-3	Enhancement of previous skills/know-how						
	A1-4	Pre-existing social networks						
	A1-5	Choice of the location (activities, residential)						
Meaning (extension officer's interpretation)	**Transversal themes**		**S**trengths	**W**eaknesses	**O**pportunity	**T**hreats	Strengths	Weaknesses
	Technical and economic feasibility			*Not attracted by the technical aspects of the profession. Fled from their old life.*				
	Territorial anchoring							
	Quality of life		*Wants strongly to live in the country, the project will depend on the location*					
	Autonomy		*Attracted by the autonomy in work*					
	Revitalisation of rural areas							
	Food security and sovereignty						*Wants to contribute to the improvement of the quality of food*	
	Natural resources						*Wants to preserve the environment*	
	Energy and non-renewable resources							

Source: adapted from Gasselin *et al.* (2013)

4.1.2 Support for current on-farm management decisions

Systems like Geographic Information System (GIS) technologies can be used in the management of geo-referenced information, for instance to make use of soil variability, climate, crop condition, plant health alerts, and biotic and abiotic risks in the decision-making process. This is for example the case of the Life sigAGROasesor project in Spain, which gives technical information at the crop management unit level and allows it to be incorporated into the decision support tool rules, in order to obtain specific recommendations for extensive crop growing (varieties, fertilisation, irrigation, pest management) (INTIA S.A., 2014). The carbon footprint calculation for agricultural parcels through GIS and its geo-database is a completely innovative feature of the project. GIS information provides more accurate data on environmental indicators for each parcel, and, at the same time sigAgroasesor is able to compile results of parcels, offering indicators for a specific production unit or the whole farm. Table 4 lists some indicators computed with this project.

Table 4: Examples of sigAGROasesor project's indicators

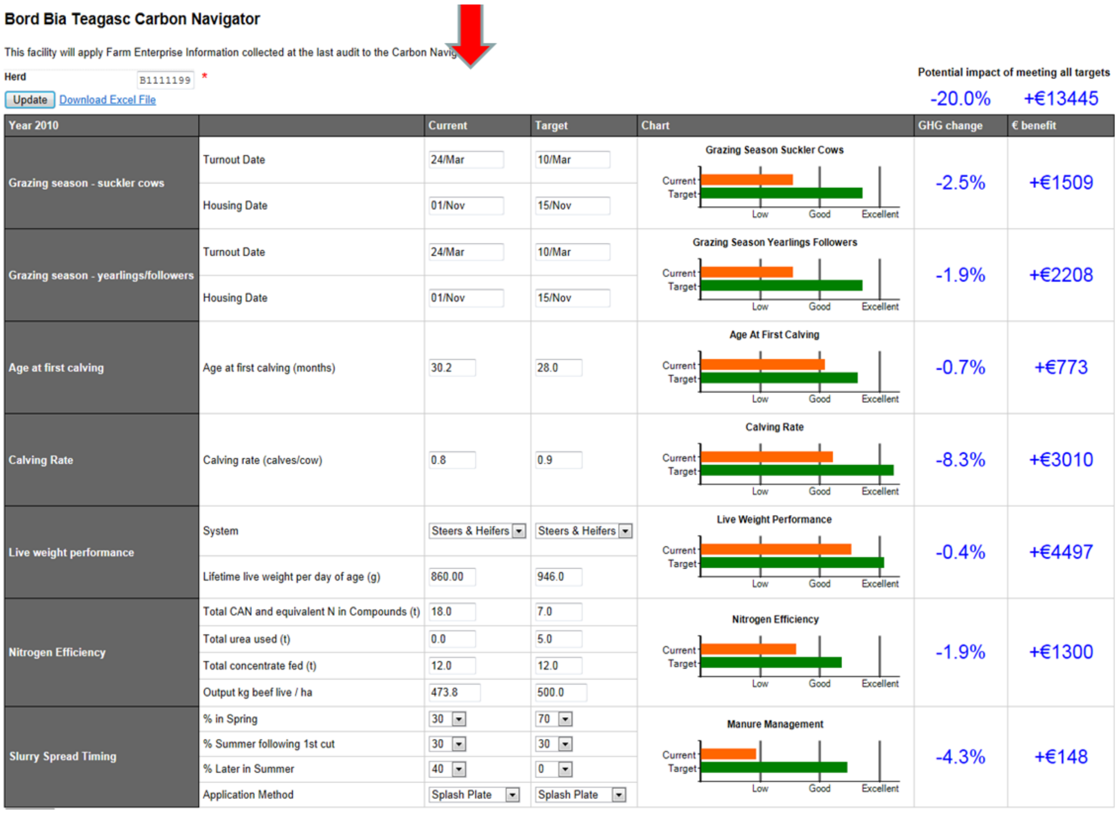
Carbon footprint indicator: direct GHG emissions; indirect GHG emissions (CO_2 equivalent)
Water footprint indicator: volume of fresh water required for a production (including volumes of water contaminated) = blue footprint + green footprint + grey footprint
Nutrient balance indicator: inputs; outputs
Energy balance indicator: direct energy; indirect energy
Psticide indicator: number of treatments; ecotoxicity

Source: adapted from INTIA S.A. (2014)

The use of models for decision support poses several methodological problems that have not yet been fulley resolved. One problem is the estimation of model parameters and this depends on the availability of farm specific data. Methods for estimating the parameters of relatively simple models are now well established. In contrast, parameter estimation remains a difficult task for dynamic models, due to the large number of parameters involved. In all cases, the quality of parameter estimates depends heavily on the quality of the database. The cost of acquiring the data required for parameter estimation is an important criterion that should be taken into account in the design of models for use in decision support (Meynard *et al*., 2002). Technological constraints also rise from this tool which is based on information technology which is not sufficiently developed on farms.

Some national initiatives make the choice of innovative units regarding the type of indicators. In Ireland the Carbon Navigator associates, for instance, carbon emissions with monetary values (see Figure 7). The Teagasc Carbon Navigator is an online farm-scale decision support system for farm advisors, to reduce GHG emissions from livestock production systems. It uses simple farm-scale indicators of practice adoption (that are underpinned by general scientific relationships) to provide a knowledge transfer tool that reinforces technical efficiency. It enables advisers and extension workers to provide technical advice, and is focused on practices' change that is scientifically proven to lower emissions. A key feature of the Carbon Navigator is that it can identify win-win practices that also improve financial performance. It requires relatively simple input data, and is efficient to use and easy to understand. The approach involves some simple benchmarking, whereby the individual farmer can see their performance in relation to other farm performance in their region. The approach can be complementary to and dependent on a more holistic measuring and modelling exercise. Note that it adopts an LCA approach and is focused on emissions intensity (emissions per unit output of product).

Figure 7: Examples of outputs from the Irish Carbon Navigator


Bord Bia Teagasc Carbon Navigator

This facility will apply Farm Enterprise Information collected at the last audit to the Carbon Navig

Herd B1111199 *

Update Download Excel File

Potential impact of meeting all targets -20.0% +€13445

Year 2010		Current	Target	Chart	GHG change	€ benefit
Grazing season - suckler cows	Turnout Date	24/Mar	10/Mar	Grazing Season Suckler Cows	-2.5%	+€1509
	Housing Date	01/Nov	15/Nov			
Grazing season - yearlings/followers	Turnout Date	24/Mar	10/Mar	Grazing Season Yearlings Followers	-1.9%	+€2208
	Housing Date	01/Nov	15/Nov			
Age at first calving	Age at first calving (months)	30.2	28.0	Age At First Calving	-0.7%	+€773
Calving Rate	Calving rate (calves/cow)	0.8	0.9	Calving Rate	-8.3%	+€3010
Live weight performance	System	Steers & Heifers	Steers & Heifers	Live Weight Performance	-0.4%	+€4497
	Lifetime live weight per day of age (g)	860.00	946.0			
Nitrogen Efficiency	Total CAN and equivalent N in Compounds (t)	18.0	7.0	Nitrogen Efficiency	-1.9%	+€1300
	Total urea used (t)	0.0	5.0			
	Total concentrate fed (t)	12.0	12.0			
	Output kg beef live / ha	473.8	500.0			
Slurry Spread Timing	% in Spring	30	70	Manure Management	-4.3%	+€148
	% Summer following 1st cut	30	30			
	% Later in Summer	40	0			
	Application Method	Splash Plate	Splash Plate			

Source: Carbon Navigator (2014)

4.1.3 *Ex-post* analysis

4.1.3.1 The case of GHG emissions assessment

National initiatives examined here using *ex-post* analyses mainly deal with climate change mitigation focusing specifically on the assessment of GHG emissions and energy consumption. The 'Climate Friendly Agriculture' report (AgriClimateChange, 2013) presents results of the evaluation of non-renewable energy consumptions, GHG emissions and variations in carbon storage carried out over a year at the farm level: the energy and GHG emissions of 118 Spanish, German, Italian and French farms were calculated using farm bookkeeping and invoices. To assess GHG emissions and energy consumption, data collected included CAP payments, notebooks recording fertiliser and pesticide spreading, and invoices for fuel or electricity and for the main inputs used on the farm.

In agriculture, three main GHG's are assessed - CO_2 (carbon dioxide), CH_4 (methane) and NO_2 (nitrous oxide) under the Kyoto protocol. Direct emissions of CO_2 arise from the use of oil, diesel, electricity, natural gas, propane, butane. By contrast, indirect emissions come from the production of external inputs (mineral and organic fertilisers, pesticides, seeds, etc.) and are in some studies calculated independently from direct emissions. Data on consumption of fertilisers and plant protection products (product type, name and dose) can be obtained from technical operation or financial documents. Data on animal purchase (number and type) and feed purchase (quantity and type) may be indicated by farmers or extracted from accounting data. Data on equipment are given by farmers. GHG emissions generated after the products have left the farm are usually not included in the calculations (e.g. meat processing and transport). GHG emissions associated with buildings and machinery are also excluded

from most analyses as it is often assumed that they do not differ across the various farming systems studied.

In most studies calculating GHG emissions, the methods used are accounting methods such as LCA (e.g. Casey and Holden, 2005a and 2005b, in Ireland; Dolman *et al*., 2014, Kool *et al*., 2010, in the Netherlands; Zafiriou *et al*., 2012, in Greece) or Intergovernmental Panel on Climate Change (IPCC) methodology (e.g. Aguilar *et al*., 2013, in Spain; Ryan *et al*., 2014, in Ireland). LCA methodology assesses the environmental impacts of a system or a product from 'cradle to grave'. It is appropriate for agricultural systems because it gives boundaries for the system studied (Audsley *et al*., 1997; Cederberg and Mattsson, 2000; Haas *et al*., 2001). For agriculture, the IPCC method quantifies GHG emissions within the farm gate only. Emissions associated with inputs imported onto the farm (e.g. animal feed, fertiliser, animals) are not taken into account. N_2O-emissions are also often calculated based on the IPCC-approach.

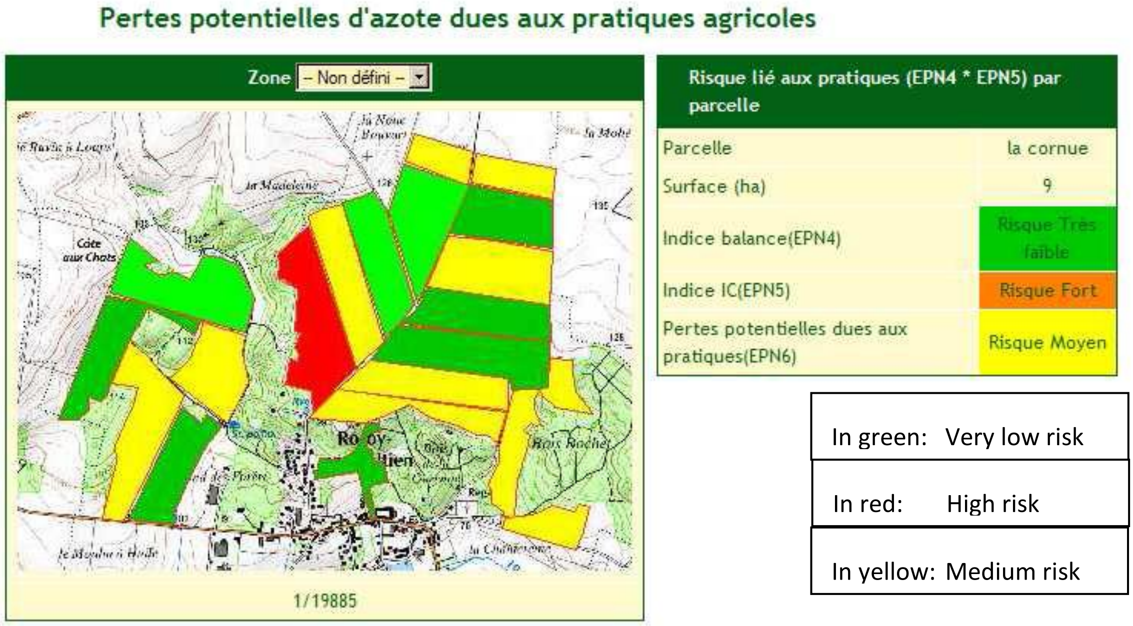
Energy consumption and GHG emissions assessment studies cover a large diversity of farming systems: pig production (Kramer *et al*., 2006, Kool *et al*., 2010, and Dolman *et al*., 2012, in the Netherlands; Aguilar *et al*., 2013, in Spain), cattle production (Aguilar *et al*., 2013, in Spain), poultry production (Fortun-Lamothe, 2012, in France; Aguilar *et al*., 2013, in Spain), rabbit production (Fortun-Lamothe, 2012, in France), vegetable production (Zafiriou *et al*., 2012, in Greece for white asparagus).

4.1.3.2 Assessment at the plot scale *vs*. the farm scale

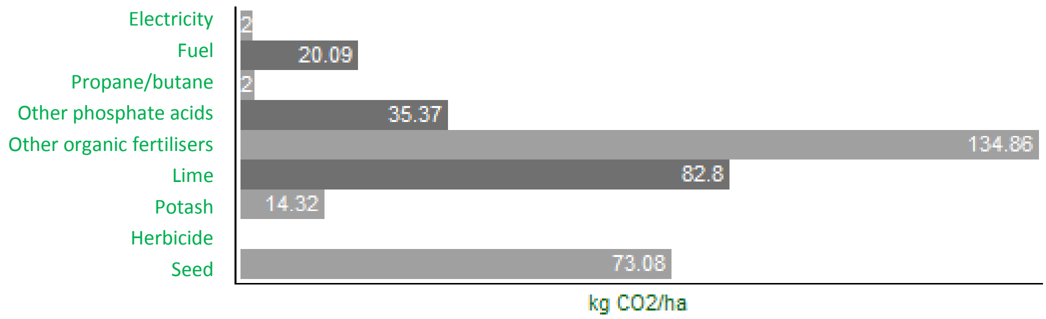
While we focus here on farm level, it should be noted that agronomists consider that nitrogen indicators (e.g. nitrogen balance, potential nitrogen losses due to agricultural practices) should be assessed at the plot level, due to the dynamics of mineral nitrogen in the soil and the requirements of the crop (Meynard *et al*., 2002). Consequent actions should also be taken at this scale. Another scale of assessment may be the inputs (cost items) on the farm (fertiliser, pesticides, fuel, etc.). Some *ex-post* farm-level methods offer the possibility of visualising the assessment results per plot and per cost item at farm level. This is the case for the French tool DAE-G (Agro-Transfert Ressources et Territoires, 2009): mainly used for global farm comparison, the tool can identify the input cost with greatest energy consumption and compute environmental indicators at the plot scale such as treatment index, risk of diffuse pollution (depth of water X pesticide use) and sensitivity of soil to leaching per plot (see Figure 8). With this detailed level of information, farmers can take concrete and localised actions on the farm.

Figure 8: Examples of results provided by the French DAE-G tool

a) Localisation of most risky plots regarding nitrogen losses



b) Identification of the input cost items that generate the highest CO_2 emissions



Source: adapted from Debomy (2013)

4.1.4 Discussions regarding indicator-based assessment methods for farm decision support

4.1.4.1 Restricted sustainability *vs.* extended sustainability

Restricted sustainability is opposed to extended (or global) sustainability. Both concepts are distinguished by the scale of analysis. Restricted sustainability is assessed at the level of the farm system, in the sense that the farm system must be sustainable in itself, using practices that ensure the reproduction of its systems. Sustainability is only viewed in terms of the future of the farm only, similar to the concept of durability, that is to say the ability of a system to last in time. By contrast, extended sustainability refers to a regional scale where all stakeholders are considered. It can be evaluated through indicators assessing the contribution of farms in the sustainability of the wider territories to which they belong.

4.1.4.2 Weak sustainability *vs*. strong sustainability

Weak sustainability characterises a situation where a farm is sustainable with regard to an issue (e.g. economic sustainability) and not sustainable with regard to another issue (e.g. environmental sustainability). A farm may be sustainable even in the case of poor sustainability performance measured by a specific indicator, if the negative effect of this specific individual indicator (for example a low level of natural resource usage) is compensated by the positive effect of another indicator. Since they are designed to measure the achievement of specific farmer's objectives, indicators used for supporting decisions tend to be individual indicators which focus on one issue of sustainability. A set of indicators is considered a superior means of measuring strong sustainability, since it would refer to various objectives. Indicators are then considered as complementary instead of interchangeable.

4.1.4.3 Adaptability to policy evaluation

Indicators initially used for farm decision supports are constructed in order to measure the achievement of famers' goals. Policy goals can nevertheless include some of these goals. For example a specific policy goals may be to reduce nitrogen spread in order to reduce water pollution, while farmers' may have the same goal but with the objective of reducing the amount of nitrogen applied and thereby reducing input costs.

4.2 Sustainability indicators to compare farming systems

Comparing the performance of one farm with other (similar or not) farms is a way to highlight the opportunities for improving production systems. The national initiatives described in this section all carry out a quantification of farm performance. A first category of initiatives compares different farming systems or different farms within one farming system, by providing a measure of their environmental, economic and social performance (benchmarking approaches). A second category of initiatives sets a level of sustainable performance via certification and labelling systems. A third category of initiatives illustrates the usefulness of farm performance indicators by identifying the factors influencing the performance of farms, thus contributing to identifying levers to improve systems.

4.2.1 Measuring the performance of farm systems

4.2.1.1 Rating the overall sustainability performance

In Spain, Arandia *et al*. (2011) use bookkeeping data from advisory centres and a complementary survey, to classify grazing livestock systems in the Basque Country and Navarra according to their sustainability. The authors calculate 98 indicators covering the three dimensions of sustainability. Batalla *et al*. (2014) use the same approach of combining bookkeeping data with complementary data collected through surveys to assess the sustainability of milk sheep production in Basque County. In this study several indicators are computed for economic sustainability (such as profitability, self-sufficiency, diversification, cost structure, stability), environmental sustainability (such as energy, nutrient balance, waste, GHG emissions, natural elements, land use), and social sustainability (job creation in rural areas, quality of life, work quality, animal welfare, landscape, traditions, product quality, nearness to consumer, gender). Indicators for each dimension are aggregated together in order to obtain three indicators per farm.

Two German initiatives, the DLG Certificate Sustainable Agriculture and the Criteria System Sustainable Agriculture KSNL, provide sustainability assessment for farms. As they are also used for certification, they are explained in more details in the next section.

Most French initiatives comparing farms in terms of performance provide a score to each farm system based on a set of indicators defining themselves as using a 'sustainable value method': it is relatively easy to compare farms based on a sustainability score. The most frequently used method is the IDEA method (Vilain, 2008; Zahm *et al*., 2008) resulting from multidisciplinary research conducted since 1996 at the initiative of the French Ministry of Agriculture. It compares farms within similar conditions (e.g. similar types of farming, similar local contexts, etc.) by attributing a score to each farm (maximum score is 100) using 41 indicators (see Table 5). Other French methods like DIAGE (FRCA Centre, 2002), DIALECTE (Solagro, 2000), DIALOGUE (Solagro, 2001) or INDIGO (Girardin *et al*., 2000) use this scoring system to measure overall or partial performance (see a review in Galan *et al*., 2007). For the environmental dimension, these methods rely on agricultural practice indicators and attribute a score to practices based, in most cases, on experts' opinions or farmer's own declarations. Scores can then be compared with national/regional benchmarks of the method. A famous French regional benchmark is Quali'Terre that identifies good farming practices in terms of nitrogenous fertilisation, land management and use of agrochemicals (Galan *et al*., 2007). More recently, the French RefAB project (Fourrié *et al*., 2013) has produced a methodological framework to generate references at the agricultural systems level in the particular case of organic farming. In RefAB the various criteria, evaluated by indicators, make it possible to qualitatively characterise organic agricultural systems.

Table 5: Indicators of the French IDEA method

Sustainability dimension	Sustainability components	Sustainability indicators
Agro-ecological sustainability	Diversity	- Diversity of annual or temporary crops
		- Diversity of perennial crops
		- Diversity of associated vegetation
		- Animal diversity
		- Enhancement and conservation of genetic heritage
	Organisation of space	- Cropping patterns
		- Dimension of fields
		- Organic matter management
		- Ecological buffer zones
		- Measures to protect the natural heritage
		- Stocking rate
		- Fodder area management
	Farming practices	- Fertilisation
		- Effluent processing
		- Pesticides and veterinary products
		- Animal well-being
		- Soil resource protection
		- Water resource protection
		- Energy dependence
Economic sustainability	Economic viability	- Available income per worker compared with the national legal minimum wage - Minimum wage
		- Economic specialisation rate
	Independence	- Financial autonomy
		- Reliance on direct subsidies from CAP and indirect economic impact of milk and sugar quotas
	Transferability	- Total assets minus land value related to non-salaried worker unit
	Efficiency	- Operating expenses as a proportion of total production value
Socio-territorial sustainability	Quality of the products and land	- Quality of foodstuffs produced
		- Enhancement of buildings and landscape heritage
		- Processing of non-organic waste
		- Accessibility of space
		- Social involvement
	Organisation of space	- Short trade
		- Services, multi-activities
		- Contribution to employment
		- Collective work
		- Probable farm sustainability
	Ethics and human development	- Contribution to world food balance
		- Training
		- Labour intensity
		- Quality of life
		- Isolation
		- Reception, hygiene and safety

Source: adapted from Zahm *et al*. (2008)

Bockstaller *et al*. (2009a) identify four groups within the diversity of previously described French methods/tools, depending on the dimension and the system evaluated:

(i) methods assessing the three dimensions of sustainability;

(ii) methods assessing the environmental dimension of sustainability at the plot or farm level;

(iii) methods assessing the environmental dimension of sustainability at the product or production of level;

(iv) methods assessing sustainability within the region.

In the context of the FLINT project, only the first two methods are considered for the French national initiatives on farm level indicators. The methods in all of the initiatives such as IDEA (Vilain, 2008), 'Arbre de l'exploitation agricole' [Tree of sustainable agriculture] (Pervanchon, 2004a), 'diagnostic du Réseau Agriculture Durable' [Sustainable Agriculture Network diagnosis] (Feret, 2004), and 'Charte de l'agriculture paysanne' [peasant agriculture charter] (Pervanchon, 2004b), deal with overall sustainability at the farm level. The three dimensions of sustainability are mainly translated into operational objectives: agro- environmental, economic and socio-territorial objectives. The agro-ecological sustainability indicators illustrate 'the propensity of the technical system to make efficient use of the environment at the lowest possible ecological cost', while the socio-territorial indicators 'assess the quality of life of the farmer and the weight of the market and non-market services rendered to the landscape and to society' and the economic sustainability indicators measure economic independence, transferability and autonomy (Zahm *et al*., 2008).

Sustainable value methods, that is to say methods providing scores to farms, were also applied in countries other than France. In a Greek study, Dantsis *et al*. (2010) identify 21 individual indicators selected from a literature review and indicators used by international and national institutions (see Table 6). They are combined into a unique indicator using the Multi Attribute Value Theory (MAVT). The first step in a MAVT analysis is the development of an attribute tree that summarises the indicators chosen. In the attribute tree the agricultural sustainability (overall goal) is divided hierarchically into the three sustainability pillars, then into lower level criteria and finally into measurable attributes. The positive or negative impact of each indicator on agricultural sustainability is specified in the model. The second step in MAVT analysis is the creation of a cardinal value for each alternative decision, elicited by the aggregated effect of all attributes. Under the assumption of mutual preferential independence of attributes the standard additive aggregation rule is used. The component value functions and the weights get values between 0 and 1 and the weights are normalised to sum up to one. The weights indicate the relative importance of the change in an indicator from its lowest level to its highest level, compared to the corresponding changes in the other indicators. All indicators are assigned linear utility functions determined by the best and worst performances of the different regions. In this study the actual range is determined by the alternatives with the largest and smallest values of each indicator based on the results of the questionnaire.

Table 6: Indicators of the Greek study relying on MAVT

Sustainability dimensions	Sustainability criteria	Sustainability indicators
Environmental sustainability	Use of fertilisers	Total quantity of nitrogen (N) applied per unit of agricultural land area (kg/ha)
		Total quantity of phosphorus (P) applied per unit of agricultural land area (kg/ha)
		Total quantity of potassium (K) applied per unit of agricultural land area (kg/ha)
	Use of pesticides	Number of replications of herbicides' applications per growing season
		Number of replications of insecticides' applications per growing season
		Number of replications of fungicides' applications per growing season
	Irrigated water consumption	Volume of water required per hectare of crop (ton/ha) (Blaney-Griddle method)
	Farm management practices	Mechanical treatment
		Agro-ecological management practices
	Type of farming system	Total utilised agricultural area under organic farming
		Total utilised agricultural area under integrated farming
Economic sustainability	Farm financial resources	Gross agricultural value
		Gross agricultural margin
	Farm structure	Crop diversity
		Holding size
		Number of holdings
	Mechanisation	Agricultural machinery
Social sustainability	Age	Age of farmer
	Education	Years of education of the farm manager
	Pluriactivity	Pluriactivity within the household (yes / no)
	Family size	Number of family members
	Agricultural employment	Human labour required per unit of agricultural land during the growing season (hr/ha)

Source: adapted from Dantsis *et al*. (2010)

Some authors recommend using indicators that are quantifiable in an objective way, such as values rather than as scores (Lebacq *et al*., 2013). Indeed, scores have no dimensional units and cannot therefore be compared with other values, observations or studies (van der Werf and Petit, 2002). Scores cannot be analysed individually but only in relation to other scores. On the other hand, in the case of mixed farms combining several types of production, such as milk, meat, and crops, expressing indicators per unit of product is a challenge in terms of allocation between the different types (Chardon, 2008). Such allocations can be made, for example, according to the economic value of the products (Basset-Mens and van der Werf, 2005), or their nutritional value in terms of protein or energy (Chardon, 2008). In terms of interpretation, the meaning of scores must be clearly specified: does the score represent a risk, an impact, an environmental performance, a negative or a positive effect (Bockstaller *et al*., 2008a)?

Previously described initiatives mainly used scores to facilitate comparisons of farms' performance but functional units can also be used for comparing farms (Lebacq *et al*., 2013). These functional units are defined according to the agricultural function we want to evaluate e.g.:

- the expression of impacts per amount of product (e.g., litre of milk, kilogram of meat) is related to the function of market goods production;
- the expression per hectare of agricultural land refers to the function of non-market goods production, such as environmental services (Basset-Mens and van der Werf, 2005);

- the function aiming to provide an income to the farmer can be taken into account, defining a third functional unit that consists of expressing impacts per income or production unit (van der Werf *et al*., 2007).

The choice of functional unit depends on the objective and the context of the evaluation (van der Werf *et al*., 2011), but also influences the relative position of farms (Lebacq *et al*., 2013). For instance, a comparison between organic and conventional milk production systems gives different results depending on the functional unit used: negative environmental impacts per hectare are generally lower for organic farms, but the impacts are fairly equivalent in both systems when they are expressed per unit of product (Halberg *et al*., 2005; van der Werf *et al*., 2011). An intensive system may consume more energy per unit of area than an extensive system, and conversely, may consume less energy per unit of product than an extensive system. Another example is given in Foley *et al*. (2011) for Ireland which suggests that an increasing stocking rate led to an increase in direct and total GHG emissions per hectare but to a reduction in GHG emissions per kg beef carcass, due to higher levels of production efficiency. Some authors recommend selecting indicators that can be expressed per amount of product and per hectare in order to evaluate the systems according to both functions (van der Werf and Petit 2002; van der Werf *et al*., 2011). For others, indicators concerning global impacts, e.g., GHG, should be expressed per unit of product, while indicators related to local impacts, e.g., eutrophication potential, should be expressed per hectare (Halberg *et al*., 2005).

4.2.1.2 Focusing on social performance

The French RefAB project (Fourrié *et al*., 2013) introduce two principles/farm properties, referring to IFOAM principles (IFOAM, 2005), to qualitatively characterise organic farms and construct references for the resilience, the equity, the autonomy, the diversity and the ecology. Indicators are thus organised according to one sustainable development pillar and according to the principles they can be associated with. Initially presented as organic specificities, the properties/principles could easily describe other types of systems. In comparison with previous methods, RefAB develop a larger amount of social indicators (see Table 7). Its sub-themes introduce new indicators, e.g., for the resilience theme, capacity to respond to global changes (adaptability), and for the equity theme, lowest wage/highest wage. Social qualitative indicators are evaluated in RefAB from open responses or using a graduated scale. For example, one of the RefAB indicators is the level of physical strain. The related question is 'How do you judge the physical strain of your work? For this question the scale of answer is very hard/hard/a little hard/not hard at all.

Family farm income is often used as an indicator of social welfare. For instance, Zegar and Wrzaszcz (2012) examine if socially-sustainable agriculture creates conditions for an increase in the competitiveness of Polish agriculture in comparison with the conventional (industrial) model of agriculture. The authors measure this socially- and also economically-sustainable agriculture using the indicator family farm income (per Family Work Unit) in relation to the average level of income in other sectors of the economy. However, there is a growing awareness that focusing on income levels fails to capture the multidimensionality of social welfare, and a more broadly based approach that encompasses a whole range of living conditions is necessary. As a result there has been an important development of social indicators that measure social cohesion, e.g. number of associations in which the farmer is involved (French RefAB, see Fourrié *et al*., 2013), collective work (French IDEA, see Vilain, 2008), as opposed to consider simply income and poverty (Dillon *et al*., 2008). Dillon *et al*. (2008) identify thus two innovative social sub-themes: the demography measured with the old-age dependency ratio and the poverty risk measured with the share of single adult households. These two sub-themes are not included in other national initiatives but were calculated using FADN data so they can be easily applied in the context of FLINT.

Table 7: Social indicators of the French RefAB method

Sustainability criteria	Sustainability criteria	Sustainability indicators	Attributes				
			R	A	D	Eq	Ec
Motivation and quality of life	Farmer's motivation to produce with organic methods	Degree of motivation	X				
	Farmer's quality of life	Perception of his/her quality of life	X			X	
Employment and work - Quality of work	Physical strain	Level of physical strain	X			X	
	Serenity / stress	Level of stress	X			X	
	Strain and peak periods	Number of peak periods	X				
		Number of on-call hours	X				
		Perception of these on-call hours	X				
		Perception of these peak periods	X				
	Sharing of responsibilities	Degree of responsibility sharing	X				
	Use of mutual assistance	Level of use of mutual assistance	X	X			
	Use of collective work	Level of use of collective work	X	X			
	Diversity of sources of mutual assistance	Number of sources of mutual assistance			X		
Employment and work - Risk / health	Risk of toxicity associated with pesticides for users	Number of spreadings per AWU who spreads, per year				X	
	Health risk of pesticide products	Pesticide pressure index				X	
	Other risks (excluding pesticides)	Presence or absence of risky practices				X	
Employment and work - Quantity of work	Amount of weekly work	Number of working hours per week	X				
	Annual rest	Number of weeks of vacation per year	X				
	Weekly rest	Number of week-ends per year	X				
Employment and work - Contribution to employment	Contribution to employment	Number of AWU per year (mean)				X	
		Evolution of the number of on farm jobs during the last 5 years				X	
		Total number of AWU per year per ha of UAA				X	
		Number of employed AWU per year per ha of UAA				X	
	Ability to generate employment	Potential on farm jobs with respect to the farm				X	
Employment and work - Quality of created jobs	Wage differentials on the farm	Lowest hourly wage/ highest hourly wage				X	
	Remuneration level of the farm head	Available farm income per family AWU				X	
	Status of employees	Type of labour contract				X	
	Local employment	Share of local employees in all employees				X	
	Sustainability of jobs	Share of recurrent seasonal employees in all employees	X	X		X	
Social links	Outside professional commitment	Number of days in a professional agricultural	X			X	

		organisation per month					
		Number of professional agricultural organisations the farmer is involved in	X		X		
	Involvement in associations linked to the environment (quantity)	Number of days per year in environmental associations			X	X	X
	Involvement in associations linked to the environment (diversity)	Number of associations in which the farmer is involved	X				
	Informal networks of knowledge through farmer exchanges	Technical exchanges between farmers (days per year)	X				
	Informal networks of knowledge via involvement in research	Involvement in research activities (days per year)	X				
	Informal networks of knowledge through advisory bodies	Receives advice by extension services (yes / no)	X				
	Informal networks of knowledge through training	Number of days per year for training and objective of these trainings	X				
	Diversity of informal networks of knowledge	Number of types of informal networks of knowledge		X			
	Relationship producer-consumer via selling activity	Number of days per week in selling activity				X	X
	Relationship producer-consumer through tourism activity	Number of days per year for tourism activity				X	X
	Interest for the relationship producer-consumer	Level of interest in the link consumer-producer				X	X
Resilience	Vulnerability	Has experienced loss of production	X				
		Threshold of loss that is considered significant	X				
		Causes and circumstances (qualitative)	X				
	Resilience and adaptability	Loss threshold beyond which an action is taken	X				
		Levers implemented to protect from global changes	X				
		Levers implemented to protect from economic risk	X				
Autonomy	Decision-making autonomy	Degree of capacity of the farmer in decision making	X	X			
		Ability of the farmer to influence prices		X			

Note: R stands for Resilience, A stands for Autonomy, D stands for Diversity, Eq stands for Equity, Ec stands for ecology. AWU means annual working unit.
Source: adapted from Fourrié *et al*. (2013)

Several works focused on the social aspect of animal welfare and health. In the Netherlands Mollenhorst *et al*. (2006) develop a method for measuring the sustainability of egg production systems based on scores/points per major themes (animal welfare and health, environment, economic performance, labour and surrounding factors). In this initiative, many indicators are specific to animal production, e.g. animal needs index, mortality rate (example of a social indicator relating to animal health), deviation from egg production curve, medication use, etc. A comparable work is provided by Hoste and van Iperen (2012) also in the Netherlands, leading to the development of additional indicators specific to animal production, e.g. antibiotics use, health protection costs, dead piglets (the latter three being examples of social indicators relating to animal welfare and health), piglet production, manure processing, manure removal costs, etc. In France, the same kind of study is done by Fortun-Lamothe (2012) on rabbit and poultry farms. The result is the development of the S+Durable method which developed animal production indicators such as the degree of melting when cooking, food costs, and mortality (example of social indicator relating to animal health). In these works, some indicators among the animal production indicators refer to animal welfare, a social issue otherwise poorly covered in selected national initiatives.

In Hungary, Tömpe (2008) study the social capital of farms, and use indicators that can relate to social sustainability: in terms of structural dimension (degree of social interrelationships, strength of social networks), and in terms of cultural dimension (identity with the community, degree of trust in the community).

4.2.1.3 Assessing economic performance

Among the selected national initiatives, few relate specifically to economic performance since we selected specific initiatives that are dealing with indicators not currently measured from existing FADN data.

Dillon *et al*. (2008) develop economic, environmental and social indicators of sustainability to present a benchmark measure of current sustainability of Irish farming. Economic indicators calculated are broadly related to farm viability, the importance of direct payments and market return from farming (e.g. family farm income minus direct payments). Many authors attempt to put the environmental performance of farms in perspective with their economic performance. Zegar and Wrzaszcz (2012) in Poland define the relationship between the level of environmental sustainability and the economic results of agricultural holdings in each type of farms system.

In Hungary and Germany respectively, Molnar (2008) and Ehrmann (2008) use as composite indicator the concept of 'sustainable value', by comparing the value added created by a company to a given benchmark as a result of efficiency difference in its capital (economic, ecological and social) use. The FP6 STREP EU-project SVAPPAS ('Sustainable Value Analysis of Policy and Performance in the Agricultural Sector') was initiated in 2007 to further elaborate the Sustainable Value method developed by Figge and Hahn (2004a, 2004b and 2005) and apply the method in the agricultural sector. The project also aimed to check usability of data from the EU FADN for Sustainable Value analysis. The Sustainable Value method is rooted in financial economics and thus applies an investor's lens to resource use. It focuses on the allocation of resources between users, answering the question of resource allocation across firms in order to create value. The link between corporate production and sustainability is established through the consumption of resources. Resources can be further decomposed into natural capital, which relates to nature's goods and services and includes for example land, manufactured capital, such as buildings and machines, human capital, referring to skills and knowledge, and social capital, which is based upon the networks and relationships between humans. Sustainable value distinguishes from traditional financial analysis as it decomposes resources in these different capital forms. It also takes the non-commodities and intangibles necessary for production into consideration. Capital theory rests upon the constant capital rule, which states that for a flow of income to be sustainable, the stock of capital needs to be constant or increasing over time. In capital theory, a distinction is made between strong and weak sustainability. Strong sustainability is attained when critical stocks of each capital form are maintained. Weak sustainability allows substitution between capital forms, as long as total capital use is sustainable. The Sustainable Value method is based upon strong sustainability principles as it does not allow extra consumption of capital employed in the economy. The value oriented perspective of the Sustainable Value method is complementary to the burden oriented perspective. While many methods seek ways to monetize and reduce the burden caused by production, Sustainable Value assesses the value created for a given environmental and social burden. This new lens allows the user to decide where capital forms

should be invested to create maximum value. Capital is considered a scarce resource and therefore, following the logic of financial markets, capital should be allocated where its use is most efficient. The opportunity cost of the firm's capital is the value created by the foregone mark*et al*ternative. As the Sustainable Value method considers social and natural capital, market prices are often not available or ill-defined. The opportunity cost principle is used to overcome this. Given the financial perspective, opportunity costs are defined at the level of the economy as a whole. The underlying idea is that a risk averse investor considers the market as the best available investment alternative for a firm.

In the Netherlands, to gain insight into a possible trade-off between economic and environmental sustainability, Thomassen *et al*. (2009) quantify the relationship between the environmental and economic indicators of dairy farms using LCA, and identify farm characteristics that influence this relationship. This improves the understanding of the relation between the economic viability and the environmental impact of milk production. The farm characteristics identified by the authors as influencing the relationship between the environmental and economic indicators are milk production per ha, annual milk production per cow, farm size and purchased concentrates per 100 kg fat-and-protein-corrected milk. High labour productivity on dairy farms is associated with low on-farm energy use, total and on-farm land use, total and on-farm global warming potential and total and off-farm acidification potential per kg fat-and-protein-corrected milk. High on-farm eutrophication and acidification potential per hectare are also related to high labour productivity. Finally in Ireland, Ryan *et al*. (2014) observe that on average, the more intensive and better performing farms, in terms of economic performance, generate less GHG emissions when compared to their less intensive counterparts and produce higher nitrogen surplus per hectare. Also, more intensive farms produce more milk per kg of nitrogen surplus. Similar analyses have been conducted for other sectors (Dolman *et al*., 2012; Koeijer *et al.*, 2002).

4.2.1.4 Quantifying environmental performance

Input Output Accounting systems (IOAs) are commonly used to assess environmental performance. Goodlass *et al*. (2003) surveyed 55 European IOAs and reported that the subjects covered by the IOAs include nutrients (N, P, K), pesticides, energy, soil and habitat conservation, waste (e.g. packaging and tyres) and other items such as veterinary products. Nutrient budgets are the most common subject, in 91% of the IOAs studied. Almost half the IOAs covered more than one subject. Most systems dealing with one single subject (26 out of 30) cover nutrients, compared to pesticides (3 out of 30) and energy (1 out of 30). The most common indicator for nutrient budgets is nutrient balance (53%) followed by nitrate leached (13%). Not all farming sectors are covered by the IOAs with arable, dairy and pig sectors the most common. As noted by Lebacq *et al*. (2013), not all indicators are suitable for comparing farms (or farming systems) due to the variation in production type (e.g. arable *vs*. livestock).In particular, nutrient balance can be used for comparison only if farms have a comparable production type and intensity.

In the previous section we presented studies assessing energy and GHG emissions designed to support farmers in their decision making. However, this evaluation can also be used to construct a reference which will give farmers an indication of their performance in relation to other comparable farm systems. Sintori *et al*. (2013), using a mathematical programming approach, calculate the overall GHG emissions of Greek sheep farms and the distribution of emissions by main sources. Results highlight for example that in semi-intensive farms enteric fermentation is responsible for 83% of the total GHG emissions, the respective figure being 91% for extensive farms.

Some national studies focus their environmental performance analysis on organic farms. While developing organic agriculture is an objective of many governments, a large number of operators and extension workers are faced with a lack of references (technical, economic, social and environmental) and a lack of methodology. The French example for organic farms (RefAB) was presented above. In Greece, Zafiriou *et al*. (2012) evaluate the energy flow and GHG emissions of white asparagus production comparing conventional, integrated and organic farming systems. Calculated indicators include the total quantity of N, P, K applied per unit of agricultural land area, the number of replications of herbicide, insecticide and fungicide applications per growing season, the volume of water required per hectare of crop, along with characteristics of farm management practices such as crop rotation and degree of adoption of environmentally friendly practices. According to this study, organic farms are in a favourable position to reduce energy inputs and GHG emissions in an efficient way, since energy inputs

from fertilisers as a percentage of total inputs are lower in organic farms than conventional and integrated farms. Additionally, although the use of fungicides in organic farms is higher than the other farm types, their production systems consume less energy and release less GHG emissions. It should also be mentioned that organic farmers use environmentally friendly practices for insect control (traps) and weed control (machinery and manual). In the Netherlands, Kool *et al*. (2010) study the difference in CO_2 emissions between conventional and organic pig producers. The authors measure the number of kg of CO_2 equivalents using LCA. The conclusion is that organic pork has a higher carbon footprint than conventional pork because of a higher use of feed per kg of pork produced. In Greece, applying LCA to data collected from farm interviews, Litskas *et al*. (2011) compare energy flows and GHG emissions for organic farms and conventional farms in the sweet cherry sector located in or close to Natura 2000 areas. Results show that GHG emissions and non-renewable energy use as a percentage of total energy are higher in conventional farming, while labour and total energy input are higher in organic farming.

4.2.1.5 Interpretation of performance results

An important step in the designing of indicators is the definition of threshold/indicator values which allows for their interpretation (Bockstaller *et al*., 2008a; Meul *et al*., 2008; van Cauwenbergh *et al*., 2007). These thresholds are a way to distinguish preferable states from unsatisfactory states. They can be (i) absolute fixed values (i.e. minimum or maximum acceptable values), or targets (i.e. values identifying desirable conditions), or (ii) relative values (i.e. comparison of indicator values with initial value, average of the sample, regional average, desirable trends, or between sectors) (Bockstaller *et al*., 2008a; CORPEN, 2006; van Cauwenbergh *et al*., 2007). Absolute values can be scientific values, legal norms (van Cauwenbergh *et al*., 2007), or values defined by stakeholders (Bockstaller *et al*., 2008a). They involve the determination of a reasonable level for a given farm, depending on the context and the system. The advantage of relative values is that they avoid the arbitrary choice of an absolute value. They enable farms to be compared but do not determine whether they are sustainable (Bockstaller *et al*., 2008a). Boone and Dolman (2010a) make a comparison between the 25% most sustainable farms and the average of all farms.

Some methods do not clarify how the threshold values are established. An example of a method stating the thresholds is the French INDIGO method (Girardin *et al*., 2000), where the value 7, on a scale from 0 to 10, corresponds to the maximum acceptable environmental impact for researchers; or the Polish studies from Wrzaszcz (2012, 2013 and 2014) in which thresholds of composite indicators are defined based on scientific literature, standards, experts opinions as well as statistical premises. According to Mancebo (2006), the issue of thresholds is often beyond the scope of scientific reasoning and is instead a matter of societal choices.

4.2.2 Use of certifications and labelling systems

In France an environmental certification of farms ('La certification environnementale des exploitations agricoles'), created and supervised by the government, was developed to identify farms that are voluntarily environmentally friendly (Ministère de l'Agriculture, 2014). This environmental certification recognises existing French initiatives and indicators. The third and highest level of this certification system is called the 'High Environmental Value' and corresponds to four composite indicators of biodiversity, pesticide strategy, fertiliser management and water management.

Other regional initiatives in France have led to the development of certifications such as the Quali'terre label, identifying good farming practices in terms of nitrogenous fertilisation, land management and the use of agrochemicals (Galan *et al*., 2007). In the case of the DAE-G tool, scores aim at being put in the perspective of the specifications of the Environmental Management System in order to meet the requirement of the ISO 14001 standards (Agro-Transfert Ressources et Territoire, 2009).

Using similar indicator-based approaches as in the French context, in Germany in 2008 a certification system, the DLG Certificate Sustainable Agriculture (DLG stands for 'Deutsche Landwirtschaftsgesellschaft' which is the German Agricultural Society) was launched to assess farm level sustainability (via audit) and to give the farms a certificate that they can use to differentiate their products from other farms (marketing advantage for direct marketing and in the value chain,

competitiveness (DLG e.V, undated). The DLG certificate provides a final sustainability index and an index for the three sustainability dimensions (environmental, economic, sociology) based on 9 environmental indicators, 6 economic indicators and 7 social indicators. All indicator values are on a 0-1 scale, where a value greater than 0.75 is considered sustainable. Some of the environmental indicators used in the DLG certification are calculated by the model REPRO, which is used in a number of national projects (Hülsbergen, 1997; Küstermann *et al*., 2010). It is a GIS-based farm management database collecting detailed farm data on field characteristics, cropping and grassland practices and livestock production, and simulating on-farm matter fluxes, particularly nitrogen and carbon fluxes. The data is detailed enough to allow for calculation of environmental indicators. However, some long term field data, for a variety of farming systems and regional conditions necessary for the implementation of REPRO, are not available.

Also in Germany, the Criteria System Sustainable Agriculture KSNL ('Kriterien-system Nachhaltige Landwirtschaft'), managed by the Thüringer Landesanstalt für Landwirtschaft, provides farm level sustainability assessments based on 34 indicators. Certification is also possible but not the prime focus. The 14 environmental indicators are derived from the widely used approach 'Kriterien umweltverträglicher Landbewirtschaftung' (KUL) which was used in more than 800 farm assessments in Germany since 1994 (Breitschuh, 2008). KSNL is also based on 11 economic indicators and 9 social indicators. Data are collected through farm bookkeeping, subsidy application forms, invoices for inputs and sales, and a specific questionnaire of 23 pages to the farm manager; the questionnaire covers environmental and social aspects. Self-reporting farmers can enjoy reduced certification fees. As in the case of the DLG certificate, indicators are calculated on a three year average, and a certificate has to be renewed every three years.

4.2.3 Factors influencing the economic, environmental or social performance of farms

When measuring sustainable performance, some authors have gone beyond the simple categorisation of farms based on their sustainability scale (benchmarking) or the definition of a minimum level of sustainability (certification). They characterise agricultural holdings depending on their sustainability, that is to say they identify factors affecting the sustainability of individual agricultural holdings in specific types of farming systems. This can help farmers take concrete actions by focusing on these specific factors.

4.2.3.1 Examples of factors affecting farms' environmental performance

Dolman *et al*. (2012) identify farm characteristics which influence variations in the overall sustainability performance of fattening pig farms in the Netherlands. Findings suggest that a low feed intake and a ration with a high share of by-products originating from the food processing industries, positively affect the environmental performance. More recently, Dolman *et al*. (2014) benchmark the performance of dairy farms with farms that are comparable in terms of size, intensity and site-specific circumstances. Findings indicate that the internal nutrient cycle is the main determinant of the level of sustainability performance. The reason for this is that the benchmark is between the average dairy farm and farms that aim at internal recycling of nutrients.

In the Greek EU-funded DoMEsTIc project ('Mediterranean biodiversity as a tool for the sustainable development of the small ruminant sector: from traditional knowledge to innovation'), biodiversity is identified as a factor influencing the sustainability of pastoral and rangeland production systems (small ruminant sector) (Ligda *et al*., 2013; Tzouramani *et al*., 2013). Another Greek study, measures the impact of intensification on the global performance of sheep farming systems, Sintori *et al*. (2013) use a mathematical programming model to derive the optimal (in terms of profit) farm plan of sheep farms, and to estimate their socio-economic and environmental performance. The model maximises gross margin which is used as an economic sustainability indicator. Labour inputs are used as a social performance indicator and GHG emissions as an environmental sustainability indicator. Results show that the main source of GHGs in sheep farms is enteric fermentation.

In Spain, Ripoll-Bosch *et al*. (2012) apply the Mexican MESMIS tool to compare farms with various intensification levels using reproductive management as a proxy: one lambing in one year; three lambings in two years; five lambings in three years. MESMIS is a comparative sustainability evaluation comparing a reference system with one or several alternative systems: sustainability cannot be evaluated *per se* but is measured as a comparison of systems. This framework allows the derivation, measurement and monitoring of sustainability indicators as part of a systemic, participatory, interdisciplinary, and flexible evaluation process. The applicability of this tool to Spanish farms shows its capacity to be adapted to any farming system and region. The framework is based on seven systemic attributes: productivity, stability, reliability, resilience, adaptability, equity, self-reliance (see Table 8).

Table 8: Indicators and attributes of the MESMIS tool applied to a Spanish case study

Sustainability dimension	Sustainability indicators	Attributes				
		Pro.	Sta.	Ada.	Equ.	S-R
Environmental sustainability	Wildlife conflict		X			
	Communal grazing areas			X		
	Grazing				X	
	Energy efficiency				X	
	Grazing protected areas				X	
	Stocking rate				X	
Economic sustainability	Labour profitability	X				
	Animal profitability	X				
	Economic efficiency	X				
	Land productivity	X				
	Feed efficiency	X				
	Animal productivity	X				
	Lambing rate	X				
	Animals per working unit	X				
	Off-farm income		X			
	Number of incomes			X		
	Main agricultural income			X		
	Feed self-sufficiency					X
	Forage self-sufficiency					X
	Indebtedness					X
	Own area					X
	Subsidies					X
	Added value					X
Social sustainability	Local breeds				X	
	Farm continuity		X			
	Advisory services		X			
	Facilities		X			
	Land access problem			X		
	Farmer education			X		
	Distance markets			X		
	Distance slaughterhouse			X		
	Salary level				X	
	Satisfaction level				X	
	Distance to services				X	
	Hired labour				X	
	Leisure time				X	
	Family labour					X
	Own area					X
	Subsidies					X
	Added value					X

Note: Pro. stands for productivity, Sta. for stability, reliance and resilience, Ada. for adaptability, Equ. for equity and S-R for self-reliance.
Source: Ripoll-Bosch *et al*. (2012)

4.2.3.2 Examples of factors affecting farms' economic performance

Wrzaszcz (2012, 2013 and 2014) investigate factors affecting the sustainability of individual agricultural holdings in several types of farming in Poland. The results show that the coincident range and direction of the endogenous determinants facilitate simultaneous implementation of environmental and economic objectives at the farm level. Among the analysed factors, the level of farm sustainability in both aspects is positively influenced by: the area of agricultural land, the level of farmers' education, the ecological system of production, the intensity of organisation of crop and livestock production, as well as participation in investment activities. The positive effects on environmental sustainability also come from such practices as: liming the soil, agri-environmental programme participation as well as multi-orientation of agricultural production. The factors that have a negative effect include the production intensity and exogenous conditions in the form of farm location in LFA. With regard to the economic aspect, the production intensity and the farmers' agricultural education increase the probability of achieving a satisfactory result. Modelling studies show that farms focused on crop production compared to bi-oriented units stand a greater chance of achieving good economic results, at least at parity-based level. Agricultural holdings with various levels of environmental, economic and environmental economic sustainability are characterised in terms of factors of production (land, labour and capital), organisation of agricultural production (plant and livestock production), level of incurred costs and obtained subsidies, and main economic and production indicators. The relationships between economic size and the sustainability level of individual agricultural holdings in the types of farming studied are verified. The studies also examine the relationships between the friendliness of agricultural production to the natural environment and the economic results obtained from the conducted agricultural activities.

Zegar (2013) considers output per hectare of agricultural land and gross margin per annual working unit (AWU) as indicators of economic performance, and shows a major convergence of environmental and economic sustainability in Poland. Farms that are larger and economically stronger have more opportunities to invest in technologies used for protection of the environment, or to use technologies involving production extensification. Indicators calculated in this study are developed on the basis of the DPSIR model and have been implemented since 2006 as a part of the Multi-Annual Programme 2005-2009 'Economic and Social Factors Conditioning Polish Food Economy Development after Poland EU Accession'.

4.2.4 Indicator-based assessment methods for farm comparison used for policy evaluation

In general, indicators designed for farm comparison translate economic, environmental and social (positive and negative) impacts into scores without defining thresholds that distinguish between low and high sustainability. Such scores may be used for measuring policy goal achievement, but this means that the definition of the level/threshold characterising these goals is needed. The French IDEA method (Zahm *et al*., 2008) can, for instance, contribute to the implementation of the CAP mandatory advisory system by self-assessing the sustainability level of different farming systems. For policy impact assessment, a simple comparison of scores with or without the implementation of the policy could give information on the impact of this policy. However, comparing conventional and organic farming, Latruffe *et al*. (2013) note that such simple comparison could give erroneous conclusions since farms that are compared (those receiving the policy i.e. the 'treatment', and the others) may not have the same characteristics. Differences in indicator scores may thus come from other sources than the implementation of policies. For this reason the authors advise the use of 'propensity score matching' techniques where farms are compared on 'similar' farms chosen on the basis of statistical methods (Michalek, 2012; Latruffe *et al*., 2013). Optimally, a temporal comparison i.e. before and after the implementation of the policy, should be undertaken, but long term data for the same observation units (e.g. farms) are rarely available.

4.3 Sustainability indicators for farm level policy analysis

4.3.1 FADN – the most widely used source for farm-level policy analysis

The most important EU-wide monitoring and policy analysis tool delivering economic indicators at the farm level is the FADN. Given that the focus in FLINT project is on new farm level sustainability, indicators that are not yet included in the FADN and existing FADN-based reports were not explicitly included in this literature review.

For reasons of completeness, an impression of the typical studies made with FADN is given here. The FADN website[2] provides an overview of the types of studies that are prepared on the basis of FADN data, primarily by the Directorate L. 'Economic analysis, perspectives and evaluations', unit L.3 'Microeconomic analysis of EU agricultural holdings'. The presented studies comprise, for example,

- (Economic) **Impact studies of CAP policy reforms** including scenario studies for specific policy instruments, e.g. the impact of different 'greening measures' on farm costs and incomes, or the impact of different modulation[3] regimes in terms of budget released and income change per Member State.
- The annual 'EU Farm Economics Review' which provides an overview of the economic developments in the European agricultural sector regarding **income and agricultural productivity** levels, the regional distribution of these figures, and an analysis of the underlying causes of developments.
- Specific **sector reports** (e.g. for beef, cereals, dairy, rice, and others).
- Selected reports that use FADN data on rural development related topics, e.g. financial reports comparing the spending for rural development measures between the EU Member States.

Similar reports are prepared in all EU countries at the **national and sub-national scales**.

In addition, FADN data are used at least partially for various other evaluations and studies by European or national bodies, or by bodies nominated by them, e.g. for the **mid-term and ex-post evaluations** of rural development measures (for example: Offerman, 2014; Vrolijk *et al.*, 2010) .

4.3.2 Evaluation of agri-environment schemes (AES)

From the national initiatives reported by the FLINT partners, the political instruments assessed most frequently are **agri-environment schemes (AES)**, and they are generally evaluated in terms of the environmental dimension (Primdahl *et al.*, 2003, in 10 Western European countries including France, Germany, Greece and Spain; Mauchline *et al.*, 2012, in 14 case studies including some in Finland, Germany, Greece, Hungary, Ireland; Kovács *et al.*, 2013, and Pesti and Keszthelyi, 2009, in Hungary; Zalidis *et al.*, 2004, in Greece; Westbury *et al.*, 2011, in Ireland; Lankoski and Ollikainen, 2013, in Finland). As part of the CAP, AES are voluntary schemes (usually of five or ten year duration) that are designed by EU Member States to promote environmentally friendly agricultural production methods. Member States are obliged to evaluate the environmental, agricultural and socio-economic impacts of their AES. For a long time, there were no agreed methodologies for assessing the impacts of AES on farms. Most research dealing with the issue has not a reliable methodology for assessing the

[2] http://ec.europa.eu/agriculture/rica/publications_en.cfm
[3] Modulation describes the transfer of funding from CAP pillar 1 (market support, direct payments) to pillar 2 (rural development).

effectiveness of AES (Kleijn and Sutherland, 2003). The Agri-Environmental Footprint project developed a common methodology to support countries in the assessment of environmental impacts of European AES. The methodology relies on an Agri-Environmental Footprint Index (AFI) measured at farm level, which aggregates agri-environmental indicators based on MCA: issues (e.g. abiotic natural resources, biodiversity, landscape quality) are associated with management (e.g. production, physical farm infrastructure, natural and cultural heritage) (Knickel and Kaspercyk, 2009). Indicators are weighted by local stakeholders, implying that indicators are farming system- and regional specific. Farms involved in an AES are compared to farms not involved. Knickel and Kaspercyk (2009) stress that focusing on the farm level is necessary since AES target the actions of individual farmers. The national initiatives listed below rely on AFI to cover topics such as natural resource protection (with indicators such as nitrogen balance and share of winter soil coverage), biodiversity conservation (with indicators such as crop diversity and share of legumes in the rotation) and landscape protection (with indicator such as visible cultural history sites).

Casey and Holden (2005a and 2005b) use LCA methodology to assess the impact of AES in Ireland comparing GHG emissions emitted by conventional farms and by farms under AES. Zalidis *et al*. (2004) use a modified agricultural DPSIR model to compare the performance results of conventional farms with those of farms participating in AES in Greece to assess the environmental impacts of AES. The modified agricultural DPSIR model includes both target values for the indicators and success evaluation criteria for the applied AES. The pressures of agriculture on the environment are expressed in the study by the use of water, agrochemicals, fertilisers, energy and crop pattern. This grouping of agri-environmental indicators presents the advantage of relying on easily obtained data and provides information about agricultural pressures, as inputs of matter and energy. This in turn leads to outputs that are expressed in terms of environmental state and ecosystem function. The study is an example of how assessing ecosystem functions in each area by using combined physical, chemical, biological and landscape indicators may be a practical and efficient approach to evaluate applied AES. Géniaux *et al*. (2009) however argue that the effects of changes in the agricultural systems caused by a policy do not follow a simple cause-effect chain, specifically when considering social effects. The authors conclude that applying the DPSIR framework could result in a biased vision of sustainable development with too much weight on environmental issues.

4.3.3 Model-based studies evaluating policy effects at the farm scale

There are also some examples of farm model-based studies for policy analysis. For example, the SEAMLESS ('System for Environmental and Agricultural Modelling; Linking European Science and Society') project has developed a computerised and integrated assessment tool for *ex-ante* impact assessment of new agricultural and environmental policies, based on indicators covering the scales of field, farm, region, the EU, and global level (van Ittersum *et al*., 2008). Farm level information is taken from FADN data and complemented by regional surveys on agricultural production practices and biophysical models. The project has developed a goal-oriented integrated framework (SEAMLESS-IF) to select indicators within <u>80 environmental, 140 economic and 11 social indicators</u> (Alkan Olsson *et al*., 2009b). Uthes *et al*. (2009) show that, in total, 31 of these indicators can be used at the farm scale (farm types). Belhouchette *et al*. (2011) and Louhichi *et al*. (2010) used the farm model FSSIM, which was developed in SEAMLESS, to evaluate different **CAP policy scenarios** (e.g. 2003-CAP reform, Nitrate Directive scenario) for France (both articles) and the Netherlands (only Louhichi *et al*.).

In the framework of the MEA-Scope project, also using FADN data, Uthes *et al*. (2011) combine agent-based modelling (AgriPoliS) and whole-farm bio-eonomic farm modelling (MODAM) to simulate <u>structural change</u> and the development of several farm-level indicators (e.g. <u>grassland use, labour requirement, livestock units, N-leaching</u>) under presence and absence of **CAP direct payments** in four EU regions in Germany, Italy, Denmark and Poland. Also using MODAM, Uthes *et al*. (2010) analyse environmental effects (risk of <u>nitrate leaching</u>) and on-farm <u>compliance costs</u> of the **agri-environmental measure** 'grassland extensification' in Germany. Schuler and Sattler (2010) apply MODAM to model the impact of CAP policy scenarios (Agenda 2000 *vs*. decoupling) on <u>farm income</u> and <u>soil erosion</u>.

Again for Germany, Ehrmann 2010 combines the farm model FARMIS with selected environmental indicators of the KUL approach to assess ecological and economic impacts of policy scenarios at the farm level (e.g. a **50% reduction of direct payments**, **introduction of a nitrogen surplus tax**).

4.3.4 Innovative evaluation studies of other policy instruments

For example in the Netherlands Vrolijk *et al*. (2009) evaluate the economic and environmental impact of different scenarios to fulfil the expected **national emission ceilings** for the year 2020.

In relation to economic impact, Wisman and Blokland's (2013) study **the impact of the government sustainability policy** in the Netherlands. The authors calculate the share of total sustainable farm investments, i.e. investments in sustainable production based on government policy (subsidies), as a share of total farm investments. This approach makes it possible to monitor sustainability policy based on fiscal measures and\or subsidies for sustainable investments in agriculture.

Bergschmidt and Schrader (2009) used the German National Assessment Catalogue for Animal Husbandry (NACAH) to evaluate the impact of **CAP farm investment schemes** on animal welfare indicators (e.g. social behaviour before and after investment) in different housing systems for dairy cows and fattening pigs.

In the Netherlands the economic and animal welfare impact of policy measures to increase animal welfare were evaluated (Baltussen *et al*., 2010).

On the grounds of the existing FADN reports and the studies reported by the FLINT partners, it can be concluded that farm-level policy analysis is most widely developed for economic impacts thanks to the existence of the FADN, followed by combined economic-environment studies while social and animal welfare are still minority topics.

Attempts are increasingly made to combine FADN with model-based results and other data sources (e.g. Ehrmann, 2010, with the KUL indicators) to provide a broader picture on farm results, particularly with regard to economic-environment relationships. However, results are often of patchy character and provide no general data foundation to assess the sustainability situation of farms EU-wide.

Different direct payment scenarios and effects of AES were more frequently studied in the initiatives reported, which is supported by a Uthes and Matzdorf (2012), who identify AES as 'by far the best-researched' EU rural development measures, while instruments with a greater heterogeneity between countries, e.g. specific rural development measures, even if they are applied at farm level, such as investment measures, are less often studied.

5 DISCUSSION

5.1 Dissemination of farm level indicators

To benefit from knowledge created by research, farmers have to be familiar with the current state of biological, technical and economic knowledge. Farmers must understand processes influencing agricultural production and aspects of the social and economic environment. In this context, it is essential that the dissemination of farm level indicators is undertaken in an understandable way. Indicator information included in the national initiatives discussed is made available to the public through three channels: the development of websites, the involvement of stakeholders in the construction of indicators (participatory approach), and the construction of composite indicators to achieve a summarised access to information. Indeed, it often seems easier for the non-scientific public to interpret composite indicators than to identify common trends across many individual indicators (Saltelli, 2007; CORPEN, 2006). Composite indicators are thus increasingly recognised as a useful tool in public communication. However, they can send misleading messages if they are poorly constructed or misinterpreted. Clear indicator presentation and dissemination should ensure the correct interpretation of these indicators.

5.1.1 The importance of knowledge transfer in the agricultural sector and for farm sustainability

Veblen (1908) identifies knowledge as the most important factor of production. More recently Floriańczyk *et al*. (2012) find a positive role for knowledge transfer and innovation on Polish farm performance. Similarly, Irish members of knowledge transfer platform/networks such as discussion groups can improve farm profit by promoting the adoption of new technologies, as reported by Hennessy and Heanue (2012). The authors find that discussion group members are more likely to adopt new technologies and best practice, which could contribute to higher farm profits. Läpple *et al*. (2013) give evidence of the positive role of discussion group membership on farm profits in Ireland by comparing the dairy gross margin per forage area between participatory and non-participatory farms. Measuring participation in knowledge transfer programmes as an indicator of sustainability is an example of a key input indicator which supports farm sustainability.

Some French initiatives account for the role of knowledge transfer in the sustainability of farms by defining social indicators measuring the social links of farmers in knowledge networks. For example RefAB (Fourrié *et al*., 2013) uses nine social link indicators: number of days per month in a professional agricultural organisation, number of professional agricultural organisations in which the farmer is involved, participation in environmental associations (number of days per year and number of associations), technical exchange between farmers, involvement in research programmes in days per year, relationship with extension offices, number of training days per year, and number of types of informal knowledge networks. The French initiative DAESE (Lesieur, 2013) includes information on knowledge access in the calculation of some of their indicators: for example the indicator regarding decisions on pesticide spreading is a qualitative indicator which takes into account subscriptions to mail or agricultural technical information bulletins and the use of technical advice services by farmers.

5.1.2 Dissemination of farm level indicators

5.1.2.1 On websites

Some of the national initiatives have led to the creation of websites which help promote projects and more generally sustainability. The German DLG certification website presents 25 fully certified farms (DLG e.V., 2014). In the Netherlands the Agrimatie website, based on the augmented FADN data, presents different indicators per sector and for a wide range of sustainability issues (LEI Wageningen UR, 2014). The EconomyDoctor is a Finish analysis/reporting environment and web service platform which hosts about 15 different web services including FADN results of all Member States, as well as profitability and solvency indicators based on FADN results (MTT Agrifood Research Finland, 2014). An example of financial ratios for France and Finland is shown in Table 9. In France the PLAGE platform ('Plateforme d'évaluation Agri-Environnementale') launched in January 2008 and inspired by the COMETE study, supports agricultural stakeholders in the selection of the most relevant sets of indicators, or methods, for agri-environmental impact evaluation (PLAGE, 2014). In this platform 18 methods are currently described, eight of which are at farm level: e.g. DAESE (100 indicators) (Lesieur, 2013) and IDEA (42 indicators) (Zahm *et al*., 2008) regarding global sustainability; DAE-G (103 indicators) (Agro-Transfert Ressources et Territoires, 2009) and EDEN (van der Werf *et al*., 2009) assessing more than three environmental themes. Methods are selected with a decision tree based on the following criteria: environmental issue or dimension of sustainability, production type, soil and climate conditions, purpose of the evaluation, type of indicators, data collection scale, data retrieval scale.

These websites provide free access to indicators. And since there is no direct exchange between users and the indicator developers, indicators are carefully presented to avoid misinterpretation.

Table 9: Example of economic indicators provided by the EconomyDoctor website

Financial Ratios	2010		2011	
	France	Finland	France	Finland
Farms represented	295,02	39,17	295,05	39,62
Farms in sample	7,000-8,000	500-1,000	7,000-8,000	500-1,000
Arable land	87.1	55.0	87.6	54.3
Livestock Units	71.5	28.4	73.3	28.4
Farm Net Income	43,199	23,907	46,738	21,445
divided by (Wage Claim	29,893	29,765	30,041	29,286
+ Interest claim)	7,737	7,35	7,798	7,968
= Profitability Ratio	1.15	0.64	1.24	0.58
Farm Net Income	43,199	23,907	46,738	21,445
- Wage Claim	29,893	29,765	30,041	29,286
= Net Profit	13,306	-5,858	16,697	-7,841
divided by Net Worth	241,34	272,951	251,352	286,637
= Return on Equity	5.5	-2.1	6.6	-2.7
Farm Net Income	43,199	23,907	46,738	21,445
- Interest claim	7,737	7,35	7,798	7,968
= Annual earnings	35,462	16,557	38,94	13,477
divided by Unpaid labour input, hours	2,353	2,177	2,309	2,119
=Hourly earnings	15.1	7.6	16.9	6.4
Hourly wage claim	12.7	13.7	13.0	13.8
* Profitability Ratio	1.1	0.6	1.2	0.6
= Return on labour	14.6	8.8	16.1	8.0
Interest rate	3.2	2.7	3.1	2.8
* Profitability Ratio	1.1	0.6	1.2	0.6
= Return on asset	3.7	1.7	3.8	1.6

Source: MTT Agrifood Research Finland, 2014

5.1.2.2 Through participatory approaches

In the literature, two methods of stakeholder participation in the production of sustainability indicators are discussed: 1) where stakeholders have a say in the design and development of indicator systems, and 2) in the collection of data needed for the calculation of indicators (Mascarenhas *et al*., 2010). For instance in Poland Wrzaszcz (2012, 2013 and 2014) completes a quantitative analysis by interviewing farmers to get their opinion on selected issues. The purpose of the research is to recognise the attitudes of farmers towards agri-environmental measures, including their knowledge related to the effects of agricultural production on the natural environment – both legally regulated practices, and practices consistent with other principles of correct agricultural management but without reference in legal documents. The issues included indirectly allow for a verification of the level of environmental awareness of respondents and the identification of incentives that influence their attitudes. Respondents' opinions regarding the possibilities of developing their farms and the need to raise and supplement professional qualifications are also collected. The last part of the survey relates only to the economic aspect. Farmers assessed the economic situation in terms of the capability to satisfy (finance) the needs related to their household and agricultural holding, as well as subjective determinants of the standard of living.

According to Knickel and Kasperczyk (2009) the involvement of stakeholders is crucial in regionally customised indicators such as the AFI. In their study of AES effectiveness, the authors observe that stakeholders could reach consensus even on issues thought to be controversial, such as biodiversity or groundwater protection, if the process is carefully organised.

5.1.2.3 The role of composite indicators in the dissemination of the concept of sustainability

By aggregating and simplifying information: composite indicators help indicator-developers to extend indicator use and influence from the small circle of experts to wider audiences. National initiatives have proposed multiple approaches for constructing composite indicators. A review by Bandura (2008) cites more than 160 composite indicators. It may be difficult to choose the one that fits both the purpose of FLINT while also being easily applied to FADN data. Even with careful construction of composite indicators, there is a risk of subjectivity stemming from specific decisions taken for their construction since there are 'no universally accepted scientific rules' (Dobbie and Dail, 2013). To avoid bias due to these choices, some methods apply the rule of key constraints and define the lowest score of the three dimensions as the final sustainability value, e.g. the French IDEA method (Zahm *et al*., 2008). Using an all-inclusive single score based on a combination of the three dimensions allows for compensation across the dimensions. The minimum of the three performances (economic, social and environmental) may be the most accurate representation of the overall sustainability of the farm (Pingault, 2007).

Composite indicators can be seen as a means of initiating discussion and stimulating public interest. In facing the complexity of composite indicators, stakeholders generally do not read methodological notes and caveats. Therefore, their interpretation of results is largely based on the key messages transmitted through summary tables or charts. Composite indicators provide a starting point for analysis, which has then to be deepened by going back to the detail, and this presentation phase can affect the relevance of the indicator and also its interpretability. Too often the presentation phase is put aside limiting the use of methods to research applications and limiting the audience for their products and their overall impact.

5.1.3 Presentation and visualisation of indicators

Indicators must have the capacity to communicate information to stakeholders quickly and accurately. With narrative description there is an onus on the reader to make a decision on the relative importance of the text (Rice, 2003). In addition, variations in personal perceptions and language could distort the message. For these reasons, visuals such as tables and figures may be more effective. Therefore those developing indicators need to decide for each situation whether to include a table or/and a graph (Tufte, 2001). There is no recommended way of presenting individual and composite indicators, which is

why they are visualised or presented in a number of different ways in national initiatives. The following discusses examples of graphical presentations of indicators.

A tabular format is the simplest visualisation for indicators which can be presented as a table of values (see for example Figure 9). Tables are a comprehensive approach to displaying results but they may be too detailed and not visually appealing. However, they can be adapted to show targeted information for sets of farms grouped into types of production or systems (e.g. livestock *vs*. crop, intensive *vs*. extensive systems, organic *vs*. conventional farms).

Figure 9: Example of tabular presentation of individual indicators per farm

Target environmental impact reduction (%) for the inefficient farms.

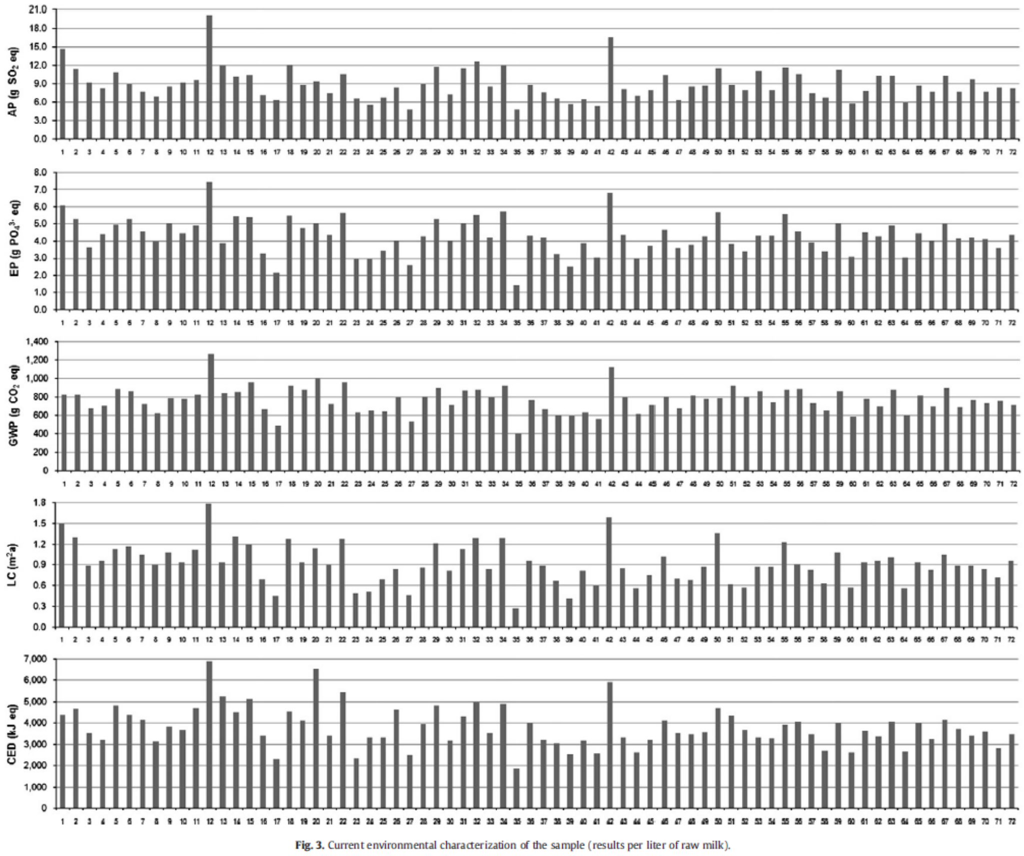
	Environmental impact reduction (%)				
	AP	EP	GWP	LC	CED
Fam 2	37.6	27.0	23.8	31.4	31.2
Fam 5	50.1	68.0	52.5	71.3	57.7
Fam 9	23.4	31.8	25.0	32.6	26.1
Fam 11	42.5	62.4	46.0	66.7	53.7
Fam 12	72.9	77.5	66.1	80.9	69.2
Fam 13	48.4	52.3	47.1	55.5	55.7
Fam 15	47.4	68.6	55.5	71.6	59.1
Fam 16	25.9	40.1	30.0	43.5	34.7
Fam 18	52.6	62.8	50.0	66.0	49.9
Fam 19	38.4	41.5	37.7	44.3	35.7
Fam 20	44.1	60.2	54.8	67.2	65.8
Fam 21	15.2	20.6	18.4	18.5	13.7
Fam 22	48.1	68.6	54.9	72.2	60.4
Fam 25	18.9	27.1	19.9	29.4	29.0
Fam 26	36.7	52.8	42.3	56.6	52.8
Fam 28	34.0	48.0	36.4	53.3	44.4
Fam 29	58.5	72.4	54.5	77.5	60.8
Fam 31	43.3	40.7	28.2	46.8	24.7
Fam 32	61.3	73.3	53.3	78.8	61.7
Fam 33	42.6	65.4	48.8	67.3	45.5
Fam 34	59.3	74.5	55.8	78.8	60.9
Fam 36	36.9	56.2	41.2	61.9	46.9
Fam 38	25.1	52.6	30.8	56.9	36.6
Fam 42	70.7	78.6	63.6	82.9	67.9
Fam 43	27.5	26.5	27.0	24.8	19.8
Fam 45	38.7	58.6	41.9	61.3	39.3
Fam 46	53.4	68.5	49.2	73.4	53.7
Fam 48	43.1	61.9	50.0	60.7	45.9
Fam 49	34.9	55.3	40.9	57.5	40.2
Fam 52	39.0	25.5	34.3	21.8	34.2
Fam 56	53.8	67.8	54.1	70.0	53.1
Fam 59	50.2	53.7	42.7	58.0	42.4
Fam 61	34.2	48.5	36.7	51.8	37.7
Fam 62	43.0	31.7	17.1	43.1	25.2
Fam 63	45.0	57.4	45.7	58.9	44.9
Fam 64	10.3	4.33	8.90	0.90	2.28
Fam 65	43.0	65.1	48.5	68.9	51.3
Fam 66	31.2	40.8	29.1	44.3	29.2
Fam 67	45.4	61.1	48.7	64.0	48.0
Fam 69	43.3	35.1	31.0	39.4	27.5
Fam 72	33.1	39.7	27.0	46.4	30.7

Note: impact categories are acidification (AP), eutrophication (EP), global warming (GWP), land competition (LC) and cumulative non-renewable energy demand (CED).
Source: Iribarren *et al*. (2011)

Indicators can also be expressed as a simple bar chart (see Figure 10). Farms are usually on the horizontal axis and the values of the indicator on the vertical axis. A specific bar can sometimes indicate the average performance of farms and enables the reader to compare a specific farm to the top performing farms (leaders), the bottom performing farms (laggards) and the average farms. Bar charts can also be used to display the contribution of each indicator for one specific issue (see Figure 11). The

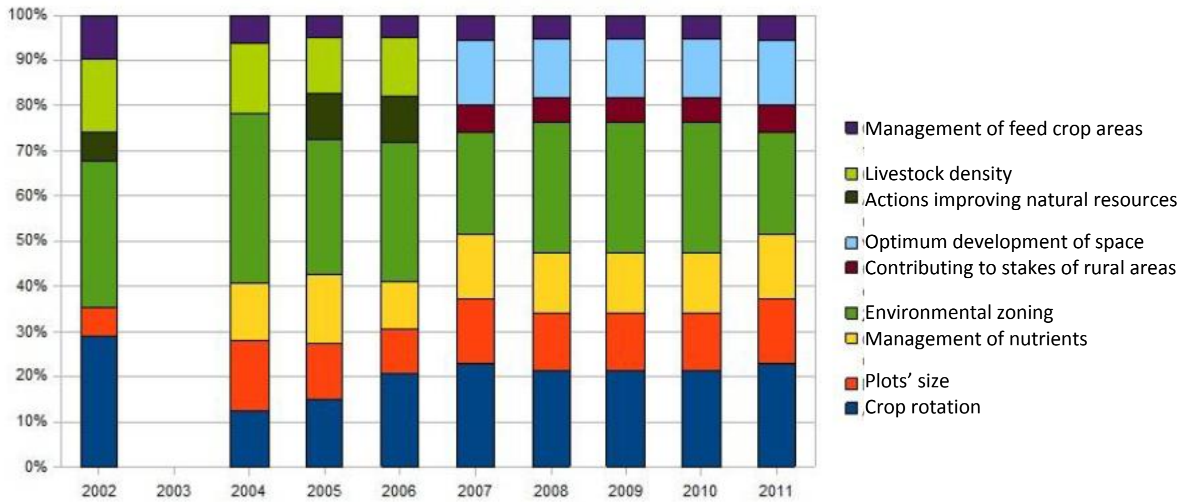
use of colours can make the graph more visually appealing. In the French IDEA method for example, the ranking of the farms (in white on Figure 12) is based on the maximum score a farm could theoretically have for each dimension (100).

Figure 10: Example of bar chart presentation of individual indicators per farm



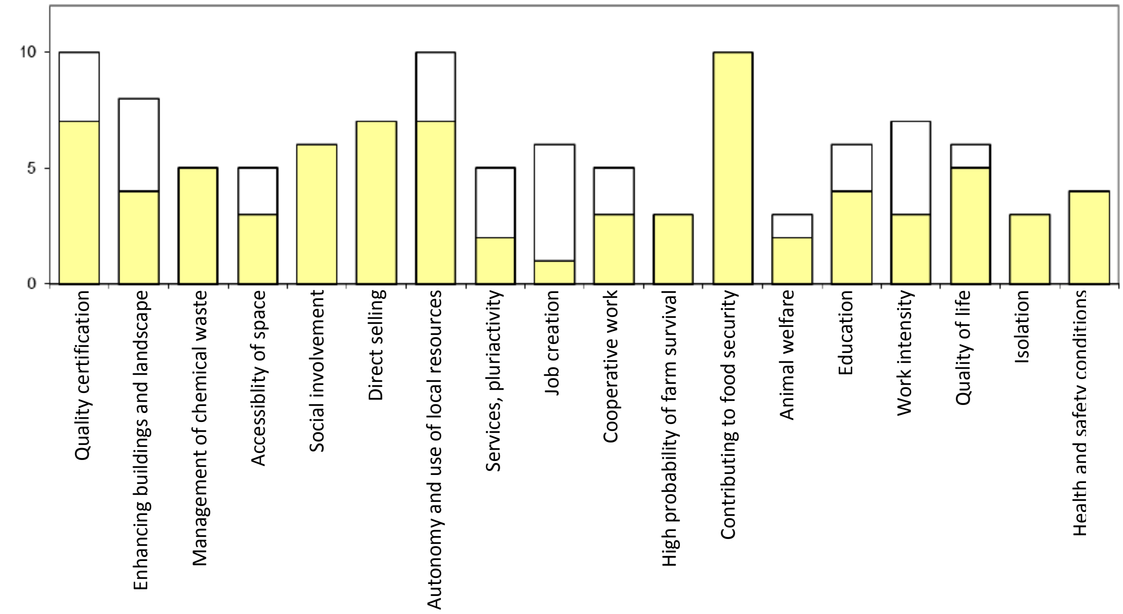
Note: impact categories are acidification (AP), eutrophication (EP), global warming (GWP), land competition (LC) and cumulative non-renewable energy demand (CED)
Source: Iribarren *et al*. (2011)

Figure 11: Example of bar chart presenting, for one farm, the evolution of the contribution of indicators in the component of organisation of space



Source: adapted from Agrocampus Ouest (2011)

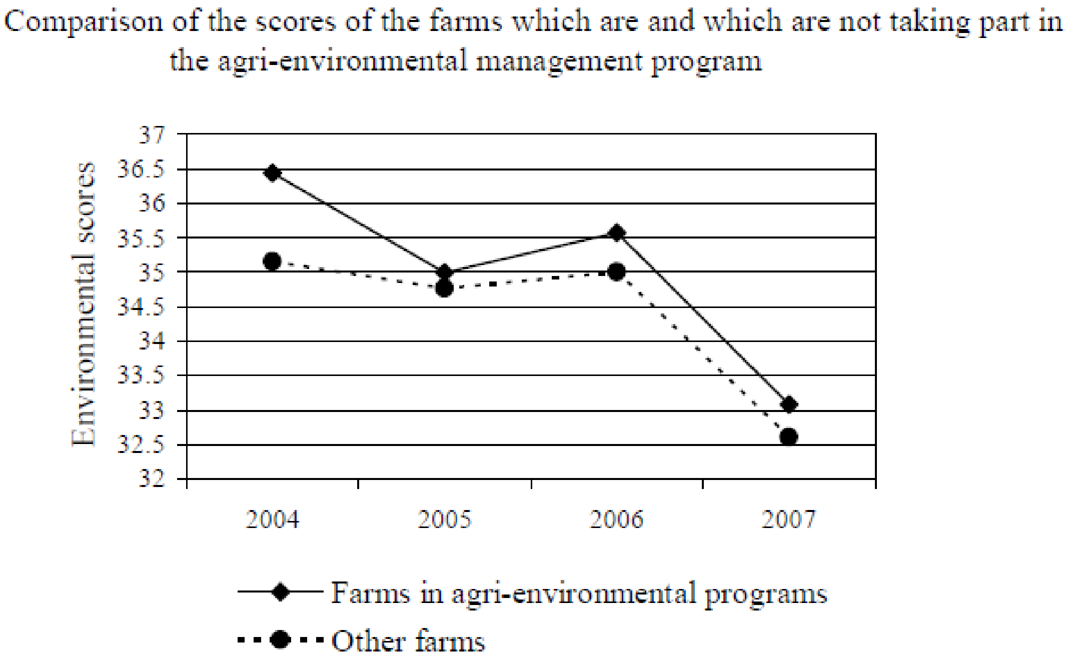
Figure 12: Example of bar chart presentation of social indicators for one farm



Note: the farm computed value is in yellow, while the farm theoretical value (maximum possible) is in white.
Source: adapted from Agrocampus Ouest (2011)

Line charts can be used to illustrate the changes in the value of indicators across time. The values for different (groups of) farms (or different indicators) are shown by different colours and/or symbols. The indicators can be displayed using, for example, absolute levels, absolute growth rates (e.g. in percentage points with respect to the previous year or several past years), indexed levels, and indexed growth rates. When indexed, the values of the indicators are linearly transformed so that the value for a given year is a specific integer (e.g. 100) (see Figure 13).

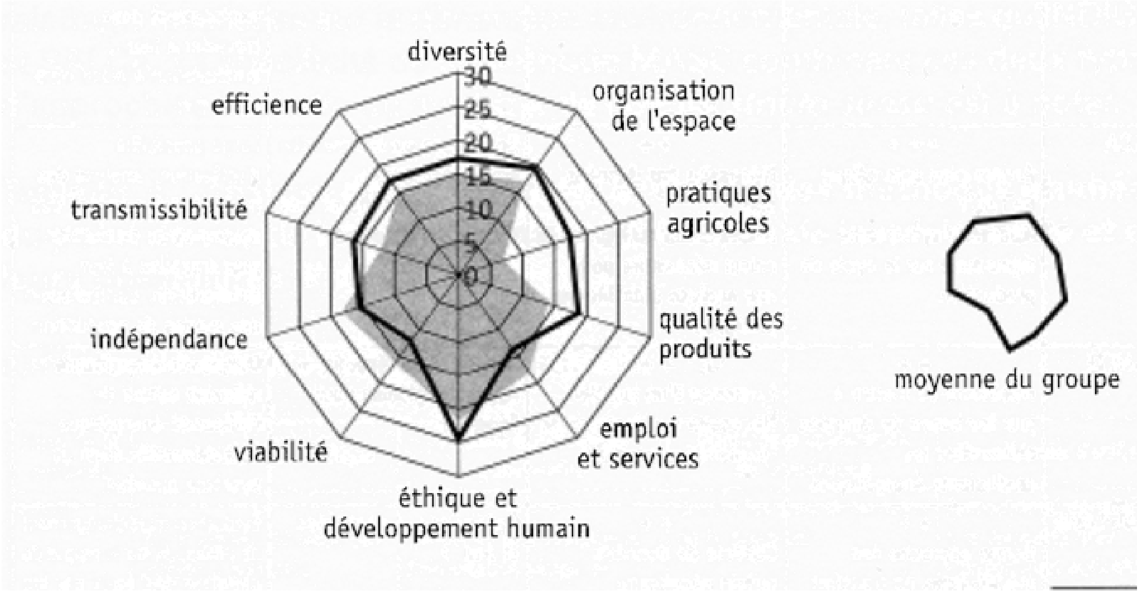
Figure 13: Example of line chart presentation of composite indicator



Source: Pesti and Keszthelyi (2009)

Another way of illustrating country performance is to use spider diagrams or radar charts (see Figure 14 and Figure 15). Results for an indicator or a set of indicators can be presented in this way which is also an efficient way to represent non-equivalent information, for example when represented indicators address different themes. In a similar way Boone *et al*. (2010a) present the 25% most sustainable farms in comparison to the scores of the average farm.

Figure 14: Example of radar chart presentation of the overall sustainability of one farm



Note: The indicators are represented by the axes ('diversité': diversity; 'organisation de l'espace': land use; 'pratiques agricoles': farming practices; 'qualité des produits': products' quality; 'emploi et services': jobs and services; 'éthique et développement humain': ethics and human development; 'viabilité': viability; 'indépendance': independence; 'transmissibilité': transmission potential; 'efficience': efficiency). The farm's scores are represented by the grey shaded area. The farm group's average is represented by the fold line.

Source: Bockstaller *et al*. (2008b)

Figure 15: Example of radar chart presentations of sustainability attributes and sustainability pillars for different farming systems

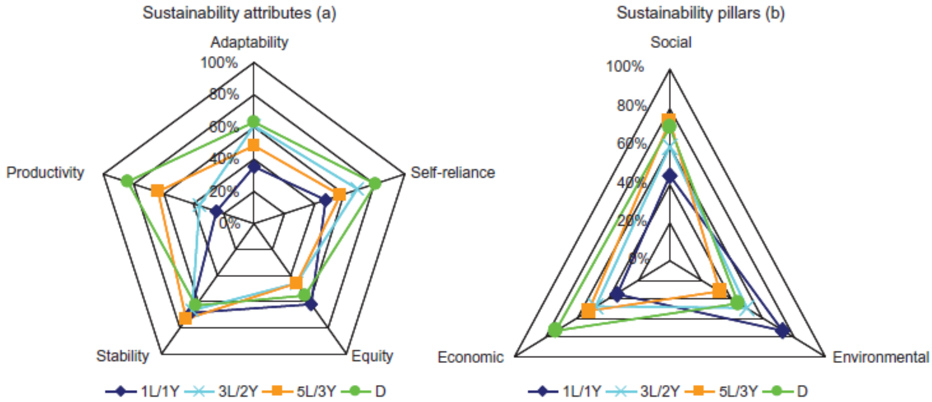


Fig. 1. Scores obtained for sustainability attributes (a) and pillars (b). 1L/1Y one lambing in one year; 3L/2Y three lambings in two years; 5L/3Y five lambings in three years; D dairy sheep.

Source: Ripoll-Bosch *et al*. (2012)

Alternative presentations used in national initiatives include the French method DAE-G which offers the possibility of mapping risk results per plot (see Figure 8 and Figure 16) (Agro-Transfert Ressources et Territoires, 2009). The Carbon Navigator also produces graphic outputs. The Carbon Navigator does not provide an overall count of GHG emissions on the farm as to do that would make it too cumbersome

and bureaucratic to be an effective tool at farm level. Instead, it focuses on distance to target by assessing current performance, comparing that performance with average and best performing farms and setting practice adoption and efficiency targets to be achieved over a three-year period. The objective of the output is to let the farmer see that by improving performance or adopting a technology he/she can both reduce GHG and also increase the profitability of the enterprise. The system outputs are graphic rather than textual and include:

- details on current performance;
- a rating of the current performance compared to average and top 10% performance in the farmer's own region/soil;
- the target for future performance;
- the financial impact of achieving the targets;
- an illustration of the potential reduction in GHG emissions at farm level based on practice adoption.

Figure 16: Example of map projection of individual indicators at the plot scale

Schlagbezogene Visualisierung der Ergebnisse am Beispiel des N-Saldos
Field-related visualisation of the results using the example of N-balance

Source: DLG e.V. (undated)

5.2 The multi-dimensional concept of sustainability

5.2.1 Imbalances in overall sustainability

Before the concept of sustainability became widespread, productivist agriculture promoted increases in yields and the evaluation of farm performance was based on yields and margin per hectare or per animal. Changes in the value system due to sustainability led to a change in the evaluation of performance: sustainable agriculture now needs to maximise the agro-ecological margin i.e. it has to

reach the potential of production with lower environmental costs (Vilain, 1997). This evolution of the concept of farm performance helps to explain why economic indicators are more easily evaluated and interpreted than ecological indicators. Some studies like the IDEA method in France made the choice to focus primarily on the economic dimension in order to express the main conditions necessary for the medium- and long-term survival of farms (Zahm *et al*., 2008). Another reason for the availability of economic indicators could be the easier calculation methods of many of them in comparison with environmental and social indicators: despite the integration of ecological concerns in the definition of performance, the evaluation of negative and positive externalities is still difficult (Vilain, 1997). By contrast, economic indicators rely on marketed goods (in opposition to non-marketed goods in the environmental and social dimensions) and uses quantitative data.

However, there is currently an imbalance in the assessment of sustainability, in favour of the environmental dimension (von Wirén-Lehr, 2001). Despite the general definition of sustainability that considers the triptych environment-society-economy, there is the 'narrower interpretation' where sustainability is only related to the environmental aspect (Pissourios, 2013). Many studies focus on environmental impacts of agricultural systems, without taking into account the economic and social components. This imbalance in favour of ecological issues can be explained by the fact that society and decision-makers are more interested in environmental issues (at the moment) and that various subthemes below this overall dimension have to be addressed. As underlined by several authors, the social aspect is the one requiring most attention in order to meet the balance between the three sustainability dimensions (Dillon *et al*., 2008; Lebacq *et al*., 2013).

Instead of developing more social or economic indicators, a solution to fill the gap could be to identify the various impacts that each indicator can assess. Authors always associate one indicator with one pillar of sustainability whereas some indicators could be used to measure other impacts. This idea should be linked with the previously introduced idea of proxy, i.e. indicators providing an indirect assessment of one pillar of sustainability. Some indicators previously described as assessing one pillar of sustainability may be used to assess other pillars of sustainability. For instance, Pesti and Keszthelyi (2009) use numerous additional environmental variables to show that Hungarian agriculture was less input-intensive in 2003-2007 compared to Western European agriculture. However, the authors explain that this is not due solely to the environment-friendly practices and policies in place, but partly to the low farm incomes that do not allow large fertiliser purchase. The detailed analysis reveals that increasing fertiliser prices would likely force rational use, which may result in a reduction of agricultural pollution. In this context, the fertiliser use indicator could thus be used as a proxy for the resilience of farms.

5.2.2 Evolution of the concept of sustainability: the role of innovation in sustainable development

As we previously outlined, the range of factors determining the performance of farms has changed over time. Recent studies have illustrated the role of knowledge transfer and innovation in the economic performance of farms (Floriańczyk *et al*., 2012). In parallel, the definition of sustainability includes the necessity to remain competitive. For this, farmers need to innovate continuously so as to adapt to market developments and changes in resource quality and availability. Innovation is a broad concept but it is fundamentally about embracing novelty, which can be 'new to the firm, new to the market or new to the world' (OECD and Eurostat, 2005). As innovations are generally specific to the farm enterprise, indicators are developed for each farm system representing innovations in farm processes, management practices (organisational forms) and farm products (Hennessy *et al*., 2013; Ryan *et al*, 2014). Van der Meer (2014) report several indicators of innovations for different farming systems in the Netherlands. Gebrezgabher *et al*. (2015), analyse the adaptation of new technologies by farmers.

At the farm level, several indicators can be associated with process innovations as they relate to the use of new production techniques, e.g. the use of improved seeds or the adoption of management practices that optimise resource efficiency. Adoption is defined here as the uptake of innovation by individuals (Leeuwis, 2004). Organisational innovations include farm partnerships and share farming (Hennessy *et al*., 2013). More efficient use of resources (including technology) reduces impacts on the environment

but also reduces production costs. In this context, Hennessy and Heanue (2012) collected data on the adoption of new technologies through participation in knowledge transfer programmes.

Products, processes or practices considered innovative in one location could be considered as widely accepted in other regions. Within the FLINT project it may thus not be relevant to define common innovative indicators regarding specific techniques at the European level.

5.3 Sustainability, CAP evaluation and FADN

In this section, we identify existing uses of FADN data for policy analysis and current and developing information needs of the evolving CAP. We conduct a simple comparison of the policy topics for which FADN collects data, and the policy topics that are relevant to farm-scale sustainability. We also point out various gaps.

5.3.1 Use of FADN data for CAP evaluation

The basis of policy evaluation is grounded in the principles of Jan Tinbergen which use targets and instruments (Tinbergen, 1952). When setting a policy target there must be a means to achieve this through the use of instruments. These instruments are sub-targets which are tailored to meet the overarching goal. The overarching goal of CAP has been evolving and changing to meet with the dynamic nature the agricultural sector is faced with.

The FADN is one such instrument which has been used in the evaluation of the CAP in relation to the income of agricultural holdings. The FADN identifies 14 high level areas under which data is collected (see Appendix A), which will be viewed here as instruments. The issues of sustainability have come to the fore as a result of the rapid changes in society, such as changing global demands from consumers and challenges for future generations in term of resources. The CAP increasingly and explicitly addresses such topics, through a variety of policy objectives.

Policies have also been formulated for judicial reasons, through regulations imposed by the EU. The reporting on policy targets is one method through which advances in the achievement of goals are identified, implemented and monitored. The concept of FADN was introduced in 1965 and given its legal basis under Council Regulation 79/65. FADN carries out a microeconomic harmonised annual survey in the Member States of the EU. The survey is primarily concerned with agriculture and the entire range of agricultural activities on farms. A key strength of FADN is that it provides a harmonised platform for the collection of farm statistics across the EU and so, data collected by Member States are directly comparable (Hennessy and Kinsella, 2013). As such, it is the only source of micro-economic data that is harmonised across the EU (Westbury *et al*., 2011). The main difficulty involved in carrying out a comparative analysis of groups of farms is obtaining comparable data and this is further compounded if analysis is at an international level (exchange rates, different accounting methods, different definitions of technical terms, etc.). The FADN guarantees the minimum coherence and homogeneity necessary for this type of approach.

The selection methodology of the FADN aims to provide representative data along three dimensions: region, economic size and type of farming. The survey only covers agricultural holdings which could be considered commercial based on size, resulting in standardised aggregate data collected across the EU. A commercial farm is defined as a farm which is large enough to provide a main activity for the farmer and a level of income sufficient to support his/her family. In practical terms, in order to be classified as commercial, a farm must exceed a minimum economic size. However, because of the different farm structures across the EU, a different threshold is set for each Member State. Consequently, the set of farms which constitute the FADN field of observation in a given country is represented by those agricultural holdings surveyed with an economic size exceeding the threshold set for that country. From 16,000 farms at its instigation, it has since undergone several important revisions (harmonisation with

new accounting methods, modernisation of data collection methods and the distribution of information) and steadily grown in size (Colson *et al*., 1998). The information collected from sample farms includes approximately 1,000 variables, which are described in a specific questionnaire called a Farm Return. These relate to (see Appendix A):

- physical and structural data, such as location, crop areas, livestock numbers, labour force, etc.;
- economic and financial data, such as the value of production of the different crops, stocks, sales and purchases, production costs, assets, liabilities, production quotas and subsidies, including those connected with the application of CAP measures.

Given the definition of the field of observation in FADN, there is a danger that certain farming activities are less well represented than others. For most countries more than 95% of the agricultural output is covered by FADN, but the percentages for the number of farmers and the hectares of land covered by FADN are lower. The FADN field of observation is defined by the Commission under Council Regulation (EC) No 1217/2009. Only commercial farms are deemed to be included. A commercial farm is defined as a farm large enough to provide a main activity for the farmer and a sufficient level of income to support his/her family, exceeding minimum economic size, using standardised output. The FADN field of observation in any Member State is defined based on the Farm Structure Survey. Farms are selected on the basis of an economic size exceeding the threshold set for that Member State. Such selection criteria must be taken into account when interpreting FADN data. In the future there may be implications for small farms classified as not economically viable. The farm may be environmentally and socially sustainable through use of non-intensive methods of farming, and may also live in the locality and so contribute to rural dynamics in a community but are not economically sustainable in isolation. If this is the case, then they are an unsustainable farm. It is often the case that an off farm income contributes to the farming activities, this situation is increasingly complex as this is not accounted for in the calculation of farm business accounts.

5.3.2 Transferability of research studies to FADN use

The harmonised nature of the FADN data offers the possibility to transfer existing national initiatives using FADN data to other Member States. Designers of data collection programmes are usually challenged to adapt existing methods to their needs and national contexts, and to develop methods to address different farming systems and heterogeneity of conditions. The challenge has at least two main components: (i) defining the local needs and context, and (ii) developing indicators that can robustly track the performance across these different local needs and contexts.

With regard to the first component, the usefulness of indicators as a policy tool must be judged within the specific context in which it is measured. The rationale for farm activities may vary across contexts for different reasons. For example, in Hungary the majority of the national agri-environmental programme funds are assigned to field crop production. This has resulted in increased fertiliser use (Pesti and Keszthelyi, 2009). The restriction imposed under the EU Nitrates directives sets a limit for nitrogen application at 170 kg/ha, which is 80% higher than the usual application rate in Hungary. Thus, such legislation does not impose effective constraint on Hungarian farms. Furthermore the low rate of fertiliser application compared to Western Europe in Hungary is not necessary based on environmentally-conscious farming but is due to the low profitability of farming. Hence, the low level of fertiliser use in Hungary may be a function of cost rather than environmental protection issues. In this context, part of the subsidies of the agri-environmental management programme was spent on fertilisers, implying that the support had leaked into the pockets of the input suppliers. It is therefore difficult to define a unique indicator when the regional context varies.

The use of indicators in new contexts should be considered, and local issues and adaptation of indicators should be outlined clearly. For Bockstaller *et al*. (2009a), French designers did not describe in sufficient detail the application areas and domains of validity of their methods, e.g. in the French DAE-G method, some indicators are based on field data (nitrogen, pesticide, erosion) (Agro-Transfert, Ressources et Territoires, 2009; Debomy, 2013). A parameterisation is usually required when a method has been developed in a given region or country and will need to take into account other specific agro-soil-

climatic characteristics or new references (new active substance, etc.). When adapting a method to a new context, it may not be needed to reassess the choice of indicators but changes in the thresholds or aggregation method may have to be designed, trialled and applied before setting methodological standards.

In the EU Agri-Environmental Footprint project, regional differences in environmental objectives were explicitly recognised (Purvis *et al*., 2009; Mauchline *et al*., 2012). Regional representatives (farmers and stakeholders) were consulted in a participatory process to assess and weight the relative importance of different environmental objectives. In a pilot survey of farms, farm-scale indicators were used to collect information on the environmental objectives, and the data used to assess the environmental impact of AES. There is certainly a transaction cost involved in conducting such participatory approaches, but they can help achieve more targeted assessment of the regional environmental pressures. As part of the post-2013 CAP, Member States are required to pay more attention to the strategic prioritisation of environmental objectives, and this could help contribute to improved clarification of differences in regional aims and targets.

Even if some indicators are common to different technical systems and could be calculated in other countries, most of them respond to a local issue. A set of indicators is not sufficient to identify and prioritise potential ways for improvement and evolution of the farm. It is necessary to understand the functioning of a farm and identify territory specific issues. For instance, in France a decrease in the corn area is often seen as an issue in the Western part of the country among dairy producers because of a local need to protect soils from erosion, percolation, inputs, etc. However, this indicator is not relevant for other areas (Vilain, 1997). Indicators related to livestock production (e.g. livestock density, use of manure, feed autonomy, local breeds) make no sense for crop specialised farms nor for granivore farms. Similarly, Wrzaszcz (2014) concludes that the analysis of specialist horticulture and specialist permanent crops farming requires a different research method that addresses the specificities of this type of production. The author did not include the agricultural holdings with permanent pasture and orchards only, because the adopted criteria for assessing the friendliness of agricultural production to the environment are essentially applied to agricultural practices carried out on arable land.

Current data collection systems can partly address this heterogeneity by including logical sequences in questionnaires whereby non-livestock systems are not required to complete questions about livestock; in future, there will probably be a need to develop similar logical sequences for other topic categories. For example, farmers may be asked whether they are participating in a European Innovation Partnerships (EIP); they would only be asked further questions about it if they are a participant. Similar possibilities apply for various other RDP measures. As the range of topics increases there will be a substantial increase in the use of such logical sequences.

5.3.3 Sustainability indicators and FADN: what is done, missing and possible?

5.3.3.1 What is currently done?

- ***Environmental, economic and social indicators with FADN alone***

It is now widely accepted that the continued existence of many farmland species, including those which are still relatively common, is heavily dependent on the maintenance of diverse agricultural practices, and the retention of a matrix of semi-natural habitats within the farmed landscape (Donald and Evans, 2006). It can be logistically and technically difficult to measure biodiversity; therefore, some studies seek to approximate a measure by identifying indicators for which the data are more easily recoverable. In many studies relating to the measurement of biodiversity, authors estimate biodiversity through practice indicators (such as livestock density, fertiliser usage, biocide inputs, farming system) and assume or look for a correlation between the two. If this reliance on practice indicators is appropriate, then this may be an advantage of the FLINT pilot study because the FADN provides more practice-based data than data on species or habitats (see Billeter *et al*., 2008; Kleijn *et al*., 2009).

In terms of economic sustainability, Colson *et al*. (1998) use FADN data for a comparative analysis of characteristics and economic performance of European cattle farms. Efficiency and productivity have also largely been assessed using FADN data (see for example Cesaro *et al*., 2009). Examples in the countries partners of the FLINT project include the works by Fousekis *et al*. (2001) and Theocharopoulos *et al*. (2007) on the technical efficiency of sheep farms in Greece, the work by Latruffe *et al*. (2012) comparing technical efficiency and productivity of French and Hungarian farms, and the works by Karagiannis and Sarris (2002), Desjeux and Latruffe (2010) and Zhu *et al*. (2011) on the impact of CAP subsidies on farms' technical efficiency in Greece and in France respectively.

Lebacq *et al*. (2013) identified social indicators such as working time, workforce, and education and indicators with a low degree of aggregation as ones which could be used as social indicators. In FADN labour is recorded as labour input based on Annual Work Units (AWU) of all individuals under the headings unpaid, regular and casual, and paid regular and casual for the farm over the year. Education of the farmer is not recorded, however if any grant was drawn down for vocational training this would be recorded. In the Farm Return this is labelled Table J (see Appendix A).

In France there has been an effort to extend and adapt the sustainability indicators in the IDEA method to assess the sustainability of the main French types of farming. This was attempted by combining the set of indicators of the IDEA method with information from the French FADN and Agricultural Census to develop the IDERICA method (Zahm *et al*., 2005; Cadilhon *et al*., 2006; Desbois, 2007). The first step involved checking if the 41 IDEA indicators could be calculated from FADN data. Then several indicators were adapted or transformed, and for other indicators values or relative weights were redefined to facilitate the computation. IDERICA indicators were validated by comparing their values with those obtained with the IDEA method on 50 French farms. For the assessment of environmental sustainability, two major IDEA indicators were missing in IDERICA: plot size and environmental zoning. For the assessment of social sustainability, due to the lack of information in FADN, the conclusions were unconvincing. As Desbois (2009) notes, IDEA should be further adapted to adjust to FADN since IDEA originated as a method for family, mixed (crop and livestock activities) and diversified (agricultural and non-agricultural activities) farms.

Westbury *et al*. (2011) use the AFI methodology in combination with Farm Business Survey (FBS) data collected in England (where FBS is the basis for FADN) and indicators were derived by approximation. For instance, amounts of fertiliser used were derived from information on the total expenditure on fertiliser and dividing this by a standard fertiliser cost to estimate an overall quantity used (Nix, 2005). This paper demonstrated that the AFI methodology can be used readily with FADN data and therefore has the potential to be applied more widely to other data sources routinely collected across the EU-27 in a standardised manner. But with more direct environmental indicators included in subsequent FADN data sets, a more comprehensive assessment of the environmental performance of different farm types could be obtained using the AFI methodology (Westbury *et al*., 2011).

- ***Environmental, economic and social indicators with FADN and complementary data***

Many national studies basing the calculation of indicators on FADN data, have to supplement the data with additional information obtained from surveys, e.g. Wrzaszcz (2012, 2013 and 2014) in Poland and Pesti and Keszthelyi (2009) in Hungary. For other, e.g. Zegar and Wrzaszcz (2012), lack of information can be supplemented by some simplification and application of agricultural production standards, e.g. use of standard coefficients to calculate production and potential distribution of natural and organic fertilisers or mineral fertiliser consumption on the basis of cost data. In Boone and Dolman's (2010b) study, for some indicators at sectoral level the choice was made to use Farm Structural Surveys data because the data was available for all farms and not just for a sample of farms. In Dolman *et al*. (2014), to benchmark the performance of Dutch dairy farms, data from the Dutch FADN is used in combination with data from the Minerals Policy Monitoring Programme which is also included in the Dutch FADN.

Dillon *et al*. (2008) examine the sustainability of farming in Ireland using FADN data to develop a number of indicators of sustainability (economic, environmental and social). The results identify a benchmark measure of the current sustainability of farming in the country. The sustainable intensification of agriculture is of particular international relevance at present and is investigated in two more recent Irish studies. A general study examined farm-level sustainability across all the farm systems (Ryan *et al*., 2014) in which a series of farm-level sustainability indicators for the sector were developed using data from the Irish 2012 Teagasc National Farm Survey (NFS). The second study examines the sustainability of

the dairy sector due to the anticipated expansion of the sector following the abolition of EU milk quotas in 2015. The environmental constraints within which production must be increased were acknowledged and the development of such indicators for 2012 served as a starting point from which future trends in the sustainable intensification of the Irish dairy sector can be examined (Dillon *et al*., 2014). These studies have used the NFS which contains farm-level data beyond what is requested in the FADN farm returns. The details include system specific data on for example inputs, costs and outputs per system as opposed to a farm-level basis. This allows for the calculation of per product emissions calculation.

In Hungary and Germany, the concept of sustainable value was applied to national FADN data, but the studies suffered from limited information regarding environmental and social sustainability (Molnar, 2008; Ehrmann, 2008). Despite the missing agri-environment data, the FADN system makes it possible to assess the farms' environmental impact to a limited extent. For example, in Wrzaszcz (2012, 2013 and 2014) some methods of indicator calculation were adapted to available FADN data, e.g. fertilisers and organic matter balances. In general, basic agri-environmental indicators of crop-producing farms can be calculated, but the indicators of farms involved in animal husbandry, horticulture and permanent crop production cannot even be estimated due to the lack of sufficient data (Pesti and Keszthelyi, 2009). Thus, availability of data depends on the farm system being considered.

In France, Samson *et al*. (2012) calculated GHG emissions and non-renewable energy use for various types of farming in the French FADN, using LCA. The authors find that livestock farms, in particular beef farms, emit more GHG than crop farms. By contrast, energy use is higher on crop farms, in particular field crop farms. Based on these FADN calculations, the authors estimate regional indicators based on regional data obtained from public statistics. They find that the regional variability is high for dairy farms when environmental indicators are considered per hectare, while it is high for crop farms when environmental indicators are considered per product unit.

- ***Indicators of innovation***

Innovation indicators identify some of the main aspects of innovation activity, classified under five headings: <u>inputs</u> to innovation, <u>actors</u> involved, the innovation <u>process</u>, the <u>outputs</u> from that process and the wider <u>impacts</u> and <u>consequences</u> (Letty *et al*., 2012). Grassroots-participatory modes of innovation are more concerned with actors and processes, the policy and management of these grassroots-participatory modes are concerned about the inputs, outputs, impacts and consequences (Letty *et al*., 2012). The Frascati Manual (OECD, 1963) identified science, technology and innovation input focused indicators, primarily focused on new knowledge created from research and development (R&D). This narrow focus failed to capture other inputs, such as engineering or marketing. As well as the indicators of output and organisational innovation, the processes (knowledge flows and interactions) are the link between inputs and outputs (Letty *et al*., 2012). The OECD published the Oslo Manual (OECD, 1992) and amended in OECD and Eurostat (2005). The Oslo Manual developed new indicators for innovation focused on non-R&D inputs, the output of innovation and the knowledge flows between actors involved in the process, and the amended document broadened its focus to account for the services industry, the differences reflected in technical novelty and knowledge flows between actors (Letty *et al*., 2012). The Netherlands monitor a set of innovation indicators on the farms included in the Dutch FADN on a yearly basis.

A joint venture between the banking sector and University College Dublin (UCD) in Ireland recently published a report (Renwick *et al*., 2014) measuring the performance of farm level innovation using Eurostat and NFS data, and the OECD indicators. The indicators developed focus on input, output and output innovation measures. Some examples relate to practice adoption, new knowledge investment (participation in technology transfer platforms) and investment in machinery renewal.

5.3.3.2 Gaps

- ***Policies***

There are broad disparities between the sample indicator topics proposed by the FLINT project and the EU policy topics on the one hand, and the topics currently available through FADN on the other hand. In other work in the FLINT project (Deliverable 1.1), a range of EU policy topics is identified that are relevant to a sustainable and competitive agricultural sector. These policy topics include:

- rural development;
- ICT for competitiveness and innovation;
- key enabling technologies;
- tourism;
- animal welfare;
- animal health;
- plant health.

Undoubtedly, rural development is a highly influential policy topic, and three long-term strategic objectives are identified for EU RDP in the 2014-2020 period:

- improved competitiveness of agriculture;
- the sustainable management of natural resources and climate action; and
- a balanced territorial development of rural areas.

These broad objectives are given more detailed expression through six priorities (EENRD, 2014a):

1. Fostering knowledge transfer in agriculture, forestry and rural areas;
2. Enhancing the competitiveness of all types of agriculture and enhancing farm viability;
3. Promoting food chain organisation and risk management in agriculture;
4. Restoring, preserving and enhancing ecosystems dependent on agriculture and forestry;
5. Promoting resource efficiency and supporting the shift toward a low-carbon and climate-resilient economy in agriculture, food and forestry sectors;
6. Promoting social inclusion, poverty reduction and economic development in rural areas.

Here, we propose a subjective assessment of some of the main policy topics that arise in the assessment of sustainability within the CAP, and the degree to which these topics are addressed by core FADN data (see Appendix A). An overview is presented in Table 10 and Table 11. Overall these point to major topics for which FADN does not collect data.

Table 10: Overview of some of the main EU policies and topics that are relevant to farm-scale sustainability

Policy	Examples of information needs	FADN coverage
<u>RDP Priority 1:</u> Fostering knowledge transfer in agriculture, forestry and rural areas	• Evidence of efforts to close the innovation gap between research and practice • Engagement in: European Innovation Partnerships (EIPs); co-operation activities; clusters or networks, and; operational groups • Incidence of trials and pilot projects to support innovation • Adoption of innovative actions • Measures to reduce risks and barriers • Increased profitability and competitiveness due to innovation • Social Return on Investment (SROI) • Co-operation operations continuing after RDP support • Agriculture holdings with RDP support for investments regarding modernisation • RDP support for business development plan for young farmers	Possibly good for those involving direct RDP payments, but otherwise very low
<u>RDP Priority 2:</u> Enhancing the competitiveness of all types of agriculture and enhancing farm viability	• Economic performance of farms • Measurement of farm structures • Measurement of farm modernisation • Degree of farm diversification • Profiles of age structures in the agricultural sector • Support for investment by young farmers	Very good coverage
<u>RDP Priority 3:</u> Promoting food chain organisation and risk management in agriculture	• Participation in quality schemes for products and food • Local and regional branding of products • Participation and contribution to short supply chains (e.g. direct sales, local markets) • Participation in producer groups • Marketing of local produce • Targeting of knowledge, training and skills for new entrants and existing producers • Targeting of financial support to assist short supply chains • Use of LEADER to support local food sectors • Participation in risk prevention and management schemes • Knowledge and information on access to RDP finance instruments other than non-repayable grants • Use of RDP finance instruments other than non-repayable grants (e.g. revolving loan fund, venture capital fund, interest rate subsidy, guarantee fund, equity fund)	Generally very low coverage in the core FADN
<u>RDP Priority 4:</u> Restoring, preserving and enhancing ecosystems dependent on agriculture and forestry	**Environment indicators*** • C31. Land cover (Crop type for example wheat barley: Table K) • C32. Less favoured areas (Majority of holding >50% response is binary Y/N: Table A Q39) • C33. Farming intensity (Possible to calculate through using Livestock units per hectare : Tables N and B)	Generally absent in the core FADN C31-34 are partially available in FADN. The issue is the level

Policy	Examples of information needs	FADN coverage
	• C34. Natura2000 areas (Available: Table A Q45) • C35. Farmland birds index (FBI) (not a farm-scale indicator) • C36. Conservation status of agricultural habitats (grassland) • C37. HNV farming • C38. Protected forest • C39. Water abstraction in agriculture • C40. Water quality • C41. Soil organic matter in arable land (current indicators are output of modelling exercise) • C42. Soil erosion by water (current indicators are output of modelling exercise) **Other possible indicators** • Proportion of farm area occupied by Natura2000 • Proportion of farm area occupied by some other legislative designation for wildlife • Proportion of farm area occupied by semi-natural habitats • Presence on the farm of a species or habitat of high wildlife value • Participation in biodiversity measures of an agri-environment scheme • Participation in water quality measures of an agri-environment scheme • Participation in soil quality measures of an agri-environment scheme • Training in issues related to wildlife or habitat maintenance • Provision of advice related to wildlife or habitat maintenance • Training in issues related to water quality • Provision of advice related to water quality • Training in issues related to soil quality • Provision of advice related to soil quality	of detail collected. Current level of data collected is not sufficient to address RDP priority 4.
<u>RDP Priority 5:</u> Promoting resource efficiency and supporting the shift toward a low-carbon and climate-resilient economy in agriculture, food and forestry sectors	• Share of irrigated land switching to more efficient irrigation system *(target indicator)* • Increase in efficiency of water use in agriculture in RDP supported projects (m3 water used/standard output/) *(complementary result indicator)* • Increase in efficiency of energy use in agriculture and food-processing in RDP supported projects (output/MJ energy used) *(complementary result indicator)* • Total investment in renewable energy production (€) *(target indicator)* • Renewable energy produced from supported projects (tonnes of oil equivalent) *(complementary result indicator)* • Livestock units concerned by investments in livestock management in view of reducing the N_2O, methane and ammonia emissions *(target indicator)* • Share of agricultural land under management contracts targeting reduction of N_2O, methane and	Generally no or very low coverage in the core FADN

Policy	Examples of information needs	FADN coverage
	ammonia emissions *(target indicator)* • Reduced emissions of methane and nitrous oxide (measured in CO_2 equivalent) *(complementary result indicator)* • Reduced emissions of ammonia from agriculture (tonnes) *(complementary result indicator)* • Share of agricultural and forest land under management contracts contributing to carbon conservation and sequestration *(target indicator)*	
<u>RDP Priority 6:</u> Promoting social inclusion, poverty reduction and economic development in rural areas	• Jobs created in supported projects *(target indicator)* • Share of rural population covered by Local Action Groups (LAG) funded through the RDP *(target indicator)* • Rural population benefiting from improved services / infrastructures supported under the RDP *(target indicator)* • Jobs created in supported projects (LEADER) *(target indicator)* • Rural population benefiting from new or improved services / infrastructures (ICT) *(target indicator)*	Some coverage in the core FADN
ICT for Competitiveness and Innovation And Key Enabling Technologies	• Adoption of ICT to improve farm business • Farm-level adoption of key enabling technologies	Generally no or very low coverage in the core FADN
Tourism	• Farm income generated from tourism • Proportion of farm labour dedicated to agri-tourism • Investment in agri-tourism • Membership of agri-tourism certification scheme, co-operative, LAG or LEADER project	Some coverage in the core FADN
Animal Welfare	• Use of RDPs to support investment and aid adaptation to higher standards in the farming sector, as well as to reward practices that go beyond minimum standards • Farmers' awareness of animal welfare programmes • Adherence to animal welfare rules on the farm, during transport and at time of slaughter or killing (with specific rules for laying hens, calves, pigs and broilers) • Participation in RDPs to support investment and aid adaptation to higher animal welfare standards in the farming sector • Participation in activities to inform consumers about animal welfare standards and influence consumers' purchasing decisions	Generally no or very low coverage in the core FADN
EU Animal Health Strategy (AHS)	• Farm-level incidence of disease outbreaks • Farm-level investment in precautionary measures for biosecurity for animal health • Participation in an eradication programme for named diseases (listed in AHS) • Participation in electronic identification schemes for traceability of live animals (to replace paper	Generally no or very low coverage in the core FADN

Policy	Examples of information needs	FADN coverage
	certification) • Receipt of effective training to be able to identify the signs of disease at an early stage • Receipt of information/training to improve farm-level surveillance of disease	
Plant Health	• Inspection of pesticides application equipment in use – All pesticides application equipment will have to be inspected at least once by 2016 to grant a proper efficient use of any plant protection product • Adherence to EU plant health rules • Actions to prevent incidence of plant pests and diseases • Incidence of alien invasive species • Support for surveillance and control systems for plant pests and diseases	Generally no or very low coverage in the core FADN

Note: Here, we indicate the policy, and provide some examples of the farm-scale information needs associated with that policy.
The final column provides a brief and subjective comment on the degree to which FADN addresses these farm-scale policies and topics.
* These codes correspond to those used by the European Commission in their draft list of indicators for the RDP. http://ec.europa.eu/agriculture/cap-post-2013/monitoring-evaluation/documents/proposed-list-common-context-indicators_en.pdf

Source: the authors

Table 11: Overview of the FLINT typology of topics that are relevant to farm-scale sustainability

Topic	Sub-topic	Subjective indication of the degree to which FADN data addresses the sub-topics
market stabilisation	risk management	*
	profitability	***
	structure	***
income support	social	*
	employment	**
	non-agricultural income	*
	income equity	***
environment	biodiversity	
	soil	
	water	
	nutrients	*
	air	*
climate change	mitigation	
	adaptation	
innovation	process innovation	
	organisational forms innovation	
	product innovation	
	market innovation	
	supply source innovation	
resource efficiency	agronomic	**
	economic	***
other	people	**
	profit	**
	planet	*
animal welfare	animal welfare	

Note: *denotes level of coverage of topic.
Source: the authors

The new greening measures as part of Pillar 1 of the CAP will be introduced for the first time as part of the new CAP 2014-2020. This Green Direct payment will account for 30% of the national direct payment envelope and will reward farmers for complying with three agricultural practices: (i) maintenance of permanent grassland, (ii) ecological focus areas, and (iii) crop diversification. These new measures will challenge existing data collection exercises. In practice, however, farm records and aims should provide output indicators to measure implementation of these policy initiatives. An important aim would be to disaggregate the greening measures on the farm as much as possible, and to indicate the environmental state of the land area to which the greening measure is being applied (e.g. species-rich grassland or intensively managed pasture, instead of permanent grassland). Impact indicators will be more difficult to measure, and may be best addressed by other approaches. Some farm-level indicators that would be relevant to greening include:

- area of permanent grassland;
- land use type under permanent grassland (e.g. protected area for wildlife, species-rich grassland, permanent grassland with intensive land use, etc.);
- levels of organic matter in soil in permanent grassland;
- area under ecological focus area;
- land use type under ecological focus area (e.g. set-aside, natural wildlife habitat, etc.);
- number of crops sown;
- changes in cropping activities (crop diversification or rotation);
- levels of organic matter in soil in areas undergoing crop diversification;
- eligibility for greening equivalence.

- ***Sample***

In narrowing the selection criterion definition of the FADN farm to include only commercial farm holdings, this possibly limits the scope of the sample and its use. FADN is a sample that remains to be representative of the national agricultural sector in economic terms but may underrepresent smaller holdings with lower levels of output. Small farm holdings may be important in terms of the local economy based on their input requirements and can produce many externalities both positive and negative. This is important from a sustainability perspective as economic criterion is not the only aspect of agriculture the concept is concerned with: sustainability is also concerned with environmental and social aspects of agriculture. By excluding small farms from the the sample selection the environmental and social aspects of small farms are not considered. This then could be an issue for the assessment of sustainability.

- ***Themes***

There is currently an imbalance in the type of data FADN requires Member States to collect (more economic data than environmental or social data). An appropriate weighting method, for example the use of multi-criteria analysis using impact assessment or weighted scoring methods, could be employed in the development of composite indicators for FLINT.

Although many economic indicators can be assessed due to available accountancy data, indicators relating to themes such as product marketing or non-agricultural income require data that are less commonly recorded as a matter of routine. These indicators can be classified as objective measures regardless of the frequency of collection in FADN.

One of the biggest criticisms of the FADN measure of income is that it is of the farm business alone (European Court of Auditors, 2003). In a sector where the incidence of off-farm employment is so significant, the farm income measure can therefore paint an inaccurate picture about the true economic status of farm families. However, it should be said that the overarching objective of FADN has been, and continues to be, to collect data on output, input and income in farming and not necessarily of farm households. A Eurostat report from the 90s states that 'an income measure which aims to be a proxy for the standard of living of the agricultural community, though clearly not an exact one, will need to cover income from all sources, not just that from farming activity' (Eurostat, 1995). For example in Ireland, despite the many requests to expand the survey to collect farm household data, the NFS stayed steadfast to its initial remit (Hennessy and Kinsella, 2013).

Bockstaller *et al*. (2007) identified a gap in indicator development with regard to water quality: according to the authors, few French indicators are calculated on the watershed scale, which is however a relevant scale for assessing surface water quality. Internationally water quality has been a core issue for catchment scale research. In Ireland the Agricultural Catchments Programme is one such example of an interdisciplinary team based approach that has been successfully used to combat water quality issues.

In general there is a huge gap in terms of social indicators. Social themes are clearly difficult to assess without collecting additional data on the farm. In fact, social indicators often depend on qualitative estimations. These indicators could also be classified as subjective in nature as they are often self-reported specifically relating to an individual in a context at a point in time.

5.3.3.3 What is possible?

Apart from providing an annual, objective and representative record of farm incomes, another key function of the NFS has been the collection of economic data for research purposes (Hennessy and Kinsella, 2013). On an annual basis also the NFS conducts a supplementary survey which gathers specific data from a sub-sample of NFS participants. Such questions are generally not asked in the main survey and are once-off questions. The range and scope for such supplementary questions is vast. In the past they have ranged from occupational issues, health and safety, farmer attitudes, animal health, farm IT, public access to walking, likelihood of afforesting land and forest owner objectives, to topical issues, for example additional information on decoupling, CAP reforms but also visionary questions which look at planning, investments and the future of farming. There are opportunities within such surveys to identify new sustainability indicators for FLINT.

In the Netherlands FADN data collection is routinely complemented with data from other sources in order to broaden the themes covered by the network, to environmental issues such as GHG, mineral balances, energy use, water use, pesticide use, rural development, animal health and innovation. The other databases linked to FADN deal with quality of soil and stock of roughage, water quality around the farm, antibiotics use, bank transactions, administrative data (Agricultural Census, nature management subsidies, identification and registration of animals and direct payments), along with experiments with management software and nature quality (Boone and Poppe, 2011). For this, the research institute LEI (who manages the Dutch FADN) cooperates with various partners, including accounting offices, soil laboratories, feed producers (who provide farm invoices), banks (who provide information on bank transactions) and IT companies. In this way, the inclusion of additional data in FADN is not costly.

In a major EU study of biodiversity indicators for European farming systems, the BioBio project emphasised the importance of farm-scale measurement, but also emphasised the use of state indicators of biodiversity, e.g farm habitat recording, species recording in habitats, recording of vascular plants, bees, spiders and earthworms (Herzog *et al*., 2012). The project also estimated that a full assessment of an 85 ha farm with eight different habitat types would require about 15 days and €1,000 (mainly for the identification of species). In a study in Ireland, Sheridan *et al*. (2011) conducted farm-scale habitat surveys on a sub-sample of 50 farms that also participated in FADN. That study found that, on average, 14.3% of the land area was maintained as semi-natural habitat. A similar study of farmland habitats was conducted, focusing on the hedgerows of these same farms (Sullivan *et al*., 2013). The farm habitat surveys required about half a day to complete per farm, with a full day required if some basic recording of the vegetation (diversity of vascular plants in grasslands) was conducted. Overall, these studies indicate that farm-scale assessments of habitat diversity are technically and logistically feasible, and it is simply a question of the resources necessary to conduct them. It is also worth noting that a fundamental feature of the farm landscape such as habitat structure is unlikely to change over time, and it may be adequate to conduct such assessments every five years, perhaps as a supplementary survey to the core FADN.

Where data for a common context indicator is not available, either from EU nor Member State sources, an estimation of the common context indicator or a proxy indicator could be used. According to EENRD (2014b), a proxy indicator for a common context indicator is a quantitative indicator that provides information on a particular territorial contextual aspect (social, environmental, economic). It serves to assess in RDP the same contextual aspect as intended by a given common context indicator but for which data is not available.

Another possibility is to develop an integrated database of farm-level EU agricultural systems which combines data from different sources and which ensures easy availability of data. The widest example is the SEAMLESS project, which integrates multiple data sources such as FADN, the European Soil Database (ESDB) and the European Interpolated Climate Data (EICD) (Janssen *et al*., 2009). The ESDB and the EICD are however not farm level data.

Data gathering for the calculation of indicators can be time-consuming and expensive. For example, according to Zapf *et al*. (2009), 1 to 3 days data collection are needed for the DLG certificate in Germany and costs €1000 - €3000 depending on farm size for initial DLG certificate, and €500 - €1500 for re-certification. For this reason, some approaches could therefore preferentially attract only the highest performers. These farms are more likely to have the required information ready and are more likely to be deemed as sustainable. In contrast, the weak performers will not be attracted by the evaluation (though they are the potentially interesting ones from a policy perspective) due to the risk of failing. In the FADN there is a clear selection criterion which sets out to capture data on commercial farms in Europe. Thus, the evaluation of a policy which impacts all farms regardless of size may not be possible using the current FADN sample which focuses exclusively on commercial farms.

In some countries, current FADN data collection requires only short on-farm visits by the data collecting authority/bookkeeping office. This may however change depending on the new indicators that will be developed. A challenge exists therefore to adapt the collection of new data to the individual Member States. Another problem may arise from the huge variety of farm management software packages and the fact that they are often not well-maintained (e.g. missing values) therefore imposing limitations on a standardised data input. Invoices and other relevant farm documentation may often not be properly stored ('paper chaos'). Particularly in larger farms with multiple crop and livestock systems, several

telephone calls and on-farm visits may be necessary to achieve good quality data and thus reliable indicator results. Application of the tools is thus most efficient in well-organised farms with simple farm structure, which are used to efficiently storing their data and potentially using them to carry out their own farm analyses. In general, the effort both for farmer and evaluator is highest in the initial assessment period, whereas in subsequent years farmers get accustomed to the data demands of the systems and adapt the data storage accordingly.

It must also be stressed that FADN is voluntary. There is a trade-off between requesting more data and the risk that farmers will no longer participate in the FADN. This risk must be addressed. One important factor may be to improve existing lines of communication between the scientist and the farmer. Firstly, farmers have usually only limited interest in applying assessment systems, due to data demands and the fact that demonstrated advantages (e.g. better marketing) are limited, and may thus, for them, not justify the relatively high cost and time needs. Secondly, changes in questions and repetitive type questions are often not received very well. Thirdly, there may be a fear that non-compliance with environmental regulations or mismanagement is detected. Fourthly, farmers may regard social issues (e.g. holiday, participation, gender) as their private business – about which the public does not need to know. One possibility is to attract farmers through offering additional services, such as advice to farmers about how to improve on-farm processes (this is for example the case for the Swiss system RISE), participation in sustainability networks that allow the individual farm to compare itself with other farms (benchmarking), or a sustainability certificate that can be used for external communication. Further work may need to be done to improve the communication mechanisms between data collection and potential for improved farm conditions across all spheres of sustainability.

Another resistance to take into account is that of the authorities who may see the inclusion of new variables in the FADN as an additional administrative burden. They may fear that farmers will no longer participate in the FADN, or that useless or invalid data will be collected and that this will discredit the whole FADN. There is also a much greater danger that, without moving on with the agricultural sector, the FADN will be left behind. Continuing to collect existing data without exploring new and emerging policy topics may also be dangerous. Some new mechanisms must be developed to address such issues for sustainable farming across all Member States.

6 CONCLUSION AND RECOMMENDATIONS

This report provides a general overview of sustainability indicators based on international literature and national initiatives, and discusses practical aspects to be considered when calculating them from FADN data. It also identifies imbalances and gaps in the assessment. The previous chapters show that there is no common, universal, methodology for assessing the sustainability of farms.

Based on this report and on the exhaustive recommendations expressed by Russillo and Pintér (2009) regarding environmental indicators, several recommendations can be drawn for the FLINT project:

- The review highlights the themes for which few indicators are available, and where more research would be needed. This typically concerns social themes, which to date are poorly investigated in the literature and would need more effort. This is also the case for innovation indicators which are only recently considered in the literature. Choices should be made regarding the number of indicators: composite indicators of global sustainability *vs*. indicators for each dimension; one indicator per dimension *vs*. a set of indicators. In addition it should be decided whether the selected indicators should apply to all countries, or whether they are adapted (in terms of indicator selection or setting threshold levels) to each country, context and type of farming. Also, when simple indicators related to farm management practices (e.g. semi-natural area, or risk protection instruments respectively) are used instead of measured indicators measuring the sustainability outcome (e.g. biodiversity, or resilience respectively), then the causal direction between the simple indicator and the sustainability outcome should be fully clear ('The input/output relationship of farmer practices linked to higher-level outcomes must be understood'; Russillo and Pintér, 2009). Finally, it should be kept in mind that the effect of policies depends also on exogenous factors, that is to say on factors on which farmers have no control such as climatic and topographic characteristics of their location, or position of the farm in its life cycle. In the words of Russillo and Pintér (2009): 'The producer does not want to be held accountable for outcomes he or she cannot control'. For this reason, additional data which are not indicators should also be collected. All of these objectives are encompassed in Workpackage 1 of the FLINT project, which aims at selecting a list of relevant indicators.
- The participation of stakeholders (which is the objective of Workpackage 2 of the FLINT project) should be carefully designed and organised. As stressed by Russillo and Pintér (2009), 'the process of developing an indicator system requires collaboration, cooperation and even compromises. It is an evolutionary process, as we learn from the system and the different stakeholders.' Within this workpackage, farmers will be among the stakeholders: 'Producers need to be included in the indicator development process, and the initiative needs to clarify who defines "best practices."' (Russillo and Pintér, 2009).
- The presentation (and/or visualisation) of indicators should be well thought out so that clear and accurate messages are transmitted. In addition, farmers who will be surveyed within the framework of the FLINT project (pilot survey) will have to be convinced to provide additional data to FADN data: 'Those collecting the data need to compensate the farmer through information that has value or other incentives' (Russillo and Pintér, 2009). This will be taken into account in Workpackage 3 which will allow farmers in the pilot survey to visualise their situation compared to the rest of the sample. Feedback will also be incorporated into Workpackage 5, where scientific analyses will be conducted and results communicated.
- As FADN is not representative of the diversity of multi-functional agriculture in the EU, careful thought should be given to the sample selected in FLINT. This is the objective of Workpackage 4. This workpackage, in association with Workpackage 3, will also discuss how the data flows will have to be modified in the EU countries where additional data will need to be collected.

- The cost-benefit of designing and monitoring new indicators within FADN should be assessed. Which indicators (or proxies) can be collected most efficiently? This is the objective of Workpackage 6. This workpackage will also help to decide whether some indicators need to be collected each year or on a longer time scale; for example, indicators relating to landscape may be collected every five years whereas nutrient balances should be examined on an annual basis. This workpackage will also examine the difficulties associated with and any resistance by authorities and farmers to a change in the FADN data collection system.

Finally, it should be noted that there is no common, universal, methodology for assessing sustainability of farms. In fact this may be for the better since it allows more scope to generate a variety of ideas and to create a diversity of methods that can be innovative and targeted to specific issues and contexts. The mix of different disciplines in the FLINT project, from economists to sociologists, agronomists and ecologists, will assist in ensuring high quality indicator selection, collection, analysis and extension.

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APPENDIX A

Table A: Table of the FADN Farm Return grouping variables

Table A	**General information.** Identification and classification of the farm
Table B	**Type of occupation.** Breakdown of the farm area: owned, rented or sharecropped
Table C	**Labour.** All labour, paid and unpaid (but excluding labour used on work under contract), which has contributed to work on the farm during the accounting year.
Table D	**Number and value of livestock.** Opening and closing valuations (in number and value) and average number of livestock
Table E	**Livestock purchases and sales.** The value of such transactions together with the value of any farmhouse consumption of livestock
Table F	**Costs.** Value of all non-capital inputs used in the production of non-capital products during the accounting year.
Table G	**Land and buildings, deadstock and circulating capital.** Includes production, replacement or major repair of any fixed assets by the farms own resources valued on a cost basis.
Table H	**Debts.** Opening and closing valuations of short-, medium- and long-term loans
Table I	**Value Added Tax.** The VAT system applying and in certain cases VAT payments and receipts
Table J	**Grants and Subsidies.** Defined as specific payments made directly to the farm business from public funds, excluding those for investment in land, plant, machinery and equipment.
Table K	**Production (crops and animal products, livestock excluded).** The area, quantity and value of all crops, animal products and other activities
Table L	**Quotas and other rights.** Quotas and other rights included those acquired free if they can be traded separately from linked land.
Table M	**Direct payments for arable crops and beef.** Detailed data concerning CAP arable crops area payments (Regulation (EC) n° 1251/99) and direct payments for beef (Regulation (EC) n° 1254/99)
Table N	**Details of purchases and sales of livestock.** Purchases and sales per categories of livestock. The sub-totals of purchases and sales per animal species (equines, cattle...) are registered in table E.

Source: European Commission (2011)