LIFT

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

Research and Innovation action: H2020 – 770747
Call: H2020-SFS-2016-2017
Type of action: Research and Innovation Action (RIA)
Work programme topic: SFS-29-2017
Duration of the project: 01 May 2018 – 30 April 2022

Review of the definitions of the existing ecological approaches

Carlo Rega[1], Maria Luisa Paracchini[1*], Davy McCraken[2*], Andrea Saba[3], Matteo Zavalloni[3], Meri Raggi[3], Davide Viaggi[3], Wolfgang Britz[4], Lise Frappier[5]

[1] JRC, Belgium; [2] SRUC, United Kingdom; [3] UNIBO, Italy; [4] UBO, Germany; [5] INRA, France

* Deliverable leaders – Contact: Maria-Luisa.PARACCHINI@ec.europa.eu and davy.mccracken@sruc.ac.uk

DELIVERABLE D1.1

Workpackage N°1

Due date: M4

Actual date: 31/08/2018

Dissemination level: Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770747

About the LIFT research project

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

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

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

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

Project consortium

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

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List of acronyms and abbreviations

CAB: Centre for Agriculture and Biosciences
CAP: Common Agricultural Policy
cm2: square centimetre
CO_2: carbon dioxide
D1.1: Deliverable 1.1
DFS: Diversified Farming Systems
EAFS: Ecological Arable Farming Systems
EC: European Commission
EEC: European Economic Community
ECA: Ecological Compensation Areas
EU: European Union
FADN: Farm Accountancy Data Network
FAO: Food and Agriculture Organization
GMO: Genetically Modified Organisms
ha: hectare
HNV: High Nature Value
IAFS: Integrated Arable Farming Systems
ICM: Integrated Crop Management
ICP: Integrated Crop Production
IFOAM: International Federation of Organic Agriculture Movements
IFS: Integrated Farming Systems
IOBC: International Organization for Biological and Integrated Control
IP: Integrated Production
IPM: Integrated Pest Management
kg: kilogram
m2: square metre
MJ: mega joule
N: nitrogen
RDP: Rural Development Programme
SGM: standard gross margin
USA: United States of America
WoS: Web of Science

Summary

The aim of this present Deliverable 1.1 (D1.1) is to lay the foundation for the development of a framework for farm typologies, which takes into account existing typologies and existing nomenclature (e.g. low-input, organic, extensive, high nature value farming, conservation agriculture, agroecological, etc.) when considering in particular the degree to which farms adopt ecological practices. This early phase of the typology work aims at providing a consolidated framework composed of farming systems and farming practices, and a first screening of which practice is associated with which system. This initial stage will be complemented in further deliverables by indicators and thresholds to link concepts to data and models.

A literature review was conducted to identify existing categorisations of farm types based on the degree of uptake of ecological approaches and practises to farming. The review involved a detailed search of three databases (Web of Science-WoS Core Collections; Scopus; CAB Direct) using a common search string, adapted where necessary to conform to the structure of the database, to identify potentially relevant papers published from 1993 onwards (the cut-off date was selected with reference to the 1992 CAP reform). All documents returned by this search were subsequently screened for relevance based on their titles, their abstracts (if the relevance from the title was unclear) or consideration of the full text (where the relevance from the title or abstract was unclear). Publications which considered farming systems based only on non-ecological criteria (such as farm size, economics, crop and livestock type) were discarded. However, documents containing mixed classification systems, i.e. based on both ecological and other criteria were retained so that the ecological aspects of the classification systems could be examined in more detail.

The search returned 1,634 documents from Scopus, 2,124 from WoS and 498 from CAB. After removing duplicates, the total number of documents obtained was 2,403. After the screening process described above, a total of 203 documents from across the three databases were considered to meet the selection criteria and were skimmed or read completely.

The terms crop/cropping systems, farm/farming system and agricultural systems are conceptualised with different nuances in the literature and sometimes used synonymously or with no clear distinctions. For the purpose of the LIFT project we will adopt the term ‘farming system’ where fields are considered to be components of farms under management of particular farmers. The principal crops, livestock, and management practices employed on a particular farm constitute a farming system. A farm is a goal-oriented system in which goals dictate how capital and labour are used in production activities. Some aspects of agricultural ecology, such as crop-livestock-pasture integration and cycling of nutrients, are therefore better analysed at the farm level.

Several studies frame the identification of farming systems based on ecological practices within the broader concept of sustainable agriculture. Although there have been a wide range of definitions of sustainable agriculture in the literature, most involve some aspects of the following common characteristics to a greater or lesser degree: adequate economic returns to farmers; maintenance of natural resources and productivity; minimal adverse environmental impacts; optimal production with minimal external inputs; satisfaction of human needs for food and income; provision for the social needs of farm families. In other words, they promote environmental, ecological, economic, and social stability and sustainability.

There are a number of ways to group farming systems based on similarities in their management ethos or ecological farming practices. The literature review has suggested the following would be useful for LIFT to investigate further:

- Conservation agriculture: In conservation agriculture the primary focus is on the preservation of soil quality and properties through alternative tillage strategies. In more recent years, the concept in the literature has been broadened slightly to encompass a variety of measures to mitigate soil erosion, improve water holding capacity and increase soil organic matter, help to improve soil health and boost crop yields. A key feature is the revision or reduction of soil disturbance through tilling and crop rotation.

- Low-input farming systems: This terminology is used in a variety of ways in the literature, with input intensity being regarded as the amount of input (e.g. kg nitrogen or kg pesticide active matter) or the frequency of intervention per area and time unit. Low-input farming system and extensive farming system are sometimes being used to refer to the same thing. Common characteristics are: seeking to optimise the management and use of internal production inputs (i.e. on-farm resources); minimising the use of external production inputs such as purchased fertiliser and pesticides; avoiding pollution of surface and ground water; reducing pesticide residues in food; reducing farmer's overall risk; and seeking to increase both short- and long-term farm profitability. Within Europe, High Nature Value (HNV) farming systems is a term used primarily to apply to low-input farming systems where the farming practices help support and maintain habitats and species considered to be of high nature conservation value.

- Integrated farming system: This terminology is also used in the literature in a variety of ways. In general, integrated farming system is often used to refer to systems which fall between conventional and organic farming. Integrated farming systems are thus distinctive from conventional farming practice in that sustainability is at the core of the objectives, as is the case in organic systems. However, unlike organic farming, integrated farming systems can still utilise inorganic inputs, albeit at lower levels or used in a less systematic way than those of conventional systems. Integrated farming systems are increasingly seen as involving a combination of biological cycles for nutrient, weed, pest, and disease management with tactical use of fertilisers and other agrichemicals. Sustainable, efficient production in these systems depends on careful monitoring of soil conditions and requirements and use of water and nutrients.

- Organic and biodynamic farming systems: amongst the different farming systems identified from the literature review, organic agriculture is the one with the greatest recognition worldwide having been established by legislation, regulations and certification schemes. Within the European Union (EU), organic farming is defined as a holistic production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. The term Biodynamic is a trademark held by the Demeter-International e.V association; national organisations who are members of Demeter International are responsible for Demeter certification in their own countries. Like organic farming, biodynamic farming uses no synthetic chemical fertilisers and pesticides, and instead emphasises building up the soil with compost additions and animal and green manures, controlling pests naturally, rotating crops, and diversifying crops and livestock. In practice, the difference with organic farming schemes is that biodynamic farmers must add eight specific preparations to their soils, crops, and composts to enhance soil and crop quality and to stimulate the composting process.

- Agroecology: the literature on agroecology has increased steadily over the past two decades. Agroecology can be considered jointly as a science, a practice and a social movement. It encompasses the whole food system from the soil to the organisation of human societies. It is value-laden and based on core principles. As a science, it gives priority to action research, holistic and participatory approaches, and transdisciplinarity including different knowledge systems. As a practice, it is based on sustainable use of local renewable resources, local farmers' knowledge and priorities, wise use of biodiversity to provide ecosystem services and resilience, and solutions that provide multiple benefits (environmental, economic, social) from local to global. As a movement, it defends smallholders and family farming, farmers and rural communities, food sovereignty, local and short marketing chains, diversity of indigenous seeds and breeds, healthy and quality food. Diversified farming systems is a term used to refer to an agroecological, systems-based alternative to modern intensive agriculture. Such a farming system is considered as 'diversified' when it intentionally includes functional biodiversity at multiple spatial and/or temporal scales, through practices developed via traditional and/or agroecological scientific knowledge. The term is considered as an extension rather than an alternative to the agroecological approach.

Considering the large number of documents describing different farming systems, there is a paucity of attempts to classify the variety of such systems into consistent frameworks or schemes, based on the degree of ecological functionality of the different systems. Based on the literature review we suggest that LIFT should consider clustering farming systems according to their uptake of ecological practices by using the five terms above together with the term conventional.

The literature review also considered similarities and differences in the terminology to describe different farming practices. Based on the literature and expert judgement we suggest a framework to cluster farming practices, and provide a first attempt to link the farming systems with farming practices. These will be investigated further in future deliverables.

This deliverable also involved an initial investigation as to whether further interpretation of the literature review findings could be achieved through automatized textual analysis. The number of documents identified in the literature review and subsequent screening process were too few to perform robust analyses. Accordingly, all documents identified in the initial literature review were analysed. A contingency matrix was produced to show which farming practice terms were occurring in association with each of the six farming systems terms. Co-citation mapping was also tested to identify which terms were occurring in association with which farming system terms. Finally, a frequency timeline was constructed showing the number of papers containing the terms relative to the six farming system clusters over time. This indicated that the literature has been dominated by a focus on conventional and organic systems.

1 Introduction

Typologies are groupings of farms having similar characteristics. Clustering farms in such a way is necessary in order to analyse results and draw conclusions on common characteristics associated with the development of ecological farming. The aim of this present Deliverable 1.1 (D1.1) is to lay the foundation for the development of a framework for farm typologies, which takes into account existing typologies and existing nomenclature (e.g. low-input, organic, extensive, high value farming, agroecological, etc.) when considering in particular the degree to which farms adopt ecological practices.

The first step is a literature review aimed at identifying established frameworks and recognised categories of farm management, in particular concerning the adoption of ecological practices. This is of course one specific way to characterise farms and farming systems. Other existing classifications are based on different aspects such as economic or social ones, or a combination of them.

The application of a text analysis software (CorTexT) can potentially help in identifying consistent links between farming systems and farming practices reported in the literature. The documents obtained from the literature review screening process were subjected to experimental analyses by this software. Note however, that the farming system literature is dominated by documents focused on conventional and organic farming systems while the farming practice literature contains many documents concerned with organic matter and grazing. Agroecology is a field in which research is growing, but at the moment accounts for a smaller literature corpus. As a result, the degree to which text analysis software can add to understanding might be expected to be limited.

The typology will include some general principles to help identify to what degree a farm is adopting ecological practices (e.g. extent of chemical input use, proportion of inputs arising from outside the farming system, appropriate rotation systems, tillage management, presence of semi-natural habitats as sources of functional biodiversity, water management, waste management i.e. recycling of biomass for composting or energy production, carbon footprint or measures to mitigate CO_2 emissions, etc.). This early phase of the typology work is intended to provide a consolidated framework composed of farming systems and farming practices, and a first screening of which practice is associated with which system. This initial stage will be complemented in further deliverables by indicators and thresholds to link concepts to data and models.

2 Literature review – concepts and methods

The objective of the literature review is to identify existing categorisation of farm types based on the degree of uptake of ecological approaches and practises to farming. The search strategy has thus been defined to reflect this specific aim, i.e. to look at this specific criterion for identifying farming systems.

The literature search covered three databases:

- Web of Science (WoS) Core Collections (http://www.wok.mimas.ac.uk/).
- Scopus (http://www.scopus.com/).
- CAB Direct (https://www.cabdirect.org/).[1]

[1] 1Note that the documents selected from this database were, following screening, used to consider system and practice relationships and were included in the core text analysis conducted on all the screened documents. However, time constraints meant that detailed information was not drawn from a full reading of these 29 documents to the same extent as was drawn from the WoS and Scopus screened documents.

The search string was refined through an iterative, trial and error approach, aiming to balance the two contrasting needs of completeness (finding all relevant farming systems definition) and specificity (finding only those definitions relevant for the purposes of this study). Search terms were identified based on keywords occurring is a number of key papers known by the authors prior to the research and on their own expert knowledge on farming systems and agricultural systems. The final search string used is shown in Table 1:

Table 1: Search string used to select documents from Scopus

Field	**Search string**	**Logic operator**
Title	(farm* OR agric*) W/1 (typ* OR system* OR class* OR taxonomy OR model OR protot* OR cluster* OR group* OR division OR subdivision OR catalog*)	AND
Title, abstract or keywords	(agroecolog* OR ecolog* OR biodiversity OR "ecosystem service" OR organic OR low-input OR extensive OR "high nature value" OR conventional OR "conservation agriculture" OR indicator* OR index OR indices OR (environment* W/1 (performance OR efficiency OR friendly OR assessment OR sustainability))	

Note: Equivalent search strings were used for the research in WoS and CAB.

The syntax in Table 1 is the one used by the Scopus engine, where the wildcard * allows a search for all terms with multiple word endings (e.g. farm* in the title returns documents whose title contains farm, farms, farming, farmers etc.) and the W/*n* is a proximity operator indicating that the searched terms must be separated at most by *n* words, but does not specify the order - e.g. 'farm* W/1 typ*' will return both 'farming type(s)' and 'type(s) of farm(s)'. We used the same string in the WoS and CAB database, adjusting the syntax accordingly. In this way, we looked at publications with farm/farming systems or agricultural systems and synonymous (types, typologies, groups, clusters etc.) in the title and other words occurring either in the title itself or on the abstract or keywords that we deemed useful to look for classification systems based on ecological principles.

To delimit the temporal range of the research, we selected only papers published after 1992 (i.e. from 1993 inclusive onward), the year of the MacSharry reform of the Common Agricultural Policy (CAP). That reform introduced agri-environmental measures, and since then concern about environment has gained more and more importance in the CAP. To further narrow down the results and discard irrelevant publications we excluded returned papers from the following subject areas: veterinary, medicine, chemistry, health professions, immunology and microbiology, pharmacology, toxicology and pharmaceutics, physics and astronomy, and mathematics. We did not apply any restriction to the type of document to be searched, thus including research articles, conference proceeding, books, book chapters, notes, letters, reviews and editorials. Similarly, no filters were applied to the country/territory of origin of the publication. We instead limited the search to documents written in English, French or Spanish.

All documents returned by this search were subsequently screened for relevance using the following set of criteria. We discarded publications presenting faming systems based only on non-ecological criteria, like farm size (e.g. smallholders vs large farms), economic aspects (subsistence agriculture/self-sufficiency farming vs commercial agriculture), legal status of land ownership (e.g. owner vs tenant), personal characteristics of farmers (age, level of education) or prevailing types of crops and livestock, as used for example in the EUROSTAT farm system classification. However, documents presenting mixed classification systems, i.e. based on both ecological and other criteria were retained so that the ecological aspects of the classification systems could be examined in case. The focus of this work is on European farming systems, thus we excluded documents reporting on contexts very different from the European ones. (e.g. tropical, sub-Saharan). We kept documents from non-European countries presenting comparable conditions, like North America or Australia or, in some cases, China.

Documents for which the inclusion criteria could not be tested at title level were screened at abstract level (i.e. the abstract was fully read). If, after reading the abstract, it was still not clear whether the paper was relevant or not, the full text was skimmed looking for any mention of farming systems. If after the skim the document was deemed relevant, it was selected for full reading. To test consistency in the application of the inclusion criteria a pilot screen was carried out individually by three of the authors of this deliverable on a subset of 100 papers returned from the search and results were compared. Each disagreement was then discussed between the authors in order to fine-tune the application of the selection criteria until total agreement was reached on every single items.

3 Results of the literature review

The search returned 1,634 documents from Scopus, 2,124 from WoS and 498 from CAB. After removing duplicates, the total number of documents obtained was 2,403. After the screening process described above, a total of 203 documents from across the three databases were considered to meet the selection criteria and were skimmed or read completely. In the following, we report on the different definitions emerging from the literature.

3.1 Cropping systems, farming systems and agricultural systems

The terms **crop/cropping systems**, **farm/farming system** and **agricultural systems** are conceptualised with different nuances in the literature and sometimes used synonymously or with no clear distinctions. Connor et al. (2011) provide a useful clarification of the terminology, according to which:

- A **cropping system (or livestock– pasture system)** is the temporal sequence of crops and management practices in individual fields. At this level, the production processes of plants, their dependence on environmental conditions, and the role of soil processes that support plant growth can be examined.
- At a higher level, fields are components of farms under management of individual farmers. The principal crops, livestock, and management practices employed on a particular farm constitute a **farming system**. A farm is a goal-oriented system in which goals dictate how capital and labour are used in production activities. Some aspects of agricultural ecology, such as crop-livestock-pasture integration and cycling of nutrients, are therefore better analysed at the farm level.
- The term **agricultural system** refers to the regional organisation of farming systems. This scale of analysis allows to consider additional aspects such as drainage and air and water pollution or service roles (e.g. grain purchase, storage, and transport) of towns and villages within the region. Agricultural systems can also be identified at broader scales, as watershed, regional, national, or global scales with regard to impact on food security and ecosystem services that include water and air quality, and biodiversity.

According to Moreau et al. (2012) the farming system is a combination of cropping systems (crop rotations and associated techniques) and livestock systems, with the animal diet as a keystone (Aubron et al., 2009), connected together by relationships of complementarity and competition for the resources use. The farming system is a model that leads to a description of generic functioning frames, which allow classification of farm types and possible management choices associated with each type (Mabon et al., 2009).

Giller (2013), as reported by Andersen (2017), suggests that farming systems are defined as a population of individual farm systems that may have widely different resource bases, enterprise patterns, household livelihoods and constraints. Andersen (2017) uses the term farming system to put forward an approach aiming at integrating agronomy and landscape ecology highlighting that a 'soft' understanding of systems, including economic, technological, environmental and social aspects, is needed to fully understand the agricultural landscapes.

Chopin et al. (2017) focus instead on management aspects, distinguishing between farming systems and cropping systems. They define a farming system as a resource management strategy designed to achieve economic and sustained production that will meet the diverse requirements of the farm household while maintaining a high level of environmental quality (Cochet, 2012). A cropping system refers to a set of management procedures applied to a given, uniformly treated agricultural area, corresponding to a field or group of fields (Sebillotte, 1990).

For Pretty and Bharucha (2014), agricultural systems are amended ecosystems with a variety of properties. At all levels they rely on the value of services flowing from the total stock of assets that they influence and control, and five types of asset – natural, social, human, physical and financial capital – are recognised as being important.

Urruty et al. (2016), in line with other authors (e.g. Renting et al., 2009), define agricultural systems as socio-ecological systems, comprising biotechnical and social factors, and dedicated to the production of productive, economic, environmental and social outputs.

Given the scale of analysis in LIFT (farm to territory), we consider farming systems the appropriate reference system for our analysis. Cropping systems offer a specific and, in a way, restrictive view on crops and relative management practices, while agricultural systems include aspects that go beyond the scope of the present exercise (e.g. social, economic, governance).

A farming system is intended as a frame describing the way crops, livestock and management practices interact, and ways capital and labour are used, to reach specific goals that in LIFT refer to the adoption of ecological practices. For the purpose of the LIFT project we will therefore adopt 'farming system' as reference analytical concept in the present deliverable.

3.2 Sustainable agriculture – an overarching concept

Several studies frame the identification of farming systems based on ecological practices within the broader concept of **sustainable agriculture**. Edwards et al. (1993) provide a comprehensive retrospective of the evolution of the concept. They refer to Harwood (1987), according to whom the concept of sustainable agriculture was first articulated by Jackson (1980) and by Rodale (1983), who outlined a concept of regenerative agriculture that renewed natural resources. Edwards et al. (1993) acknowledge that hundreds of definitions of sustainable agriculture have been provided by the literature (e.g. Rodale, 1983; Committee on Agricultural Sustainability for Developing Countries, 1987; Edwards, 1987; Weil, 1990), but identify the following common characteristics: adequate economic returns to farmers; indefinite maintenance of natural resources and productivity; minimal adverse environmental impacts; optimal production with minimal external inputs; satisfaction of human needs for food and income; provision for the social needs of farm families. In other words, they promote environmental, ecological, economic, and social stability and sustainability.

Edwards (1987) provide a detailed definition of sustainable agriculture as: "Integrated systems of agricultural production, with minimum dependence upon high inputs of energy, in the form of synthetic chemicals and cultivation, which substitute cultural and biological techniques for these inputs. They should maintain, or only slightly decrease, overall productivity and maintain or increase the net income for the farmer on a sustainable basis. They must protect the environment in terms of soil and food contamination, maintain ecological diversity and the long-term structure, fertility, and productivity of soils. Finally, they must meet the social needs of farmers and their families and strengthen rural communities in a sustainable manner." (Edwards, 1987 as cited in Edwards et al., 1993). They also list the main farming practices that characterise sustainable agriculture: maintenance of organic matter, cropping of legumes, no-till (direct drilling), various forms of conservation tillage and ridge tillage, use of living and dead mulches and trap crops to protect the soil from erosion, trees planting and use of agroforestry as sources of alternative foods; integration of animals into agroforestry systems to optimise productivity and sustainability; crop rotations; use of various forms of polyculture to control pests, diseases, and weeds (Edwards et al., 1993).

Ruttan (1994) traces the evolution of the concept of sustainable agriculture over time. He recalls the writings of Douglass in the early 1980's, who identified three alternative conceptual approaches to the definition of agricultural sustainability. The first one defines sustainability primarily in technical and economic terms, as the capacity to supply the expanding demand for agricultural commodities on increasingly favourable terms. A second approach conceives agricultural sustainability primarily as an ecological question: "an agricultural system that depletes, pollutes, or disrupts the ecological balance of natural systems is unsustainable and should be replaced by one which honours the longer-term biophysical constraints of nature" (Douglass, 1984, p. 2). The third approach emphasises not just the physical resource base, but also a broad set of social values, such as the well-being of rural people and rural communities, the preservation or revitalisation of their culture, and recognises the values of stewardship and self-reliance and an integrated or holistic approach to the physical and cultural dimensions of production and consumption (Committee on the Role of Farming Methods in Modern Production Agriculture, 1989).

Synthetic definitions of sustainable agriculture were subsequently provided by Spencer and Swift (1992) as cited in Brussaard (1994): "a sustainable agricultural system may be defined as one in which output trend is non-declining and resistant, in terms of yield stability, to normal fluctuations of stress and disturbance"; and Reganold et al. (1990), as reported by Reganold (1995): "To be sustainable, a farm must produce adequate food of high quality, be environmentally safe, protect the soil, and be profitable and socially just". The first one focuses on the stability of production over time, whilst the second one refers to the so-called three pillars of sustainability, the environmental, economic and social ones.

Along similar lines, Rasul and Thapa (2004) maintain that three basic features of sustainable agriculture can be identified despite the diversity in conceptualising it. These are: (i) maintenance of environmental quality, (ii) stable plant and animal productivity, and (iii) social acceptability. They also report a previous similar conceptualisation proposed by Yunlong and Smith (1994) whereby agricultural sustainability should be assessed from the perspectives of ecological soundness, social acceptability, and economic viability. In this frame, 'ecological soundness' refers to the preservation and improvement of the natural environment; 'economic viability' refers to maintenance of yields and productivity of crops and livestock, and 'social acceptability' refers to self-reliance, equality and improved quality of life.

According to Pretty (2008 p. 451, as cited in Migliorini et al., 2018), the principle of sustainable agriculture can be summarised as follows: "(i) integration of biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation, and parasitism in food production processes; (ii) minimization of the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers; (iii) productive use of the knowledge and skills of farmers, thus improving their self-reliance and substituting human capital for costly external inputs; (iv) productive use of people’s collective capacities to work together to solve common agricultural and natural resource problems, such as pest, watershed, irrigation, forest and credit management.”

3.3 Conservation agriculture

Conservation agriculture, also referred to as ‘conservative agriculture’ or in some instances as ‘conservation farming systems’ (e.g. Young et al., 1994), is a widespread term in the literature. In conservation agriculture the focus is on the preservation of soil quality and properties through alternative tillage strategies, variously named: no-tillage, minimum tillage, conservation tillage, shallow tillage, strategic tillage. This is often associated with crop rotation and use of cover crops.

Young et al. (1994), in developing a conservation farming systems in the highly erodible Washington-Idaho Palouse region (USA), point out that the difference with conventional farming include crop rotations and a conservation tillage system defined as a hybrid no-till, minimum till system for both rotations. These conservation tillage systems were projected to provide adequate residue at all points in the rotation to meet compliance requirements. Herbicides were used when necessary.

Pierce et al. (1994) set up an experimental design consisting in comparing a conventional system of with four tillage treatments: conservation tillage, no-tillage with a clover cover crop strip killed in the corn row, no-tillage with a rye cover crop strip killed in the corn row, and no-tillage with a rye cover crop completely killed prior to planting corn. Also in this case herbicides were used to control weeds and to kill the cover crops.

In more recent literature, a slightly wider understanding of conservation agriculture is provided. Mitchell et al. (2016) describe conservation agriculture as a variety of measures to mitigate soil erosion, improve water holding capacity and increase soil organic matter, help to improve soil health and boost crop yields. A key feature is the revision or reduction of soil disturbance through tilling. Zero tillage involves no ploughing prior to sowing. Conservation agriculture entails a group of management strategies to minimise soil disturbance, maintain soil cover and rotate crops. This seeks to maintain an optimum environment in the root zone in terms of water availability, soil structure and biotic activity.

Mitchell et al. (2016) list the following three key principles of conservation agriculture: reducing soil disturbance (tilling less, or not at all), retaining crop residues on the soil surface year-round and fostering crop and soil biodiversity. Cultivation practices include surface mulching and increases in soil organic matter to reduce soil water evaporation and increase soil water storage capacity; long term rotations in combination with cover cropping to increase soil organic carbon; limiting tractor passes and other operations to reduce costs and air pollution. Similarly, Casagrande et al. (2017) state that conservation agriculture relies on minimum soil disturbance, maximum soil cover and diversified crop rotations. They studied the on farm implementation of biodiversity-based techniques on a large sample of French farmers to compare conventional farmers, organic and conservation agriculture. They found that whilst farmers adopting conservation agriculture mainly used diversified crop rotation and cover cropping, they were not significantly applying other biodiversity-based techniques (i.e. agroforestry, intercropping, agroecological infrastructures, cropped varietal mixtures and agroforestry).

According to this review, we intend here conservation agriculture as a farming system that, regardless of its overall intensity, adopts some practices aimed at preserving the physical and functional properties of the soil, through alternative tillage strategies and one or more of the following practices: crop rotation, use of cover crops, management of crop residues.

3.4 Low-input farming systems

The second group of farming systems emerging from the examined literature is labelled '**low-input farming systems**'. Alternative used wordings include 'low (external) input', 'low intensity' and 'reduced input' (farming) systems.

Viglizzo (1994) reports an early definition by Wagstaff (1987) according to which "Low external input systems are farm production systems that have a low support energy requirement per hectare or livestock unit. They use substantially lower levels of manufactured fertilizers, agrochemicals, fuels, and concentrate feeds than is typical of modern high-input systems, and resemble natural ecosystems more than industrial systems (Gliessman, 1984)". In his study, Viglizzo (1994) considers that low utilisation of support energy and money are sufficient conditions to describe low-input systems.

In a study comparing conventional and reduced-input farming system in Ontario (Canada), Stonehouse (1996) defines reduced-input farms as those employing synthetic herbicides for at least one of the focus crops at less than the recommended government rates. He also lists some of the farming practices used in such farms to replace the use of herbicide, such as tillage, cover crops or timeliness of field operations.

Bignal and McCracken (1996) list the characteristics of low-intensity livestock and crop-based farming systems building on the work from Beaufoy et al. (1994). For livestock systems, these are: low nutrient input, predominantly organic; low stocking density; low agrochemical input; little investment in land drainage; relatively high percentage of semi-natural vegetation; relatively high species composition of sward; low degree of mechanisation; often hardier, regional breeds of livestock; survival of long-established management practices, e.g. hay-making, transhumance; reliance on natural suckling; limited use of concentrate feeds.

Concerning crop systems, the identified characteristics are: low nutrient input, predominantly organic; low yield per hectare; low agrochemical input (usually no growth regulators), little investment in land drainage; use of crops and varieties suited to specific regional conditions; use of more traditional crop varieties; low degree of mechanisation; use of fallow in the crop rotation; use of more traditional harvesting methods; use of tree crops tall rather than dwarf; absence of irrigation.

Similarly, Liebman and Davis (2000) define low external input systems as those systems where herbicides are largely or entirely avoided, and weeds are suppressed largely through physical and ecological tactics. Common practices in these systems are identified by the authors mainly with regard to their contribution to weed management and include crop rotation, cover crops, intercrops, but also use of composts and animal manures.

An example of a study from outside the EU, but within Europe, is provided by Pfiffner and Luka (2003) who study cereals cultivation in Switzerland. They refer to low-input integrated crop management (ICM) farming systems as those systems that use no insecticides, fungicides and growth regulators in cereal production, though herbicides are allowed and used. Management practices include crop rotation (7-8 crops) and organic fertiliser application (slurry and ammonium nitrate).

Nemecek et al. (2011b) report a definition by Parr et al. (1990) according to which low-input farming systems are defined as farming systems that ''seek to optimise the management and use of internal production inputs (i.e. on farm resources) […] and to minimise the use of external production inputs [...] such as purchased fertiliser and pesticides, wherever and whenever feasible and practical, to lower production costs, to avoid pollution of surface and ground water, to reduce pesticide residues in food, to reduce a farmer's overall risk, and to increase both short- and long-term farm profitability''. In their work Nemecek et al. (2011b) intend intensity as the amount of input (e.g. kg nitrogen or kg pesticide active matter) or the frequency of intervention per area and time unit. Low-input farming system and extensive farming system are used by these authors synonymously.

Low-input farming systems are conceptualised in our framework as systems where the overall input (in terms of agrochemicals, fertilisers, mechanic work, etc.) is lower than the average input in conventional systems. However, this does not necessarily imply that the input comes from within the system itself, nor that the system is specifically designed to support biodiversity.

3.5 Integrated farming systems

'Integrated farming system' (IFS) is also used in a wide variety of ways in the literature but, compared to conservation agriculture, it has somewhat more complex and varied definitions.

The term boosted in the literature following the starting, in the Netherlands, of various research projects to develop new farming systems with markedly reduced inputs of pesticides and fertilisers (Vereijken, 1992; Wijnands and Vereijken, 1992, as cited in Lotz et al., 1993). These new systems were referred to as 'integrated farming systems' (Vereijken and Royle, 1989). Reported practices that differentiate them from conventional farming systems include limited chemical weed pest and disease control, achieved mainly with mechanical operations, the use of resistant varieties when available and minimum soil tillage (Lotz et al., 1993).

One of the main proponents of such an approach was the Dutch Programme on Soil Ecology of Arable Farming Systems (1985-1992), a cooperative research effort launched in response to growing concerns about the sustainability of agriculture in the industrialised countries in terms of long-term soil fertility and effects on the environment. The focus of the programme was the analysis and simulation of the dynamics of soil organisms and the concomitant nitrogen mineralisation and in the analysis of biologically-mediated soil structure (Brussaard, 1994). In the frame of this programme, integrated farming systems differed from conventional ones mainly in the reduced use of pesticides (based on observations vs. calendar; no soil fumigation vs. nematicides against potato cyst-nematodes), fertilisation (manures in addition to inorganic fertiliser and crop residues vs. inorganic fertiliser and crop residues only), and less intensive tillage.

Additional practices in some experimental farms reported by Lebbink et al. (1994) include: 4-year crop rotations; cultivation of green manure crops to take up mineral nitrogen (N) released from the soil after early harvest of the cereal crops of; use of mushroom compost (organic waste product remaining after mushroom production), worked into the soil together with crop residues from winter wheat, intended to prevent N loss by immobilisation; partial replacement of mineral N by organic N (e.g. pig slurry). Herbicides were however used if necessary. The tillage differences between conventional and integrated systems were the depth of ploughing and, whenever possible, omitting inversion of the topsoil in the latter. The same practices, with slight variations, were applied in the studies by Didden et al. (1994), Zwart et al. (1994), Vreeken-Buijs (1994), and Vos and Kooistra (1994). Didden et al. (1994) use 'integrated farming systems' as a synonymous of 'Reduced input farming system'.

Another impulse to the research on integrated farming system comes from the work of the IOBC (El Titi et al., 1993) who defines the concept of integrated agriculture or integrated production.

In this frame, Helander (1997) describes the principle and methods for what he refers to as integrated arable farming system (IAFS). The emphasis is on the reduction of inputs, achieved through the use of the following methods:

- Multifunctional crop rotation: the major method to preserve soil fertility in biological, physical and chemical terms and to sustain quality production with a minimum of inputs (pesticides, fertilisers, support energy and labour).
- Integrated nutrient management: supports multifunctional crop rotation by maintaining agronomically desired and ecologically acceptable nutrient reserves in the soil and contributes, together with minimum soil cultivation (see below), to maintain an appropriate content of organic matter.
- Minimum soil cultivation: supports multifunctional crop rotation by incorporating crop residues, controlling weeds and restoring physical soil fertility, while maintaining sufficient soil cover as a basis for avoiding nutrient losses, shelter for natural enemies and for landscape/nature values.
- Ecological infrastructure management: supports multifunctional crop rotation by providing airborne and semi-soilborne beneficials a place to overwinter and recover and disperse in spring. In addition, EIM should achieve different nature and landscape objectives.
- Integrated crop protection supports multifunctional crop rotation and ecological infrastructure management by selectively controlling remaining harmful species with minimal exposure to the environment of pesticides.
- Farm structure optimisation: the method to make a farming system economically optimal by determining the minimum amounts of land, labour and capital needed.

In addition, IAFS use non-ploughing tillage practices. The same definition was subsequently applied in further studies (e.g. Helander and Delin, 2004; Sterk et al., 2007).

Bockstaller et al. (1997) propose a set of agroecological indicators for IAFS, defined as in Helander (1997). They fully develop seven indicators covering nitrogen, phosphorus, pesticide, irrigation, organic matter, crop diversity and crop sequence; and put forward the elaboration of additional indicators for energy, soil structure, soil cover and ecological structures. Each indicator is scored on a scale from 0 to 10, based on expert judgement or, in some cases, quantitative data. A score of 7 represents the minimum to meet the requirements of IAFS. Later, Pervanchon et al. (2002), propose a new indicator to complement this set based on energy use. They use energy as a comprehensive metric to assess the intensity level of arable farming systems, considering direct and indirect energy consumption due to fertilisers, pesticides, irrigation and machinery (MJ/ha). They then convert it into a dimensionless indicator ranging from 0 (most extensive systems) to 10 (most intensive systems) through a non-linear equation. A score equal or greater than 7 (corresponding approximately to 10,000 MJ/ha) represents the achievement of the required level for IAFS.

Vereijken (1997) presents a method for prototyping IAFS and another type of system called ecological arable farming systems (EAFS) (developed in the Netherlands). The definition of IAFS as well as the characterisation of farming practices are the same as those described by Helander (1997), reported above. In Vereijken (1997), IAFS are the first step, to be achieved in the short term, towards the more ecological farming systems EAFS, to be reached in the long-term. In the latter systems, chemical crop protection is entirely substituted by “a package of non-chemical measures, to achieve ambitious objectives in environment, nature/landscape and quality and sustainability of food supply” (Vereijken, 1997, p. 294). EAFS are conceived therefore as an agroecological whole consisting of a 'team' of steadily interacting and rotating crops, plus their accompanying (beneficial or harmful) flora and fauna. In this view, organic systems can be considered to be a forerunner of EAFS, but they have no quantified objectives in environment and nature/landscape and hence they need to be improved to become EAFS.

To quantify the objectives of IAFS and EAFS in term of environmental performance is precisely the aim of Vereijken's (1997) work. In particular, indicators and quantitative thresholds are defined for each of the farming practices and methods characterising IAFS as described by Helander (1997) (see above).

These are at least 6 different crops for multifunctional crop rotations in IAFS and at least 8 crops in EAFS. The share per single crop and crop groups shall not exceed 25% and 50% in IAFS and 16.7% and 33% respectively in EAFS. Scores are assigned to crops and crop groups with regard to their contribution to soil cover, enhancing soil structure, N uptake, N transfer and N need. The multifunctional crop rotation shall be designed in a way that minimum mean scores are reached for the system to classify as IAFS or EAFS (in this letter case the requirement is more stringent). The share of cereals should be less than 50% in IAFS and less than 30% in EAFS, as it is assumed that the larger the share of cereals in rotation, the greater the biotic stress and the need for external inputs for this crop group. Finally, ecological infrastructure should cover an area greater than 5% of the farm area in both IAFS and EAFS.

Along similar lines, Morris and Winter (1999), following Wibberley (1995), conceive IFS as "a middle course between the extreme constraints of organic farming standards and the increasingly unacceptable pursuit of intensive cereal monocultures" (Morris and Winter, 1999, p. 193). IFS is thus intended as a 'third way' between conventional and organic farming. IFS are distinctive from conventional farming practice in that sustainability is at the core of the objectives, as is the case in organic systems. However, unlike organic farming, IFS still rely upon the use of inorganic inputs, albeit at lower levels than those of conventional systems. The authors also highlight the semantic confusion surrounding the use of terms such as IFS, ICM and integrated pest management (IPM) (as pointed out also by Pacini et al., 2003, see below). However, they identify emerging consensus about the broad objectives of IFS, which have been defined as "an holistic pattern of land use which integrates natural regulation processes into farming activities to achieve maximum replacement of off-farm farm inputs and to sustain farm income" (El Titi, 1992, p. 34).

According to these concepts, the main element of IFS are: crop rotation; minimum soil cultivation; use of disease resistant cultivars; modifications to sowing times; targeted application of nutrients; rational use of pesticides; management of field margins to create habitats for predators; use of tillage systems that favour natural control of pests, improvement of soil structure and reduced demand for external nitrogen; modifications to cropping sequences to increase crop diversity; promotion of biodiversity or ecological infrastructure management (3-5% of total cropping area).

Morris and Winter (1999) argue that, conceptually, IFS appears to be closer to organic agriculture than to agri-environmental schemes, the main difference being that the main objective of the first is sustainable resource use, while the second are mainly aimed at conservation and supply of public goods and ecosystem services. Under agri-environmental schemes, crop production may in fact continue as in a conventional system, with conservation taking place on the margins of this, thereby allowing the two activities to co-exist. The authors also provide a summary of the differences between organic agriculture and IFS. Concerning the production techniques, the main difference is that under organic farming, the use of non-biological fertilisers and pesticides is not allowed, and emphasis is put on the sustainable use of resources and farm animal welfare. In IFS, instead, technologically intensive production techniques are used that emphasise equally environment, farm incomes and food quality.

Other differences brought out by the authors regard the social origins of these two approaches. While organic farming is seen as a radical social movement whose origins lie in a small minority of ecologically committed practitioners, IFS is seen as less radical though it has emerged as a response to the problems of conventional agriculture. Unlike organic agriculture, IFS does not originate from grass roots level, but is rather an approach to sustainable resource use that, like agri-environment schemes, has evolved within the conventional food supply system, and in particular as a new agricultural science.

The idea of integrated farming as a mid-way, or an intermediate step, between conventional and organic agriculture is expressed also by Bellon and Hemptinne (2012). These authors also point out how 'integration' may actually refer to different aspect: vertical/horizontal integration; crop/livestock integration; integrated production/protection; integrated farming/agriculture. They highlight how, however, all interpretations somehow convey the idea to reconnect what has previously been separated. They refer to the work of the IOBC and in particular to Boller et al. (2004) defining integrated production/farming as "a farming system that produces high quality food and other products by using natural resources and regulating mechanisms to replace polluting inputs and to secure sustainable farming". In this frame, emphasis is placed on: (i) a holistic systems approach involving the entire farm as the basic unit, (ii) the central role of agroecosystems, (iii) balanced nutrient cycles, and (iv) the welfare of all species in animal husbandry. Biological, technical and chemical methods are balanced, carefully taking into account the protection of the environment, profitability and social requirements.

In accordance with this concept is also the definition found in Stavi et al. (2016) that associate integrated farming systems with moderate-intensity systems, both referring to combinations of certain conventional and conservation concepts with regard to the core farming practices of tillage methods, crop residue management, nutrient management, and pest management. They too consider integrated practices of moderate tillage, moderate on-site retention of crop residue, integrated nutrient management, and integrated pest management as lying between two extremes of higher and lower intensity.

Outside Europe, Li and Min (1999) describe the features of IFS in China. According to these authors, IFS, or agroecological engineering, is a compound (in space and/or time) agricultural production system based on eco-economic principles and managed with a system engineering approach aimed to optimise integrated economic, ecological and social benefits to ensure sustainable agriculture in the current situation. IFS is conceived not merely as a combination of different crops/animals in space and/or time, nor merely as a land-use system, but rather as an integrated rural development pattern. Following Yan (1986), they propose that the main principles to be considered in agroecological engineering are species symbiosis, recycling, regeneration, and harmony between organisms and environment. These principles have been simplified as holism, harmony, regeneration and cycling.

IFS is thus a system-oriented multicomponent agriculture. Farming is intended in a holistic manner emphasising the interactions between its different components. IFS is conceptualised as a complex biological-socioeconomic system that has the biological components as its core. Management aims at integrating the effects of the whole system, and not only those of its individual components. To pursue such integration, IFS try to combine agriculture, forestry, horticulture, animal husbandry, aquaculture, side-line production, and village cottage industries, as well as other biological production, into an interconnected system. Increase in primary and corresponding secondary productivity is a key indicator to evaluate the successfulness of the system. This goal is to be reached, according to the authors, mainly by multiplying the composition and structure of the system in space and/or time; by raising the converting effects; by increasing the recycling of nutrients within the system and using the surplus labour in the rural areas rather than relying on high input from outside the system. The system is expected to meet the economic needs of the farming community by providing multiple products. It is expected to overcome or mitigate the risks of monoculture. According to Li and Min (1999), IFS are expected to achieve higher economic efficiency through recycling organic materials. Another feature of IFS is the use of renewable energy and the adoption of energy-saving techniques. Chemical input is limited, but not excluded. Typical IFS in China include: relay-intercropping and intercropping systems; paulownia-crop systems (agroforestry); phyto-animal symbiosis system (fish in rice paddies, rice-duck systems); and the dike-pond system.

Although coming from different contexts, there seems this to be consistency, at least at a fundamental conceptual level, between the definition of IFS developed in European countries and the one from Chinese authors Li and Min (1999), as systems in which inputs are reduced, integration between the different elements of the system is sought under a holistic approach.

From the USA, Mueller et al., (2002) adopt a slightly different definition of integrated crop-animal systems (that they equal to biologically diverse agroecosystems) as farming systems benefitting from synergies provided by the wise integration of crops and livestock. Perennial species and long crop rotations supporting a biological diverse farming system are also features of such systems. Farming practices include cover and pasture crops for every field in the rotation, nutrients recycled from animals and establishment of agroforestry.

Pacini et al. (2003) compare in their study the financial and environmental aspects of sustainability of organic, integrated and conventional farming systems. They adopt the IFS definition by Morris and Winter (1999 see above). They also provide a link with the European regulations, stating that IFS analysed in their work meet the requirements of the integrated farming code of the EU Regulation 2078/92 and the Tuscany region agri-environmental enforcement programme (as updated by the 2000-2006 Tuscany Region Rural Development Plan, which enforces the EU Regulation 1257/99). They too highlight the somewhat confusing use of similar terms such as IFS, ICM and IPM.

Integrated farming has been adopted widely in Switzerland. In their study comparing conventional, integrated and organic systems in this country with a life cycle assessment approach, Nemecek et al. (2011a) explain that integrated production (IP) emerged indeed from integrated pest management, but evolved to include all areas of the production system. In Switzerland, since 1998, most of the integrated production principles have been declared as the required legal standard for ecological performance with the key elements equilibrated nutrient balance, ecological compensation areas (ECA) on at least 7% of the farm area, diversified crop rotation, soil protection during winter to reduce the risk of erosion and nitrate leaching, and targeted and restricted application of pesticides. The Swiss regulations on integrated production is thus more restrictive than the European equivalent.

In the framework proposed in this deliverable we adopt the definition of integrated farming given by Connor et al. (2011): a combination of biological cycles for nutrient, weed, pest, and disease management with tactical use of fertilisers and other agrochemicals. Sustainable, efficient production in these systems depends on careful monitoring of soil conditions and requirements and use of water and nutrients. Integrated farming systems also require limiting losses of nutrients and applied chemicals to minimise negative impacts on quality of ground and surface waters, and emission of nitrous oxide.

3.6 Organic farming systems

Amongst the different farming systems identified from the literature review, **organic agriculture** is the one with the greatest recognition worldwide having been established by legislation, regulations and certification schemes (Bellon and Hemptinne, 2012). Nonetheless, there is a variety of definitions of organic farming systems (Pacini et al., 2003). Mannion (1995), as cited by Pacini et al. (2003), defines it as “a holistic view of agriculture that aims to reflect the profound interrelationship that exists between farm biota, its production and the overall environment”.

The International Federation of Organic Agriculture Movements (IFOAM - Organics International) adopted in 2005 this succinct definition: “Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved”. In the EU, it is defined by council regulation 834/2007 as “a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. [Organic production] emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems”.

Outside Europe, referring to the Canadian system, Stonehouse (1996) defines organic farmers, in his comparative study, as those who use neither synthetic herbicides nor synthetic fertilisers, but rely for weed control and plant nutrient provision on diversified animal and crop enterprises with wide crop rotations, carefully selected sequences of crops, judicious timing of all field and animal care procedures, and other management practices. The latter include cover crops, smother crops, tillage, timeliness and timing of field operations, and composting of animal manure for weed control.

A large number of studies have carried out comparative trials of conventional systems versus organic systems to evaluate the difference in economic and environmental performances (Stonehouse, 1996; Haas et al., 2002; Panzieri et al., 2002; Delate, 2002; Pacini et al., 2003; Lantiga et al., 2004; Basset-Mens and van der Werf, 2005; Widmer et al., 2006; Stockdale and Cookson, 2007; Nemecek et al., 2011a, 2011b, just to mention a few).

From this body of literature and from existing regulations and schemes, organic agriculture principles include most of those belonging to conservation agriculture and integrated farming, the main additional feature being the ban of chemical synthetic active principle for pesticide and the use of mineral fertiliser (see Annex 1 for details). Other farming practices applied in organic agriculture recurrently cited in the international literature include: crop rotation, carefully selected sequences of crops, planting of cover crops, conservation tillage/minimum tillage, timeliness and timing of field operations, composting of animal manure, mechanical weed control, biological pest control, use of biopesticides (see Annex 1), establishment of a minimum percentage of the farm areas as natural or semi-natural habitats, cultivation of legumes, use of green manures or deep-rooting plants in an appropriate multiannual rotation programme; ban on landless animal production, ban on genetically modified organisms, use of organic feed for livestock (minimum thresholds are established, e.g. 90% in the EU); limitation to the applicable quantities of manure and other organic fertilisers.

Ideally, organic farming systems should be also spatially heterogeneous and achieve self-sufficiency in nutrient provision (Stockdale and Cookson, 2007). However, this is not always the case. Navarrete (2009) investigates organic market-gardening farming systems in south-eastern France and finds that, despite all examined cases complied with EU organic regulations, they were extremely diverse. Several organic farming systems observed in the sample differed greatly from those commonly advocated by global organic agriculture regarding the combination of crop and livestock farming: with the exception of two farms combining crops with poultry farming, the farms surveyed were crop specialised. They were not, therefore, self-sufficient in terms of soil fertility management. For instance, only 8 farms out of 18 combined market-garden and cereal or perennial crops, usually fruit orchards or olive groves. As a consequence, organic farming systems, while conceived in principle to apply ecological principles of closure of nutrient cycles and support to biodiversity, can actually range from traditional, low-input systems to very intensive ones (*ibid*.). Two different strategies can be pursued to comply with organic standards: input substitution and system redesign (Altieri and Rosset, 1996, as cited in Navarrete, 2009). In the first case, banned chemical inputs are simply substituted by allowed alternatives (e.g. biological pesticides), but the whole cropping system remains little changed. Conversely, system redesign entails that the entire agroecosystem is reconfigured according to agroecology principles to enhance positive interactions between techniques, crops, and biological organisms and favour natural pest regulation (*ibid*.). A similar point is made by Kremen et al., (2012), who point out that organic agriculture is now often practiced in large-scale monocultures that, except for reducing the impacts of inputs by replacing chemical products with organic ones, do otherwise little to foster biodiversity or sustain ecosystem services.

In the organic agriculture category, we include biodynamic agriculture**,** given its long term and established tradition.

Biodynamic agriculture is portrayed by some to be the oldest organised alternative agriculture movement in the world. Its founder is considered Rudolf Steiner. Currently, the term biodynamic is a trademark held by the Demeter International e.V association; national organisations who are members of Demeter International are responsible for Demeter certification in their own countries. The International Certification Office of Demeter International itself is responsible for the certification of products and enterprises in countries that have no independent Demeter certifying organisation. Like organic farming, biodynamic farming uses no synthetic chemical fertilisers and pesticides, and instead emphasises building up the soil with compost additions and animal and green manures, controlling pests naturally, rotating crops, and diversifying crops and livestock. In practice, the difference with organic farming schemes is that biodynamic farmers must add eight specific preparations to their soils, crops, and composts to enhance soil and crop quality and to stimulate the composting process. The eight preparations, designated by their ingredients or by the numbers 500 to 507, are made from cow manure, silica, flowers of yarrow, chamomile, dandelion and valerian, oak bark, and the whole plant of stinging nettle. According to Reganold, (1995, p. 37) "The thoughts behind the preparations are unconventional and based on a holistic approach to nature. When applied, extracts of the preparations are so highly diluted in water that physical or biological effects seem unlikely". Following Steiner's ideas, biodynamic conception also attributes an influence on crop growth by the moon and the planets. Accordingly, 'cosmic rhythms' should be considered, "cultivation, sowing and harvesting are scheduled if possible on favourable days" (Demeter International, 2018). This has raised criticism in the scientific literature (see Reganold, 1995 and Turinek et al., 2009 for reviews on biodynamic agriculture).

Migliorini and Wezel (2017) investigate converging and diverging principles and practices between organic farming and agroecology. Organic agriculture is further split in the analysis of EU and IFOAM regulation. Their conclusion in synthesis is that regarding principles, EU organic regulations have a main focus on limiting external inputs in general and chemical inputs in particular. They do not mention social issues. IFOAM principles are wider, in the sense that are based on a holistic vision of sustainability, which includes i.e. the rights of indigenous people, welfare of farmers, employees and their families, avoiding favouring land grabbing. Agroecology is based on a defined set of principles that go beyond land management and include the food system, and has a strong focus on the socio-economic dimension. Many cropping practices are the same across EU organic, IFOAM and agroecology. The largest differences are present in animal production, where practices for animal management, health control, housing, welfare, nutrition are addressed differently. A main difference remains, that there are no certification schemes for agroecology, and whether this should happen is part of the current debate.

Given the European context of the research in the LIFT project, for organic agriculture we adopt the definition reported in the EU regulation 834/2007: "a holistic production management system, which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. [Organic production] emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems."

3.7 Agroecology

The literature on agroecology has increased steadily over the past two decades. According to early works, agroecology integrates the techniques and paradigms of ecology with the practices of agricultural sciences for the study of agroecosystems (Edwards et al., 1993). For Francis et al. (2003), it is "the integrative study of the ecology of the entire food systems, encompassing ecological, economic and social dimensions". These authors outline the following key principles (see also Reijntjes et al., 1992, completed by Altieri, 2000):

- Enhance recycling of biomass and optimising nutrient availability and balancing nutrient flows;
- Secure favourable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity;
- Minimise losses due to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover;
- Diversify species and genetic composition of the agroecosystem both in time and in space;
- Enhance beneficial biological interactions and synergisms among components, thus resulting in the promotion of key ecological processes and services.

In Bellon and Hemptinne (2012) agroecology is described as a polysemic term that can be understood alternatively or jointly as a science, a movement and a practice, following Wezel et al. (2009). For Bellon and Hemptinne (2012, p. 317), "topics and levels of organisation addressed in agroecological research evolved: (i) from plants domestication and biological pest management, (ii) to farm and agroecosystem design and (iii) more recently to the ecology of food systems". The first phase had strong linkages with entomology, and biological control as promoted by IOBC (Warner, 2007). The second one enabled us to conceptualise agroecosystems as a basic unit of agroecological analyses resulting from a co-evolution of nature and societies (Gliessman, 2004). The latter one led to a renewed definition of agroecology as: "the integrative study of the ecology of the entire food systems, encompassing ecological, economic and social dimensions" (Francis et al., 2003). This definition entails multidimensional and interdisciplinary approaches and practices (Buttel, 2003; Dalgaard et al., 2003).

The interconnection of all the agroecological principles described above supports a farm system design where "overall biological efficiency is improved (with optimal use of sunlight, soil nutrients and rainfall), biodiversity is preserved, and the agroecosystem productivity and its self-sustaining capacity are maintained" (Altieri, 2000, as cited in Bellon and Hemptinne, 2012). Similarly, focusing on livestock systems, Ingrand (2018) maintains that "Agro-ecology consists of bringing together ecology and agronomy, that is, enhancing ecological processes and regulations to increase both yields and robustness (Dumont and Bernues, 2014). Five goals need to be considered in order to move toward more agroecological livestock farming systems: the integrated management of animal health, low level of pollution (air, water, soil), low level of inputs, high adaptive capacity, thanks to diversity within the system and a high level of biodiversity (Dumont et al., 2013)".

However, agroecology deals with not only farming practices *stricto sensu*, but more in general with the whole food systems, including production-consumers relations, and pays attention to socio-economic aspects such as farmers' wellbeing, food security, preservation of local traditions, equitable distribution of income. As highlighted by Lamine and Dawson (2018, p. 2) "Some of agroecology's best-known theorists explicitly include food-related issues and food systems into their theoretical frameworks (Francis et al. 2003; Gliessman 2007), and thus suggest that agroecology might be a paradigm which more adequately takes into account the necessity to reconnect agriculture, environment and food".

In their review of organic and agroecological principles and practices, Migliorini and Wezel (2017) start their article by citing Gliessman's (2014) definition of agroecology "a fully systemic approach to sustainability, addressing a transformative process of the entire food system, including its perspectives on equity, justice, and access. The transformative process implies the redesign of the food system and the integration of both horizontal and vertical diversification of production systems within sustainable food systems". In general, agroecology can be defined as a scientific discipline, a set of practices, a movement. Other definitions reported are:

- Agroecology is the integrative study of the ecology of the entire food systems, encompassing ecological, economic, and social dimensions (Francis et al., 2003).
- Agroecology is the application of ecological concepts and principles to the design and management of sustainable food systems (Gliessman, 1997).
- Agroecology is considered jointly as a science, a practice and a social movement. It encompasses the whole food system from the soil to the organisation of human societies. It is value-laden and based on core principles. As a science, it gives priority to action research, holistic and participatory approaches, and transdisciplinarity including different knowledge systems. As a practice, it is based on sustainable use of local renewable resources, local farmers' knowledge and priorities, wise use of biodiversity to provide ecosystem services and resilience, and solutions that provide multiple benefits (environmental, economic, social) from local to global. As a movement, it defends smallholders and family farming, farmers and rural communities, food sovereignty, local and short marketing chains, diversity of indigenous seeds and breeds, healthy and quality food (Agroecology Europe).
- Agroecology is based on applying ecological concepts and principles to optimise interactions between plants, animals, humans and the environment while taking into consideration the social aspects that need to be addressed for a sustainable and fair food system. By building synergies, agroecology can support food production and food security and nutrition while restoring the ecosystem services and biodiversity that are essential for sustainable agriculture. Agroecology can play an important role in building resilience and adapting to climate change. Agroecology is based on context-specific design and organisation, of crops, livestock, farms and landscapes. It works with solutions that conserve above and below ground biodiversity as well as cultural and knowledge diversity with a focus on women's and youth's role in agriculture. To harness the multiple sustainability benefits that arise from agroecological approaches, an enabling environment is required, including adapted policies, public investments, institutions and research priorities. Agroecology is the basis for evolving food systems that are equally strong in environmental, economic, social and agronomic dimensions (FAO).

Agroecological practices aim at imitating natural processes in order to enhance ecosystem services that support production and at the same time maintain and guarantee a high environmental quality and no resources depletion. Its social dimension constitutes an integral part of the discipline.

We include in this section also the work by Kremen et al. (2012) who introduce the concept of **diversified farming systems (DFS),** presented as an agroecological, systems-based alternative to modern industrial agriculture. The authors refer to a farming system as 'diversified' when it "intentionally includes functional biodiversity at multiple spatial and/or temporal scales, through practices developed via traditional and/or agroecological scientific knowledge. Farmers manage this functional biodiversity to generate critical ecosystem services to agriculture. […] Components of the agrobiodiversity within DFS interact with one another and/or the physical environment to supply critical ecosystem services to the farming process, such as soil building, nitrogen fixation, nutrient cycling, water infiltration, pest or disease suppression, and pollination, thereby achieving a more sustainable form of agriculture that relies primarily upon inputs generated and regenerated within the agroecosystem, rather than primarily on external, often non-renewable, inputs (Pearson 2007, Shennan 2008)."

There seems to be thus much in common between DFS and agroecology. However, Kremen et al. (2012) maintain that "DFS is not an alternative to agroecology. Rather, DFS is a framework that draws from agroecological, social, and conservation sciences to focus analytical and action-oriented attention toward farming systems in which cross-scale ecological diversification is a major mechanism for generating and regenerating ecosystem services and supplying critical inputs to farming. […] While DFS generally exemplify the characteristics of multifunctional, organic, sustainable, or ecoagriculture, the reverse may not always be true. […] In summary, DFS, while closely allied to all of these concepts, places more emphasis upon the relationship between functional biodiversity and ecosystem services.

Concerning the specific farming practices to be adopted at the plot (i.e., within-field) scale, DFS may include multiple genetic varieties of a given crop and/or multiple crops grown together as polycultures, and may stimulate biodiversity within the soil through addition of compost or manure. In principle, DFS should not require the use of pesticides or inorganic fertilisers and thus meets the definition of organic agriculture, while the converse is not always true. DFS is similar to another concept, ecoagriculture, in recognizing that landscapes, not single farms, are important targets of land management (*ibid*.)."

Agroecology is a science, a practice and a movement, in the frame of the present deliverable the proposed definition focuses and expands the farming practices component:

> Agroecology results from the fusion of two scientific disciplines, agronomy and ecology. By enhancing natural processes (soil fertility, natural pest control, N fixation and uptake, etc.), it aims at increasing resilience, maintaining agroecosystems productivity and their self-sustaining capacity. This therefore involves the interconnection of all of the agroecological principles described above to support a farm design where the overall biological efficiency is improved and biodiversity is preserved or enhanced.

Five milestones need to be considered in order to move toward more agroecological farming systems:

1. increased crop diversity (spatial and temporal)
2. appropriate soil management (e.g. low soil disturbance, permanent soil cover)
3. integrated management of crops and livestock
4. presence of semi-natural features
5. no use of chemical inputs, nutrients mostly produced in the farm.

In practice, therefore, the degree to which any farming system is practicing agroecological principles will depend on how much the system is relying on internal rather than external inputs, and especially how much what would be considered conventional farming system inputs have been substituted via services (e.g. soil nutrient cycling, pest and disease control) arising from natural processes on the farm that are being maintained and enhanced through the farming practices.

3.8 Classification systems based on ecological criteria

Considering the large number of documents describing different farming systems, often comparing them in trial experiments or through meta-reviews, there is a paucity of attempts to classify the variety of such systems into consistent frameworks or schemes, based on the degree of ecological functionality of the different systems. The following are the documents that we identified through our review.

Dalsgaard et al. (1995) make an attempt to linking theoretical ecology with indicators of ecological sustainability in farming systems. They propose a typology that organises systems along a scale of increasing ecological sustainability. They identified four system attributes, namely diversity, cycling, stability and capacity and applied them to rice systems. They identify four systems: 1) high external input monocropping systems; 2) integrated rice-fish systems; 3) diversified, non integrated systems; 4) low external input integrated resources management systems.

Leeson et al. (1999) use a multivariate classification system based on quantitative variables describing aspects of cropping history and chemical input levels using multivariate techniques. They identify seven clusters of farms starting from cropping history and chemical input levels. The latter is divided in three classes: organic (no chemical input for herbicides and fertiliser), moderate input (less that recommended application rate) and high (equal or above the recommended rates). In particular, the management practices considered are: fallow frequency; perennial forage frequency; crop diversity; herbicide rate (%); herbicide passes; herbicide ingredients; herbicide groups; tillage passes; cultural controls; nitrogen rate (%); phosphate rate (%); seed treatment frequency. The seven resulting clusters are: (1) moderate input - fallow; (2) high input - fallow; (3) moderate input diversified annual grains; (4) moderate input diversified grain forage; (5) organic - fallow; (6) organic diversified annual grains; (7) organic diversified grain forage.

Lantinga et al. (2004) propose a classification scheme by elaborating on that proposed by Schiere and De Wit (1995) and it explains what is meant by high-input systems by placing them in a sequence of modes in agriculture that address sustainability problems in different ways. It assumes that differences among farming systems can be explained on the basis of relative access to the resources land, labour, and capital. Land is considered as an aggregate of land quantity and quality, and labour is an aggregate of individual skills and numbers of persons. Access to capital is defined as access to inputs such as fertiliser and commercially compounded feeds. Four modes of farming systems are distinguished: expansion agriculture, low-external-input agriculture, high-external-input agriculture and new-conservation agriculture. The classification of Lantinga et al. (2004) shows that expansion agriculture and high-external-input agriculture systems are grounded on throughput, at the expense of reserves, also called biophysical capital (Giampietro et al., 1992). As a sharp contrast, one can say that low-external-input agriculture and new-conservation agriculture aim at circulation of nutrients.

Hendrickson et al. (2008) identify four major farming systems in the USA (not representing the whole of USA agriculture however). These come from the complex interactions among social, political, economic, environmental and technological drivers. The resulting four systems are: (1) commodity crop production, (2) supply chain livestock production, (3) organic production and (4) extensive livestock production. These systems are evaluated also in relation to their degree of sustainability. From the less sustainable to the more one, they are:

- Supply chain livestock production system is highly specialised, requires high inputs to maintain high productivity levels, and uses contract sales to reduce risk.
- Commodity crop production system relies on high inputs and is heavily influenced by government policy. This system is highly specialised, often focusing on one or two crops such as corn and soybeans, relies on farm policy for income and risk protection, and is impacted by government policies regarding conservation, such as the Conservation Reserve Program.
- Extensive range livestock grazing systems are based on livestock grazing forage produced by rangelands. Although these systems rely on a diverse forage base, the animal component is highly specialised. The lack of direct government payments in livestock production indicate the importance of markets in determining prices received for products. Extensive range livestock grazing systems are sometimes impacted by government policy in establishing grazing fees on public rangelands as well as the impact of environmental concerns with livestock grazing on western rangelands.
- Organic production system relies on a diverse crop rotation to achieve environmental benefits for the entire system, resulting in greater diversification in organic systems than that seen in other systems.

Sutkowska et al. (2013) provide a classification of farm systems in Polish HNV based on a questionnaire administered in 2005 distributed to 80 farms in Wigry National Park in north-eastern Poland. The questionnaire concerned agricultural production and the attitudes of farmers for future plans, especially connected with sustainable development, e.g. organic farming. Environmental variables included: livestock density, the amount of mineral fertiliser used, ways of using the meadows and pastures, performance of a soil chemical analysis and the application of liming. Six cluster of farms were identified:

1. Mixed farms with medium intensity, whose farmers did not show initiative in use of co-financing from EU funds.
2. Low intensity farms, usually plant production, whose farmers frequently benefit from co-financing from EU funds.
3. Low-intensity farms, with a prevalence of plant production and a high share of cereals in the structure of arable area on the farm.
4. Farms specialising in animal production, cattle keeping, medium intensity.
5. Farms where activities other than crop and livestock production are significant sources of income.
6. Farms with a significantly higher scale of production than the remaining farms.

Moraine et al. (2014) identify four types of crop-livestock integration based on the level of diversity and synergies between elements:

Type 1: exchange of materials (e.g. grain, forage, straw, waste as organic fertiliser) between specialised farms, regulated by the market, in a rationale of ‘coexistence’.

Type 2: exchange of materials between spheres in a rationale of ‘complementarity’ at the farm if not territorial level. Crop systems are designed to meet the needs of livestock enterprises (need for concentrates, raw forages and straw) and livestock waste to fertilise arable plots.

Type 3: increased temporal and spatial interaction among the three spheres in a rationale of 'farm-level synergy': stubble grazing, temporary grasslands in rotations, intercropped forages. A high level of diversity in farm components is targeted to enhance regulating services.

Type 4: increased temporal and spatial interaction among the three spheres in a rationale of 'territory-level synergy': organisation optimises resource allocations, knowledge sharing and cooperation, including work.

Types 1 and 2 focus on improving metabolic properties of farming systems, while types 3 and 4 focus on using ecosystem services to regulate pests and increase soil fertility.

Stavi et al. (2016) conduct a literature review focusing on the impact of each of the following core farming practices: (1) tillage methods, (2) crop residue management, (3) nutrient management, and (4) pest management on nine soil functions and ecosystem services, namely (i) water availability for crops (as determined by the soil-water dynamics); (ii) weed control (as determined by the applied agro-techniques); (iii) insect and pathogen control (also, as determined by the applied techniques); (iv) soil quality and functioning (including physical, chemical, and biological components); (v) soil erosion control (including rill, inter-rill, and gully erosion); (vi) soil organic carbon pool (the total organic carbon pool, without relating to specific functional fractions); (vii) environmental pollution control (including preventing contamination of water, soil, and air resources); (viii) greenhouse gas refuse (including carbon dioxide, nitrous oxide, and methane); and (ix) crop yield productivity (including both vegetative and reproductive plant material).

A score (1-3) based on three levels of intensity for each of these services is assigned. In this way, the high intensity level is discussed in relation to conventional tillage, full removal of crop residue, chemical nutrient management, and chemical pest management. Medium intensity is discussed in relation to moderate tillage, moderate removal of crop residue, integrated nutrient management, and integrated pest management. Finally, low intensity is discussed in terms of no-till, no removal of crop residue, organic nutrient management, and organic pest management.

Three systems are identified: (1) conventional; (2) integrated/moderate-intensity and (3) conservation.

Therond et al. (2017) identify three biotechnical types of farming systems according to the portion of agricultural production derived from ecosystem services and external anthropogenic inputs:

- Chemical input-based farming systems: they are based on strongly simplified crop sequences, standardised crop management and systematic use of chemical inputs: Haber-Bosch-based nitrogen and pesticides. They seek to optimise inputs according to spatiotemporal plant/animal requirements and, to limit pollution, follow an efficiency-based modernisation pathway. Precision agriculture and new technology can be used to achieve this. Amortising these technologies may lead farmers to continue to increase the size of their farm to reach suitable economies of scale.
- Biological input-based farming systems: they implement a substitution-based modernisation pathway entailing classic use of organic fertilisers as substitutes for inorganic ones, new biocontrol practices being applied in short rotation- or monoculture-based cropping systems. Use of industrially developed natural enemies and other service-providing organisms, soil biostimulants and bioinoculants. They can also use biopesticides to avoid eco-toxicity of chemical pesticides.
- Biodiversity-based farming systems: they are based on input ecosystem services. This requires increasing species/cultivar/breed diversity (e.g. intercropping, diversified field edges, crop

sequences) and soil cover (cover crops) while minimising mechanical and chemical disturbances of beneficial biological processes. Regarding biological regulations, two main complementary strategies can be distinguished: (i) developing direct effects of plant biodiversity on pathogens, animal pests and weeds via, for example, traps, barriers and resource dilution effects and the breaking of pest cycles ('bottom-up' effects) and (ii) developing effects of planned biodiversity and non-crop habitats on naturally occurring associated biodiversity, which provides biological control of weeds and animal pests ('top-down' effects of natural enemies).

4 Discussion

Based on the literature review presented in section 3, we suggest that LIFT should consider clustering farming systems according to their uptake of ecological practices by using the five terms described above (sections 3.3 to 3.7) together with the term conventional (Table 2). Each of the six terms includes a number of farming systems drawn from the literature that can be associated under the same umbrella. As it is the case with all taxonomies aiming at classifying a complex domain into specific categories, identified farming systems clusters are ideal categories and the boundaries between them, in reality, should not be considered strictly demarcated; rather, they represent a continuum along which systems can range, with blurred boundaries and possible overlaps between different clusters. However, they are ranked in a lexicographical order with respect to their degree of uptake of agroecological practices, meaning that, in our proposed frame, agroecology is the most ecological farming system cluster, followed by organic systems and so on, with conventional systems at the other extreme of the spectrum.

The literature review also considered similarities and differences in the terminology to describe different farming practices. Based on the results from the review we also suggest a framework to cluster farming practices (Table 3).

In Table 3, the first column contains the proposed working title for the farming practices and the subsequent three columns contain, where necessary, an indication of the farming practice terms that were considered by the authors to be inter-changeable along each row, based on the literature review. Each row thereby indicates a set of terms that are considered to be different from those in the other rows. For example, the 'Agri-environmental measures' cluster contains two types of practices, the 'Agroforestry' cluster contains only one and the 'Use of chemical inputs' cluster contains six separate practice terms.

The initial list of farming practices identified from the literature analysis is very long and includes 118 separate practices that have been grouped together into 36 main groups. These 36 groups are not necessarily mutually exclusive - for example semi-natural habitats can be part of agri-environmental measures as well as being a cluster of their own.

Table 2: Clustering tree for farming system terminology drawn from the literature review

Farming systems clusters		Farming systems
Systems incorporating differing degrees of ecological practices	Agroecology	Agroecology
		Biodiversity-based farming systems
		Diversified Farming Systems
		Ecoagriculture
		Ecological Arable Farming System
		Permaculture
		Natural system agriculture
	Organic farming systems	Biodynamic
		Biological input-based farming systems
		Organic agriculture
		Organic farming systems
	Integrated farming systems	Integrated arable farming systems
		Integrated crop-livestock systems
		Integrated crop-range-livestock systems
		Integrated farming system
		Integrated perennial crop systems
	Low-input/Extensive systems	Extensive grass-based systems
		Extensive systems
		Low external input systems
		Low-input systems
		Low-intensity systems
		Reduced input systems
		Silvopastoralism
	Conservation agriculture	Conservation agriculture
		Conservative agriculture
		Minimum tillage systems
		No tillage systems
		Reduced tillage systems
		Strategic tillage systems
Conventional systems	Conventional systems	Chemical input-based farming systems
		Conventional systems
		Crop intensification systems
		Intensive systems

Table 3: Clustering of farming practices

Proposed cluster label	Practices		
Agri-environmental measures	Agri-environmental measures	Agrienvironmental measures	
	Agri-environmental schemes	Agrienvironmental schemes	
Agroforestry	Agroforestry		
Use of chemical inputs	Agrochemical	Agrochemical input	
	Herbicide	Herbicide input	
	Insecticide	Insecticide input	
	Inorganic chemicals		
	Mineral fertiliser		
	Pesticide	Pesticide input	
Use of organic pesticides	Biological insecticide		
	Amendments		
	Copper		
	Sulphur		
Biodynamic preparations	Biodynamic preparations		
Semi-natural habitat on farmland	Diversified field edges		
	Conservation buffers		
	Border planting		
	Ecological compensation areas	Ecological focus area	(Agro) ecological infrastructure (management)
	Grassy buffer strips		
	Habitat	Semi-natural habitat	Wildlife plots
	Hedgerows		
	Insectary strips		
	Living fences		
	Noncrop plantings		
	Beneficial fauna	Beneficial flora	Functional biodiversity
Intercropping	Alley intercropping		
	Intercropping	Intercrops	Mixed intercropping
	Multiple intercropped species		
	Relay intercropping		
	Polyculture		
Crop-livestock integration	Animal circulation		
	Crop-livestock integration	Livestock-crop integration	
Use of organic animal manure	Manuring	Manure fertiliser	
	Farmyard manure	Feedlot manure	
	Organic manure	Animal manure	
Use of green manure	Compost	Compost application	Composting
	Green manure		

Biological pest control	Bio-control	Biological pest control	Natural pest control
	Plant extract bio-control		
	Diversionary strategy		
Biological nitrogen fixation	Biological nitrogen fixation	Biological N fixation	
	Legume-cereal rotations		
	Legumes	Pulse crops	Pulses
Cover crops	Catch crop	Clover	Cover crops
Conservative tillage	Conservative tillage	Strategic tillage	
	Minimum soil cultivation	Reduced soil cultivation	
	Minimum tillage	Shallow tillage	
	No tillage	No-tillage	
	Occasional tillage	Reduced tillage	
	Ridge till	Ridge tillage	
	Asynchronous tilling		
	Direct drill	Direct sowing	
Crop rotation	Crop rotation	Crop sequence	Rotation
	Dryland rotation		
	Irrigated rotation		
	Multifunctional crop rotation	Diversification of crop rotation	
Sustainable water management	Deficit irrigation	Reduced irrigation	
	Drainage		
	No irrigation		
	Flooding		
Extensive livestock systems	Transhumance		
	Silvopasture		
	Extensive livestock	Extensive livestock management	
Inclusion of fallow land	Fallow	Fallow land	Fallowing
Spatial heterogeneity	Diversification		
	Farm heterogeneity		
	Spatial diversity		
	Patch intensification		
Selection of breeds and cultivars	Breed	Breed selection	
	Seed selection		
	Genetic diversity	Genetic varieties	Multiple genetic varieties
	Crop variety improvements		
	Local breed	Regional breed	
	Varietal diversity	Varietal mixtures	
	Local variety	Regional variety	Traditional variety
Use of genetically modified organisms (GMO)	Genetically modified organisms	GMO	Biotech crops

Sustainable grazing	Grass ley	Grass-clover ley	
	Ley	Ley farming	
	Perennial leys with legumes		
	Improved pastures		
	Grassland mixtures		
	Grazing		
	Grazing on crop residues	Use of fallow	
	Rotational grazing	Management-intensive rotational grazing systems	
Integrated pest management	Integrated crop management		
	Integrated crop protection	Integrated pest management	
Low agrochemical input	Low agrochemical input		
	Low herbicide input	Reduced herbicide application	Reduced herbicide use
	Low insecticide input	Reduced insecticide use	
	Low pesticide input	reduced pesticide use	reduced plant protection
Low fertilisers input	Low fertiliser input	Low nutrient input	Reduced fertiliser application
	Low-solubility mineral fertilisers		
Low mechanisation	No mechanisation		
	Low mechanisation	Low degree of mechanisation	Reduced mechanisation
Integrated nutrient management	Integrated nutrient management		
	Bioinoculants	Soilbiostimulants	
Mulching	Organic mulching		
	Mulching		
Alternative weed management strategies	Fumigation	Soil fumigation	
	Mechanical operations		
	Mechanical weeding		
	Mechanisation		
	Weeding		
	Push-pull system		
Use of concentrate	Use of concentrate	Concentrate	
No use of concentrate	No concentrate	No use of concentrate	
No use of chemical input	No mineral fertilisation		
	No pesticide input	No pesticides	
	No herbicide input		
	No insecticide input		
Management of soil organic matter	Organic matter	Soil organic matter	
Precision farming	Precision farming		
	Precision livestock farming		

Set aside	Set aside	Setaside	set-aside
Crop residue management	Stockpiled forages		
	Crop residue manage-ment		
	Stubs not grazed		

Note: practices on the same rows are considered synonyms.

Table 4 represents a first effort to link the farming systems in Table 2 with the farming practices in Table 3. The assignment is made on the basis of the links emerging from literature. It should be intended as a table linking practices that are clearly being considered as part of a specific farming system. In each cell, an X indicates a recurrent association between the practice and the farming system, whilst XX indicates practices that typically represent a specific farming system. Therefore, where no link is present in a cell, it does not mean that the practice cannot be implemented in that system, but only that no recurrent association emerged from the surveyed literature. For example, semi-natural habitats/spatial heterogeneity may well be present in conventional farming, but are not characterising that farming system specifically.

The links reported in Table 4 should be considered as a basis for further discussion and refinements, not as a definitive outcome. The table, as well as the preliminary farming system classification, will be discussed with LIFT project partners and stakeholders in the continuation of the project, and an updated version will be elaborated and presented in Deliverable 1.3 as a result.

Table 4: Main associations between farming practices and farming systems derived from literature analysis

Practices	**Agroe-cology**	**Organic Farming**	**Low-input/Ex-tensive sys-tems**	**Integrated farming sys-tems**	**Conserva-tion agricul-ture**	**Conven-tional sys-tems**
Agri-environmental measures	X	XX	X	X		
Agroforestry	XX		X	X		
Use of inorganic chemical inputs					X	XX
Use of organic pesticides	X	XX		X		
Biodynamic preparations		XX				
Semi-natural habitat on farmland	XX	X	X	X		
Intercropping	XX	X				
Crop-livestock integration	XX			X		
Use of organic animal manure	XX	XX	X	X		
Use of green manure	XX	XX				
Biological pest control	XX	XX	X	X		
Biological nitrogen fixation	XX	XX	X	XX		
Cover crops	XX	XX	X	X	XX	
Conservative tillage	X	X	X	X	XX	
Crop rotation	XX	XX	X	XX	XX	X
Sustainable water management	XX	X	X			
Extensive livestock systems	XX	XX	XX			
Inclusion of fallow land	XX	X	X	X		
Spatial heterogeneity	XX	X	X	X		
Selection of breeds and cultivars	XX	X	X	X		
No use of GMO	XX	XX				
Sustainable grazing	XX	X	X	X		
Integrated pest management			X	XX		
Low inorganic chemical input			XX	X		
Low fertilisers input	X	X	XX	X		
Low mechanisation	X	X	X	X	X	
Integrated nutrient management	X	X	X	XX		
Mulching	XX	XX	X	X	XX	
Alternative weed management strategies	XX	XX	X	X		
No use of concentrate feed	X	XX				
No use of chemical input	X	XX				
Management of soil organic matter	XX	XX	X	X	XX	
Precision farming				X		X
Set aside	X	X	X	X		
Crop residue management	XX	X	X	X	X	
Crop diversification/Polyculture	XX	X	X	X		

Note: X= recurrent association between farming system and practice; XX= practice that typically represent a specific farming system.

In summary, ecological approaches include practices addressing:

- crop management in terms of rotation and diversity
- soil management in terms of cover and disturbance
- livestock management and links to grassland management
- presence/management of semi-natural features (hedges, grass/flower strips etc.)
- varying degrees of inorganic fertilisers and pesticides management.

It is worth noting that rarely does any one group of practices have a strong association with only one farming system. In addition, as highlighted in Annex 2, although data on the use or not of some of these practices can be readily obtained from datasets of on-farm information, data on others are not easily available as they fall out with the normal range of data collected as part of on-farm data collections.

5 Semantic analysis

The tables presented in section 4 are the product of expert interpretation of literature. A further step in the interpretation of results can be achieved through automatized textual analysis. CorTexT (www.cortext.net) is a platform that provides users with state-of-the-art tools to process, characterise, analyse and quantify textual data that has undergone little to no calibration. It offers several options, among which:

- socio-semantic analysis of heterogeneous bodies of text
- data mining and information extraction
- sciences of complexity applied to social networks
- computer sciences for the social sciences and humanities.

In the case of the present deliverable, its application was twofold:

1. mapping the direct link farming system/farming practice cluster as reported in the body of identified literature
2. clustering the identified farming systems on the basis of the occurrence of identified farming practices in the body of literature, and identifying relations among them.

Several trials were run to combine the information acquired in the literature review. The following has been identified as most relevant.

5.1 Links between farming practices and farming system clusters

One of the possibilities offered by CorTexT is to count the number of times a term is reported in a literature corpus (whether in title, abstract, keyword, text etc.). This option has been used in the following way:

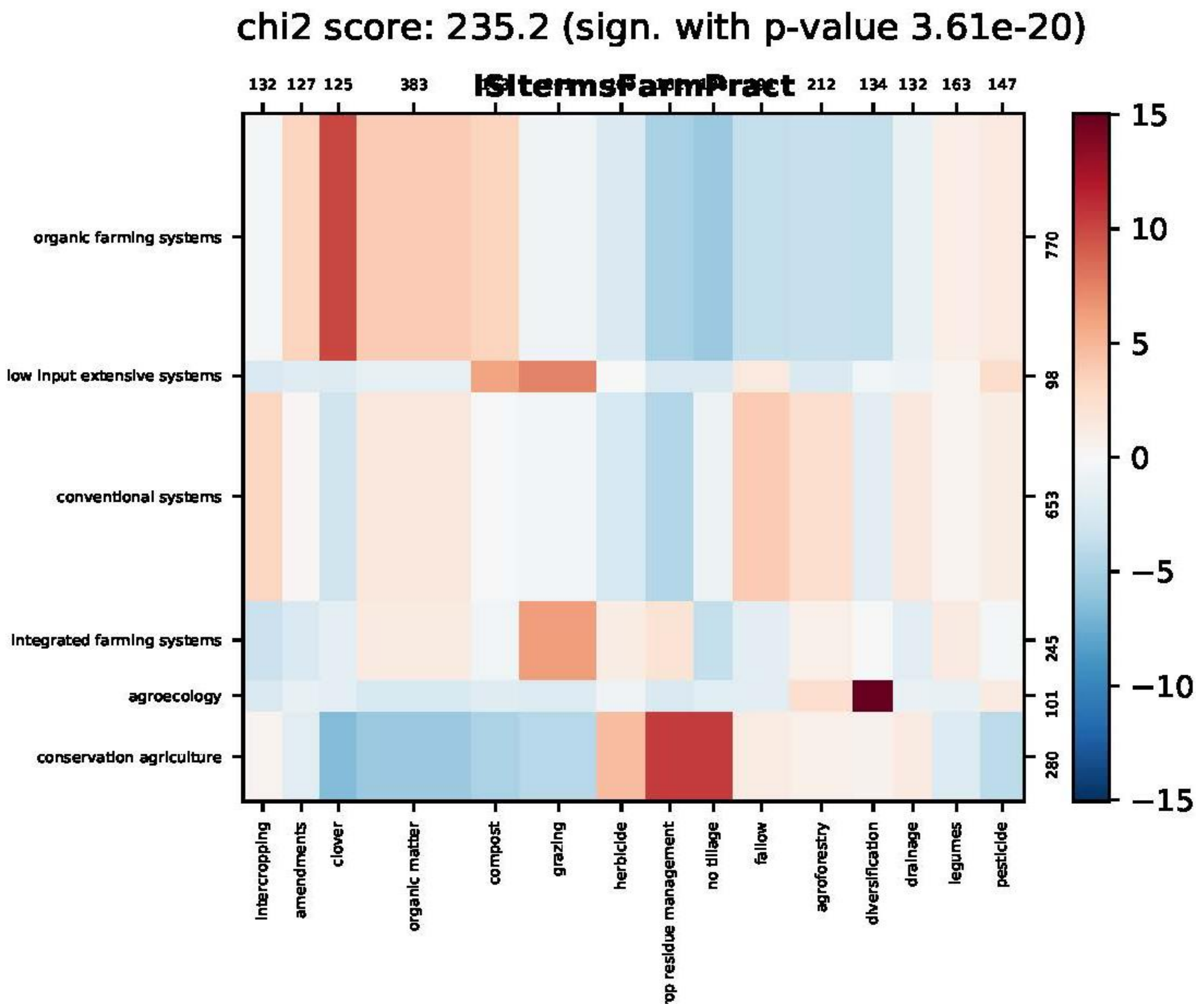
- the literature review described in section 3 is based on the total corpus of 2,403 documents resulting from the research in the three examined databases;

- taking into account double (or triple) counting and the availability of indexed papers (note that it is not possible to run the analyses on non-indexed papers), the final corpus was composed respectively by:
    - farming system clusters: 989 references indexed;
    - farming practices: 1,298 references indexed.

In this corpus the occurrences of the terms representing identified farming practices in relation to farming systems has been counted and mapped. Terms have been searched in titles and abstracts. There are two caveats associated with this work:

- it would have been interesting to look for these correlations in the selection of papers deriving from the literature review explained in section 3, but this would result in a too low number of papers (183 indexed documents) for this type of analysis. Therefore, it has been run on the larger corpus of indexed literature mentioned above;
- the list of farming practices is very long and it had to be reduced in order to launch the analysis. The 15 most occurring terns have been used in the current work.

Figure 1: Contingency matrix of farming practices vs farming systems



In Figure 1[2], beside correlation among cells, the number of occurrences is also shown by the height and width of lines and columns.

The graph should be interpreted with care and a number of caveats should be taken into account:

- the fact that a line is more or less high does not mean that the specific farming system is more important, it simply means that it is more studied;
- the fact that a correlation is reported, is linked to the number of papers exploring that relation;
- a correlation means that a certain practice is reported in conjunction with a certain farming system, and it is not necessarily positive. This is most likely the case for pesticide and low-input systems.

The matrix shows a dominance of literature concerning conventional and organic systems. Among farming practices, papers concerning organic matter and grazing are most numerous.

5.2 Co-citation map

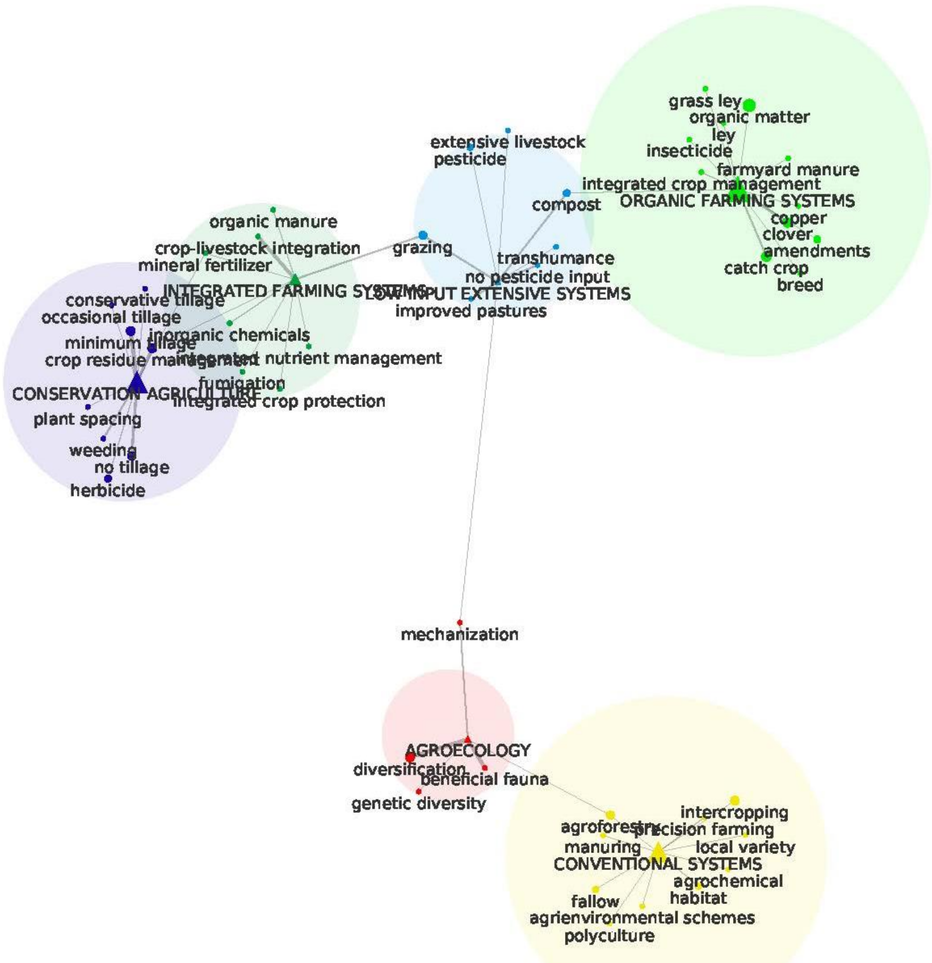
In this part of the textual analysis, a 3D representation of the links between farming systems and farming practices is made, through heterogeneous mapping analysis, which identifies co-citations. In this case, the analysis is made on the first 50 occurrences of farming practices listed in the second column of Table 3. Entries are much more numerous, the cut-off at 50 is necessary to keep the graph readable.

Figure 2 represents the network between farming systems and farming practices, where the farming system clusters are represented by circles of area proportional to the associated papers. A farming practice in most cases is associated to more than one clusters, but for the purpose of this work the link is maintained to the cluster with the highest number of occurrences. Links are represented by coloured dots, whose dimension is proportional to the frequency of the associations. Clusters are connected through one or more links.

It is interesting to notice which term(s) connect the clusters. For example ‘grazing’ connects ‘integrated farming systems’ to ‘extensive farming systems’; ‘compost’ connects ‘extensive farming systems’ to ‘organic farming systems’, crop residue management links conservation agriculture and integrated farming systems. While these links are not problematic, what should be further investigated is the perspective under which ‘mechanisation’ links ‘extensive systems’ to ‘agroecology’.

[2] Note: Red cells are the most correlated (many documents mentioning item A(i) also mention B(j)). Blue ones are anti-correlated (few documents mentioning A(i) also mention B(j)). White cells do not feature any correlation (B(j) and A(i) joint mentions are neither more nor less numerous than average) (source: CorTexT manual).

Figure 2: Co-citations of identified farming systems and farming practices (first 50 hits)



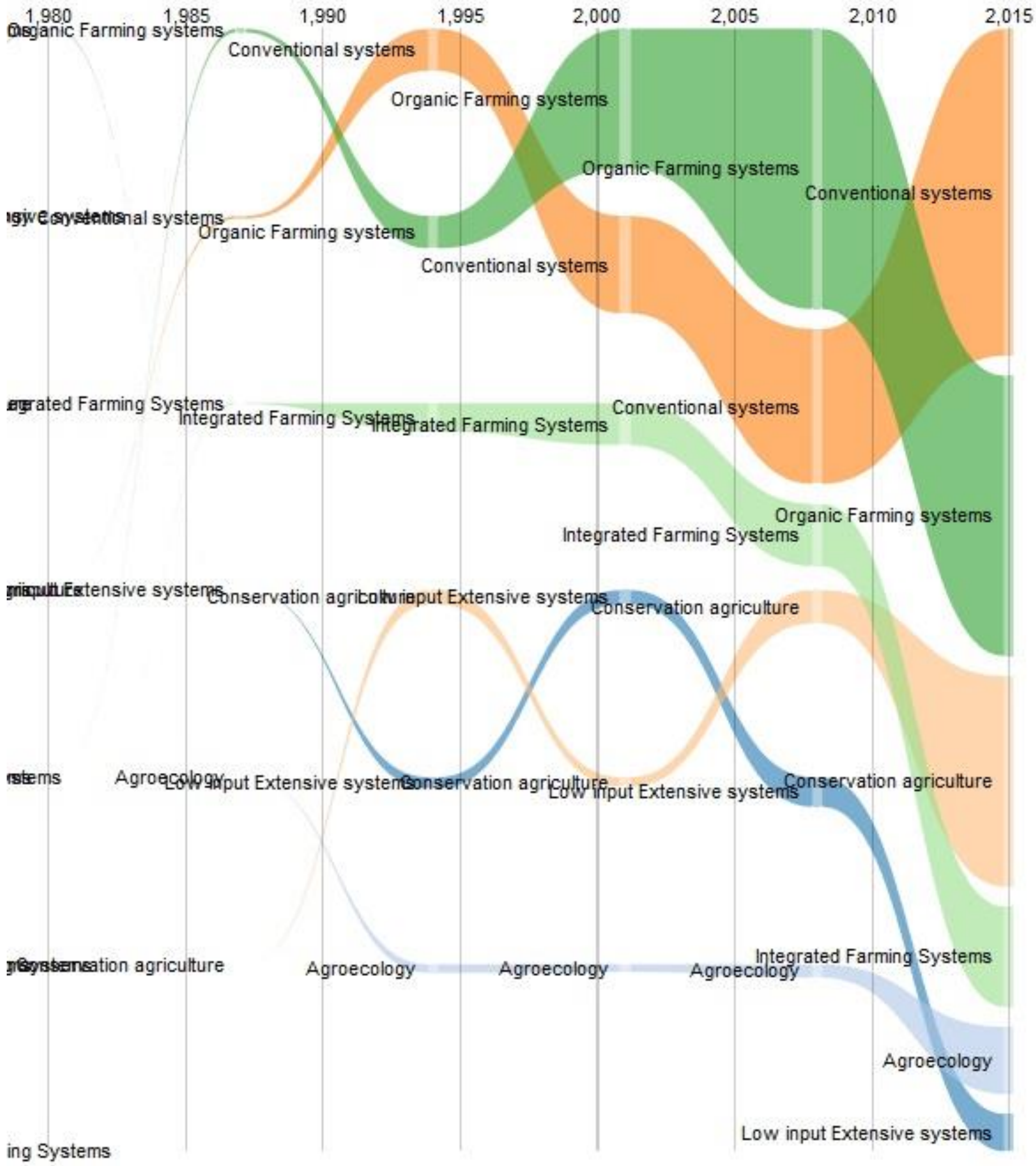
5.3 Frequency timeline

Figure 3 shows the frequency timeline of the number of papers containing the terms relative to the six farming system clusters over time. It can help explain why some of the fields in the contingency matrix (Figure 1) are blue. It can be seen how conventional and organic systems have been supported by a large bulk of literature already for some time, and that while references to conventional systems grew in the past 10 years, for organic agriculture the quota remained pretty stable.

Integrated farming systems have a lower share but grew in the past 10 years; low-input/extensive systems remain at the lower part of the scale. Among all systems, the ones that are drawing more attention are agroecology and conservation agriculture, which are characterised by a boost in publications starting from the early 2000's.

Blue cells in the contingency matrix (Figure 1), or at least some of them, are likely to become red if this trend continues.

Figure 3: Frequency timeline of the number of papers containing the terms relative to the six farming system clusters over time



6 Conclusions

This deliverable presents the first step to the definition of a framework that identifies main farming systems and the degree to which each of them adopts ecological practices. The core of the deliverable is Table 4, which synthesises the findings, but also prepares the way ahead.

Next steps consist in attaching data and thresholds to the farming practices, to feed the analysis and modelling processes. The aim is to be able to characterise individual farms with reference to their uptake of ecological practices. The proposal is that individual farms could be labelled according to one of the six farming system clusters, which show internally different degrees of uptake of ecological practices.

Table 4 provides the basis for identifying which farming practices should be considered in analysis and modelling. More work needs to be done on linking indicators and data for the description of each farming practice, this is one of the goals of deliverables that will follow. In some cases, it will be necessary to define thresholds, since the same farming practice can be attached to more than one farming system (i.e. grazing density for livestock farming). In this regard, Annex 1 provides a review of EU law on organic and integrated production, which already contains clear thresholds; Annex 2 provides a first introduction to the needs of modelling exercises.

Further semantic analyses may also help to refine Table 4. For example, if it was feasible to include all 36 farming practice cluster terms in a contingency matrix against the six farming systems, then this may shed more light on the strength of the relationships postulated in Table 4 or, at the very least, indicate where potential relationships between farming practices and farming systems need to be looked into in more detail.

As indicated in section 3.7 above, agroecology can be considered a science, a practice which stretches from the farm through the supply chain, and a movement. The LIFT project is primarily concerned with how well agroecological practices are – or could be – incorporated into European farming systems. Consequently, the primary focus within LIFT is at the level of farm practices within differing farming systems, though it is also recognised that how agroecological principles ultimately stretch out along the supply chain to and from the farm will require some consideration within LIFT.

7 Deviations or delays

None

Acknowledgements

The authors thank all project partners who provided useful comments to an early version of this deliverable: Andrew Barnes (SRUC, United Kingdom), Sophia Davidova (University of Kent, United Kingdom), Yann Desjeux (INRA, France), Laure Latruffe (INRA, France), Marine Paupière (INRA Transfert, France), and Lena Schaller (BOKU, Austria).

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Annex 1: Review of EU law on organic production and integrated crop production

Introduction

The review is aimed at exploring the definition of organic production and integrated crop and pest management in Europe. Within the EU, organic production has a clear legal basis, defined by the Regulation (EC) No 834/2007. Non-EU regulations, like the Swiss one, are substantially similar (Organic farming ordinance 910.18). For integrated crop production (ICP) there is no counterpart, since the only EU wide legal framework is on IPM (Directive 2009/128/EC). ICP guidelines are sometime set with respect to Rural Development Programme (RDP) measures (e.g. RDP of Emilia-Romagna or Lombardy). When this is the case, ICP practices are set on a local, yearly and crop specific basis, with further differentiations that could be based on e.g. slope, chemical and soil characteristics of cultivated land.

The main characteristic of organic plant production is the restriction of external and chemical input in the production process, with only some exceptions on inputs that are allowed (as defined in Regulation 889/2008). On the contrary, the main feature of ICP is the 'appropriate use' of external inputs in the plant production process. In this sense, there is no distinction on input quantity between organic and ICP (but only products that are or are not allowed), whereas the distinction between ICP and conventional farming can only be traced at the plot level. More specific thresholds are set on the organic animal production.

Organic production

The legal framework on organic production is governed by the Regulation (EC) No 834/2007 on organic production and labelling of organic products and the implementing Regulation (EC) No 889/2008 with regard to organic production, labelling and control. The definition of organic products and productions is based on an overall system of farm management and food production that links best environmental practices, a high level of biodiversity to the preservation of natural resources and the application of high animal welfare standards (Preamble of Regulation 834/2007). According the EU legal framework, the label 'organic' refers to products and productions, but not to farms. The main characteristics of organic production are set in Article 4, providing details on the design and management of biological processes based on ecological systems using natural resources and the restriction on the use of external inputs.

Specific principles applicable to farming are listed under article 5 that establishes, in relation to plant and animal production:

(a) the maintenance and enhancement of soil life and natural soil fertility, soil stability and soil biodiversity preventing and combating soil compaction and soil erosion, and the nourishing of plants primarily through the soil ecosystem;

(b) the minimisation of the use of non-renewable resources and off-farm inputs;

(c) the recycling of wastes and by-products of plant and animal origin as input in plant and livestock production;

(d) taking account of the local or regional ecological balance when taking production decisions;

(e) the maintenance of animal health by encouraging the natural immunological defence of the animal, as well as the selection of appropriate breeds and husbandry practices;

(f) the maintenance of plant health by preventative measures, such as the choice of appropriate species and varieties resistant to pests and diseases, appropriate crop rotations, mechanical and physical methods and the protection of natural enemies of pests;

(g) the practice of site-adapted and land-related livestock production;

(h) the observance of a high level of animal welfare respecting species-specific needs; (i) the production of products of organic livestock from animals that have been raised on organic holdings since birth or hatching and throughout their life;

(j) the choice of breeds having regard to the capacity of animals to adapt to local conditions, their vitality and their resistance to disease or health problems;

(k) the feeding of livestock with organic feed composed of agricultural ingredients from organic farming and of natural non-agricultural substances;

(l) the application of animal husbandry practices, which enhance the immune system and strengthen the natural defence against diseases, in particular including regular exercise and access to open air areas and pastureland where appropriate.

Chapter 2 of the Regulation provides further rules on farm production and requires that the entire agricultural holding shall be managed in compliance with the requirements applicable to organic production. However, according to article 11, a holding may be divided into clearly separated units or sites which are not all managed under organic production requirements. In such a case, the operator is required to ensure that land, animals, and products used for, or produced by, the organic units is to keep separate from those used for, or produced by, the non-organic units and keep adequate records to demonstrate the separation.

The use of external input in the plant production processes are required to be managed in such a way that they prevent or minimise any contribution to the contamination of the environment. While the use of biodynamic preparations is allowed, fertilisers, soil conditioners and plant protection products may only be used if they have been authorised for use in organic production under article 16 of the Regulation, as well as products for cleaning and disinfection in plant production. In this prospect, the categorisation of organic production is not based on quantity of input use, but only on a list of allowed products. The use of mineral nitrogen fertilisers is prohibited. However, the prevention of damage caused by pests, diseases and weeds is required to be based primarily on the protection by natural enemies, the choice of species and varieties, crop rotation, cultivation techniques and thermal processes.

In relation to livestock production, article 14 provides details requirements with regard to the origin of the animals, to husbandry practices and housing conditions, to breeding, to feed, to disease prevention and veterinary treatment as well as cleaning and disinfection, products for cleaning and disinfection in livestock buildings and installations. Differently from the plant production, precise thresholds are set with respect to e.g. maximum number of animal per hectare.

The European Commission authorises the use of products and substances in organic production and include in a restricted list those which may be used in organic farming for purposes, inter alia, as plant protection products, as fertilisers and soil conditioners, as feed additives and processing aids, as products for cleaning and disinfection of buildings and installations used for plant and animal production, including storage on an agricultural holding as well as ponds and cages.

The authorisation procedures that the European Commission follows is laid down under article 16 and shall be carried out in accordance with the procedure referred to in Article 37(2) of the Regulation.

Within this background, Member States may regulate the use of products and substances in organic farming for different purposes within their territory, provided that the national rules are compliant with general and specific criteria set out in the Regulation and respects EU law. In any case, the Member State is required to inform other Member States and the European Commission of such national rules.

The provisions set out in Regulation 834/2008 continue to apply until 1 January 2021, when the new Regulation 2018/848 of 30 May 2018 on organic production and labelling of organic products will entry into force and repeal the previous Regulation. The Regulation 2018/848 will introduce a simplified framework for production rules that is further harmonised through the phasing out of several exceptions and derogation, provided under Regulation 834/2008. The Regulation will establish, *inter alia*, a strengthened control system thanks to precautionary measures and risk-based checks that are applied on the entire supply chain, while certification will be easier for small farmers due to the introduction of a system of group certification and the scope of organic rules will cover a wider list of products (such as salt, cork, beeswax, mate, vine leaves, palm hearts).

Integrated crop production

As regard integrated crop production (ICP), the EU legal framework only addresses IPM. IPM approach is established under the Directive 2009/128/EC that provides a framework for action to the Member States to achieve the sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment as well as promoting the use of integrated pest management, as provided under article 1.

According to article 2, the Directive applies to pesticides recognised as plant protection products that are defined in accordance with Regulation 1107/2009 concerning the placing of plant protection products on the market. Article 2(3) provides that Member States are not prevented from applying the precautionary principle in further restricting or prohibiting the use of pesticides in specific circumstances or areas. For the purpose of the Directive, Member States are required to adopt National Action Plans under article 4 of the Directive. In the Plans, Member States shall set up, *ex pluris*, the measures to reduce risks and impacts of pesticide use on human health and the environment and to encourage the development and introduction of integrated pest management. Member States shall undertake the necessary measures to promote low pesticide-input pest management and to provide wherever possible priority to non-chemical methods, according to article 14. For the purpose of the Directive, low pesticide-input pest management includes integrated pest management as well as organic farming according to Regulation 834/2007 on organic production and labelling of organic products. Under article 14(4), Member States are required to establish appropriate incentives to encourage professional users to implement crop or sector-specific guidelines for integrated pest management on a voluntary basis.

IPM is the cornerstone of the Annex 3 of the Directive which sets out its general principles. A first principle (principle 1) concerns the prevention and suppression of harmful organisms and provides that they should be managed, *ex pluris*, through crop rotation, the use of adequate cultivation techniques, the use of resistant/tolerant cultivars and standard/certified seed and planting material, the use of balanced fertilisation, liming and irrigation/drainage practices. Monitoring activities are required in relation to harmful organisms, as provided under principle 2. Such monitoring activities shall consist in observation in the fields and as scientifically sound warning, forecasting and early diagnosis systems. On the basis of the results derived from the monitoring, the professional user has to decide whether and when to apply plant protection measures under principle 3. Robust and scientifically sound threshold values is crucial in decision making, where threshold levels shall take into account the region, specific areas, crops and particular climatic conditions. However, principle 4 provides that sustainable biological, physical and other non-chemical methods must be preferred to chemical methods when they deliver satisfactory pest control. When used, the pesticides have to be as specific as possible for the target and have the least side effects on human health, non-target organisms and the environment, under principle 5. Within this, the professional user should act in keeping the use of pesticides and other forms of intervention to levels that are necessary, taking into account the level of risk in vegetation and the risk for development of resistance. Where such a risk of resistance is known, but the application of pesticides is required on the basis of the level of harmful organisms, anti-resistance strategies are required to maintain the effectiveness of the products under principle 7. The success of the applied plant protection measures has to be checked by the professional users against the records on the use of pesticides and on the monitoring of harmful organisms, as provided under principle 8.

In Italy ICP practices are sometime subsidised through Rural Development Plans within measure 10, Agri-Environment-Climate payments. This is the case for example in Emilia-Romagna and Lombardy. In both cases, a detailed list of practices and input use doses are defined and are required for a farm to apply for the given sub-measures related to ICP.

Comparison of organic production and integrated crop production

Table A1 reports for different generic agricultural practices the different requirements defined by the EU and Swiss regulation on organic production, and the requirements on ICP defined in Italy by the Emilia-Romagna and Lombardy region. Table A2 reports the standard set by the EC Regulation 889/2008 on minimum surface areas indoors and outdoors for animal productions.

Table A1. Plant production process in organic and ICP in selected examples

Practices	ORGANIC		ICP	
	EU	Switzerland	Emilia-Romagna (Italy)	Lombardy (Italy)
Seeding	No GMO, organic	No GMO, organic	No GMO	No GMO
Fertiliser	• Only natural sources • No mineral fertilisers • Livestock manure ≤ 170kg/ha	• No chemical/mineral fertilisers • Maximum of 2.5 livestock manure units per ha	Local and plant specific requirements and mandatory practices	Local and plant specific requirements and mandatory practices
Crop plan and rotation	Requirements are not indicated	Permanent crops can be non-organic	5 year rotation plan	5 year rotation plan
Pest management	• Use of natural enemies • List of products allowed (889/2008)	No chemical inputs	Local and plant specific requirements and mandatory practices	Local and plant specific requirements and mandatory practices
Natural and semi-natural elements	To be preserved but no clear requirements	Not indicated	5% of the utilised agricultural area	Not indicated
Cover crops	Not indicated	Obligatory	Obligatory	Obligatory

Table A2. Standard set by the EC Regulation 889/2008 on minimum surface areas indoors and outdoors for animal productions

Bovines, equidae, ovine, caprine and porcine	Indoors area (net area available to animals)		Outdoors area (exercise area, excluding pasturage)
	Live weight minimum (kg)	Area (m2/head)	Area (m2/head)
Breeding and fattening bovine and equidae	up to 100	1.5	1.1
	up to 200	2.5	1.9
	up to 350	4.0	3
	over 350	5 with a minimum of 1 m2/100 kg	3.7 with a minimum of 0.75 m2/100 kg
Dairy cows		6	4.5
Bulls for breeding		10	30
Sheep and goats		1.5 sheep/goat	2.5
		0.35 lamb/kid	0.5
Farrowing sows with piglets up to 40 days		7.5 sow	2.5
Fattening pigs	up to 50	0.8	0.6
	up to 85	1.1	0.8
	up to 110	1.3	1
Piglets	over 40 days and up to 30 kg	0.6	0.4
Brood pigs		2.5 female	1.9
		6 male If pens are used for natural service: 10 m2/boar	8.0

Poultry	Indoors area (net area available to animals)			Outdoors area
	No animals/m2	cm perch/ animal	nest	m2 of area available in rotation/head
Laying hens	6	18	7 laying hens per nest or in case of common nest 120 cm2/bird	4, provided that the limit of 170 kg of N/ha/year is not exceeded
Fattening poultry (in fixed housing)	10 with a maximum of 21 kg liveweight/m2	20 (for guinea fowl only)		4 broilers and guinea fowl 4.5 ducks 10 turkey 15 geese In all the species mentioned above the limit of 170 kg of N/ha/year is not exceeded
Fattening poultry in mobile housing	16 (1) in mobile poultry houses with a maximum of 30 kg liveweight/ m2			2.5, provided that the limit of 170 kg of N/ha/year is not exceeded

Sources used in Annex 1

Legal documents for organic production:

Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91.

Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products.

Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007.

The Swiss Federal Council, Ordinance 910.18 on Organic Farming and the Labelling of Organically Produced Products and Foodstuffs (Organic Farming Ordinance) of 22 September 1997 (Status as of 1 January 2018).

Legal documents for integrated crop production:

Directive 2009/128/EC the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides.

Italy - Rural Development Programme (Regional) - Emilia-Romagna, 2014-2020.

Italy - Rural Development Programme (Regional) - Lombardia, 2014-2020.

Annex 2: Farm typologies used in modelling exercises

Many farm-scale analysis modelling exercises draw on the European Farm Accountancy Data Network (FADN) data set which offers a harmonised unbalanced panel of single farm observations for many years (cf. Britz et. al., 2012). FADN is inviting as it covers production quantities, on-farm use, yields, acreage and herd sizes as well production costs and revenues, data on labour use on farm and an overview on subsidies. There are three main shortcomings: firstly, farms often stay only for some years in the panel such that e.g. changes in land or labour endowments or regime switches are not frequently observed which hinders certain econometric exercises. Secondly, the FADN sample tends to be biased towards larger, commercial farms representing major production branches in the FADN regions. Thus, the number of farms found in low extensive system will be probably quite small in most regions, despite the fact that organic farms are now systematically covered in FADN. Thirdly, at least in the standardised EU FADN there is quite limited detail on farm management. Both points render an analysis encompassing more 'niche' farming systems such a HNV farming or even agroecology quite challenging. FADN covers data on costs such as on fertilisers, plant protection or compound feed which can be used to inform a typology comprising the dimension farming intensity. It should however be noted that specialised organic farms tend to buy both plant protection and fertilisers certified for application in organic farming.

The per unit costs of these products is typically more expensive compared to conventional ones which can lead to bias if costs per hectare of these products are used to define a typology. Nevertheless, FADN was the basis to develop typologies aiming to better characterise environmental impacts of farming system such as in Andersen et al. (2007). However, the typology which mainly adds some indicator on livestock density would be far too coarse to capture differences between farming systems as envisaged in LIFT.

The agricultural census gives a far better overview on the farm population, but misses with yields as even the simplest measurement of intensity in crop production. Clearly, the relation between herd sizes and total land or land used for fodder production can be used to characterise the intensity in livestock production. Furthermore, cropping shares and the number of crops present on farms can be used as a measurement of diversity. These indicators can clearly also defined for observations from FADN. Neither FADN nor the census offer direct inside into the landscape configuration per se or report landscape elements such as hedges which are important to assess bio-diversity aspects.

The characterisation of farm specialisation in both FADN and the agricultural census is based on economic indicators. These were until recently the so-called 'standard gross margins' (SGMs), an estimated measure of the difference between average revenues and costs per hectare or head at regional level. These SGMs provided the weights to aggregate hectares of individual crops or sizes of specific herds to farm branches (such as cereals), the resulting shares of these branches on the total SGM of the farm was then used to classify the farm. The estimation of the SGMs is a challenging exercise as it requires to allocate the cost e.g. of fertiliser, diesel, plant protection, insurance etc., to individual crops. The methodology was therefore simplified by now using standard revenues which only require data on average yields and prices. The switch to standard revenues also asked for a change in the shares used to define the farm specialisation. The economic characterisation of farm specialisation based on standard revenues (or before SGMs) will in most cases fit to the one a production specialist will use, however, in case of mixed systems, division lines might look differently. It is important here to understand the consequences of using regional economic averages such that the intensity of management or the impact of quality on output prices received or input prices paid for a single farm in the sample are not reflected when its specialisation is defined.

A closer look at attributes proposed to distinguish different systems (see Table 4 in the main text of this deliverable) reveals that only a quite limited of them can be found directly in the European FADN or agricultural census or derived thereof. Agri-environmental measures can be found under subsidies received in the FADN, but what measures are included will differ from region to region. As far as pest and weed control and fertilisers are products bought form the market, it will not be possible to make a distinction between chemical and organic ones. Biological nitrogen fixation can be link to legume shares, these are however typically not known for grasslands. Similarly, all detailed farm management measures (e.g. use of green manures, conservation tillage, selection of breeds and cultivars, use of GMO, mulching, alternative weed management, precision farming, crop residue management) are not available.

Generally, neither econometric modelling nor simulation modelling would require a strict classification of single farms. If observations on farm-specific sustainability indicators (such as profits, work load or environmental status) are available, they can be regressed on continuous variables and would not need dummies linked to a classification which would actually rather remove information from the estimation or simulation exercise. Similarly, such indicators are more easily constructed from continuous variables as thresholds are often more debatable and lead to jumpy responses.