



Handbook of resilience and working definitions

Preliminary results

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¹ **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other

² **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified



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Introduction

The AGROMIX project aims at building a practical framework of attributes that would guide farmers to recognize and implement changes to improve their holdings to become more resilient towards environmental and socio—economic fluctuations caused by climate change. On the way to reach those practical guidelines and tools to be used in the field, we start out from theoretical basis, gather the knowledge and outline conceptual framework. This handbook collates the known, highlights the important, points to gaps, and defines relevant terms.

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1 Complexity, adaptivity and resilience of agricultural systems (in climate change)

1.1 Complexity and resilience thinking

According to Darnhofer (2014) resilience thinking in farm management affords balance between short-term efficiency and long-term transformability. Unpredictability, related to climate change, extreme and undesired events, linkages between local and global “limit the possibility to identify and implement an ‘optimal’ set of technical measures (Darnhofer 2014).” For farm management is relevant first to understand two contrasting approaches - whether resilience includes adaptation (‘bouncing back’) or transformation (‘bouncing forward’). The first approach focuses on keeping the existing regime, structure, and functions of the system, by buffering impacts. This approach is closer to the concepts of resilience dealing with “maintaining ecosystems within thresholds”. The other approach is pervasive in social systems, where in long-term there is a need for transitions, as for example towards lifestyles with smaller carbon and environmental footprint (Darnhofer 2014). Second relevant issue for farm management is to understand whether resilience is a property of the system that is ‘revealed through the impact of a shock’ or an emerging process (Darnhofer 2014). Farms as social-ecological and economic systems are complex and dynamic, continually changing due to interactions in multiple temporal and spatial scales. There, resilience is ‘actively and creatively performed’ when confronted with disturbance and stress, and cannot be ‘reduced to automatic response directly deriving from the properties of the system (Darnhofer 2014). Full prediction and control of continuously changing systems is very limited, thus raising methodological challenges. Meuwissen et al. (2019) defined resilience of a farming system as ‘its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of robustness, adaptability and transformability’.

1.2 Components of resilience of a farming system

1.2.1 Agroecology

It has become inevitable to apply agroecological principles when we aim towards “ecologically sound and socially just forms of agricultural systems” (Nicholls et al 2020). Agroecology studies the whole food system, with all actors and “total flow of energy and materials from their sources through production and other steps to the consumer, and the potential to return nutrients to the field” (Francis et al 2003). Bringing more complexity and diversity into the system would gradually help to strengthen internal ecological functions and eventually replace the reliance on external inputs, as the soil fertility, productivity and crop protection will be based on ecological interactions and synergies (Nicholls et al 2020). A farm is dependent on external inputs if fertilizers, pesticides, and other resources are purchased off-farm, at expensive prices.

1.3 Operationalization of resilience framework

In SUREFARM project, building the resilience framework, Meuwissen et al. (2019) worked out methodological steps to enable comparative analysis across cases, including farming system, challenges, functions, resilience capacities, and resilience attributes.

1.4 Productivity and diversity

Productivity can be supported by diversity. Species richness in ecological and agro-ecological systems can enhance multifunctionality and ecosystem services. An option to reduce external inputs: “biological mechanisms leading to enhanced biomass production in diverse grassland communities are as effective for productivity as a combination of several agricultural measures” (Weigelt et al. 2009).

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2 Agroforestry and Mixed Farming – diverse agroecological systems

2.1 Concepts of agroforestry, mixed farming, and their extent in Europe

Agroforestry (AF) is a collective modern term for various old land-use practices widespread in Europe where woody perennials, animals and / or crops are managed in one combined system. Besides production (diverse range e.g., milk, meat, hides, wool, forage, fruit, nuts, honey etc.) they cover ecological (interaction between species, biodiversity) as well as cultural components (landscape, recreation). This inherent diversity allows AF systems to provide all main types of ecosystem services, provisioning, regulating, cultural and supporting (MEA 2005). Environmental benefits include soil quality, regulation of run-off and erosion, biodiversity protection etc., bringing a renewed interest in integrating trees with agriculture into focus in EU policies (Augère-Granier 2020). Understanding the importance of agroforestry for sustainable rural development, the AGFORWARD Project (2014 -2017) set one of its objectives to understand the context and map the extent of AF in Europe. Using data from LUCAS, Copernicus, remote sensing, and statistical inventories they found that taken together the extent of systems that could be considered as AF, was larger than estimated in separate summaries by e.g., LUCAS and by Herder et al. (2015). The AGFORWARD project summed up the areas including the following categories: high value tree AF systems, arable AF systems, livestock AF systems, single trees, linear elements such as hedgerows, and agricultural land with tree cover > 10% in (AGFORWARD, Deliverable 1.2), > 15 million ha.

Agroforestry is widely defined in projects and EU level documents as “the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or livestock production systems to benefit from the resulting ecological and economic interactions” (Burgess et al., 2015). The AGFORWARD project used a triangular conceptual scheme depicting the integration of trees (and shrubs) with crop and/or livestock systems where essentially two production systems are used (Figure 1a). A common share in this triangle encompasses mixed farming (MF) where livestock is integrated with arable practices or trees and agroforestry on the same area of land. AGROMIX adopts an adapted conceptual representation of agroforestry and mixed farming systems (Figure 1b.)

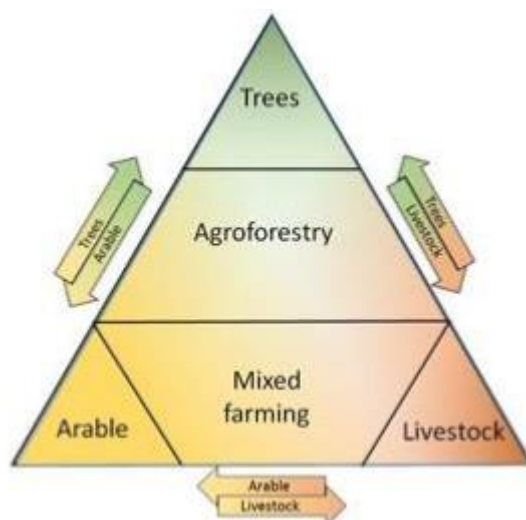


FIGURE 1a. Adopted conceptual scheme from the AGFORWARD project, integrating trees-livestock-arable practices, where agroforestry-mixed farming systems share common features in its core. Dynamics among the corner components allow development of a variety of possible internal designs of the AF/MF systems, depending on local conditions and demands of market.

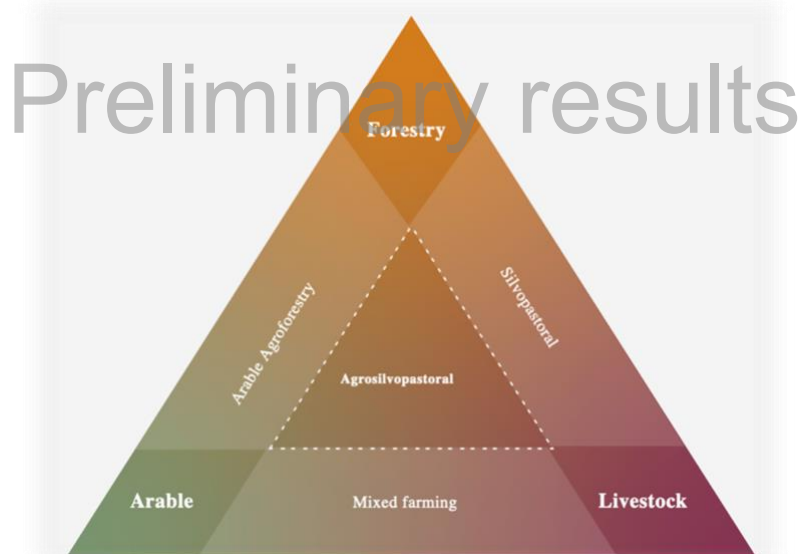


FIGURE 1b. Adapted conceptual representation of agroforestry and mixed farming systems.

2.2 AF and MF systems in Europe: diversity, natural conditions and management

AGROMIX Task 1.4 will map the distribution and diversity of AF/MF systems in Europe. It will also provide a description of the diversity (characterization) of multifunctional activities, their products, land use diversification, etc. including an estimation of the extension of MF/AF systems by regions and climatic zones

(spatial distribution). The task will also address the selection of systems to be included; for example, bocage (widespread in France), high nature value (HNV) farming, non-agricultural activities, such as hunting, collection of mushrooms, leisure, tourism, educational activities. A revised version of LUCAS database as the basis, is currently in work.

According to the EU, agroforestry is considered as “a land use system in which woody vegetation is grown and/or managed in combination with agriculture (livestock rearing and/or crop production) on the same land.” AGROMIX adopts a definition of **agroforestry** that takes into account synergies more explicitly: the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions (Burgess et al., 2015; AGFORWARD project). Similarly, AGROMIX considers **mixed farming** as the practice of deliberately integrating crop and livestock production to benefit from the resulting ecological and economic interactions.

Source: Modification of Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005.

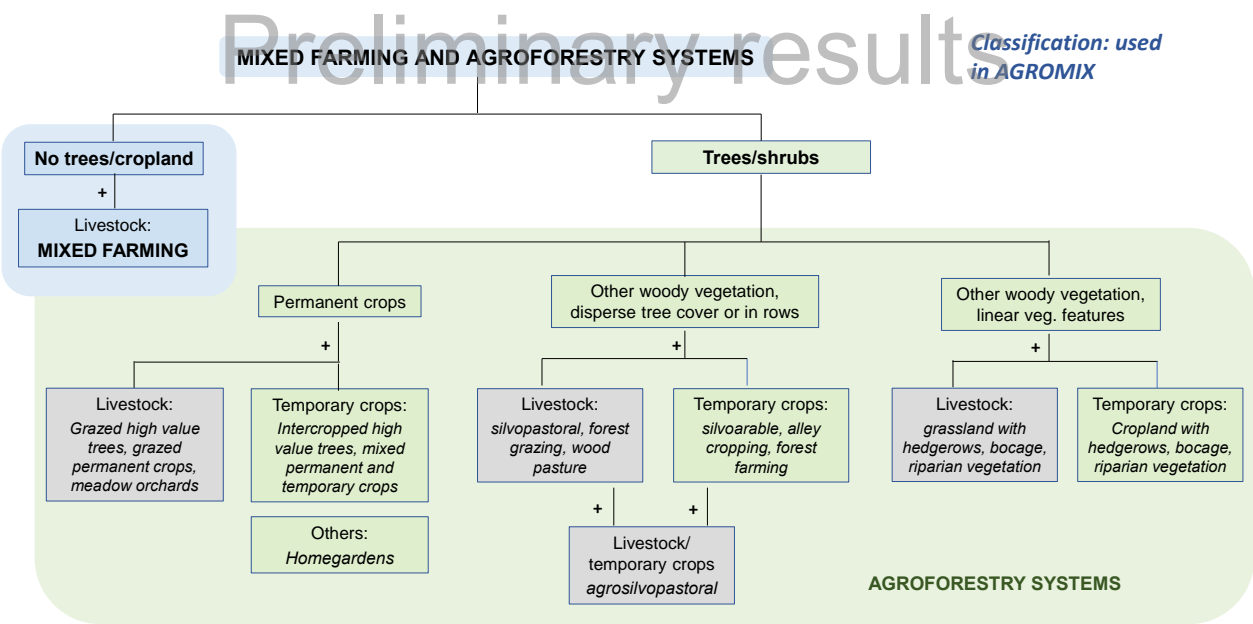


FIGURE 2: Classification used in AGROMIX.

3 Ecological vs socio-economic resilience: potential conflicts

3.1 Resilience or sustainability

Two concepts, resilience and sustainability, share overlapping goals and application areas while consensus on definitions is often lacking (Marchese et al., 2018). Both encompass environmental (ecological), economic and social dimensions. The concepts are similarly used to describe state of a system over time, resilience as a response of a system to disturbances or stress and sustainability focussing on the persisting quality of life (Marchese et al. 2018). Considering the potential conflicts and need for joint implementation of the concepts of resilience and sustainability, Marchese et al. (2018) after conducting literature review, organized sustainability, and resilience concepts into three management frameworks:

- resilience as a component of sustainability, e.g., sustainability can be measured with resilience indicators, as in Jarzebski et al. (2016),
- sustainability as a component of resilience; the ultimate objective of the system is resilience (resilient system maintains critical functionality during and after disturbances), to which sustainability is a contributing factor
- sustainability and resilience as separate conceptual objectives

The authors point out that sustainability efforts tend to be preserving (traditional methods, use of resources, knowledge), focus on longer time and larger spatial scales than resilience, which tends to focus on adapting to and creating new (conditions, knowledge) (Marchese et al., 2018).

3.2 Instruments and policies towards low-carbon world

Moving towards low-carbon world, avoiding further depletion and over-exploitation of the earth's resources involves a necessary system change from linear to circular, "reducing the use of raw materials through more efficient use within cycles. The question is [...] how do we make the transition to a sustainable and circular agro-food system? (OECD Circular Approach, 2019)". Food system is an integral part of the broader network of economic, social and political network (Giller et al. 2021). Agroecological principles (Nicholls et al 2020) are used in several practices, such as regenerative agriculture. From agronomic perspective the latter focusses largely on restoration of soil health and reversal of biodiversity loss (Giller et al. 2021).

Proposals on the CAP reform addressed "environmental challenges by coupling agricultural subsidies to stricter cross-compliance with environmental legislation and 'greening measures': compulsory crop diversification and maintenance of permanent grassland and ecological landscape elements" (EEA 2012). Green payment mechanism or greening was introduced with the CAP reform in 2013 as direct payment to farmers, an environmental instrument. It was meant to support adopting farming practices that help to meet environment and climate goals. The effort of providing public goods is not included in market prices and

should be rewarded for farmers. Through this mechanism greening was meant to enhance the environmental performance of the CAP. European Court of Auditors (2017) found that “greening, as currently implemented, is unlikely to significantly enhance the CAP’s environmental and climate performance” (Special Report 21). European level movements such as European Institute of Innovation and Technology, EIT Climate-KIC and EIT Food pursue to involve all stakeholders, including consumers, “to make the food system more sustainable, healthy and trusted” (EIT Food, 2021).

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- Special report no 21 of European Court of Auditors 2017. <https://op.europa.eu/webpub/eca/special-reports/greening-21-2017/en/#chapter4> (10.03.2021)

5 Appendix

This Appendix is a collection of definitions that are relevant to the concepts of resilience in agroforestry and mixed farming systems. This collection is a draft that will be regularly updated and reviewed in collaboration with Task 1.5.

KEYS:

- **Dimension(s)** - Ecological (Ec), Economic (En), Social (So), tick several when overlap.
- **Definition(s)** - a concise clear phrasing + interpretation explaining the context's relevance to AGROMIX. When quotes are included, indicate these in quotation marks.
- **Measure** - when a measurable indicator or relevant variables to an indicator are involved, give a short description of what was measured + the method + units.
- **Indicator** - value as an indicator, specify
- **Relevance** - important conceptual, general term (*yellow*); less important, not conceptual, branch / sub-term of a conceptual term (*green*); not relevant (*blue*)

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CI	Ec	En	So	Definition	Expanded Definition	Measure	Indicator	Reference	Type of reference	Remarks
Acclimation										
Adaptation	x	x	x	change that takes place as a result of the response to a stressor. Adaptation tries to lower the risks posed by the consequences of climate change (The Guardian)		individual/evolutional, short-term/long-term	survival	Seyle Stress Theory, https://www.theguardian.com/environment/2012/feb/27/climate-change-adaptation		
Agribashing			x		Systematic denigration of agricultural sector					
Agrivoltaic	x	x	x	co-developing the same area of land for both solar PV power as well as for agriculture				Dinesh, H., & Pearce, J. M. (2016). The potential of agrivoltaic systems. Renewable and Sustainable Energy Reviews, 54, 299-308.		
Agroecological principles	x	x		Nicholls et al (2020) listed agroecological principles 'for the design of biodiverse, energy efficient, resource-conserving and resilient farming systems (Table 1): 1) recycling of biomass -> nutrient cycling 2) enhancement of functional biodiversity by creating appropriate habitats 3) favour soil conditions by managing organic matter and enhancing soil biological activity 4) minimize losses of energy, water, nutrients, genetic resources 5) diversify species and genetic resources at the field and landscape level 6) enhance beneficial biological interactions and synergies among the components of agrobiodiversity (promote key ecological processes and services)	Agroecological principles 'guide the spatial and temporal design of a farm' undertaking practices that support key ecological processes. E.g., usage of variety mixture (genetic diversity) -> reduce disease incidences, intercropping -> enhance functional biodiversity, cover cropping -> recycling of biomass and improving soil organic matter accumulation, etc.			Nicholls et al. 2020. Assessing the agroecological status of a farm: A principle-based assessment tool for farmers. Agro Sur 48(2), 29-41		
Agroecologically based farming				Design and management of a farm match agroecological principles		1) assessment survey based on grading of 8 indicators, 2) use the indicators to define a 'threshold level', above or below which a farm is estimated being or not 'agroecologically based'		Nicholls et al. 2020. Assessing the agroecological status of a farm: A principle-based assessment tool for farmers. Agro Sur 48(2), 29-41		
Agroecology	x			In Agroecology, productivity, sustainability and resilience are achieved by breaking monocultures via enhancement of diversity and complexity in farming systems in which ecological interactions and synergisms between its bio-physical components replace external inputs to provide the mechanisms for sponsoring soil fertility, productivity and crop protection.	There are principles for agroecology, see Nicholls 2020			Nicholls et al. 2020. Assessing the agroecological status of a farm: A principle-based assessment tool for farmers. Agro Sur 48(2), 29-41		
Agroecology 2	x	x	x	A transdisciplinary science that includes all economic, social, ecological and political aspects of the food system from production to consumption	Agroecology is a dynamic concept that has gained prominence in scientific, agricultural and political discourse in recent years. It is increasingly promoted as being able to contribute to transforming food systems by applying ecological principles to agriculture and ensuring a regenerative use of natural resources and ecosystem services while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced. Agroecology embraces a science, a set of practices and a social movement and has evolved over recent decades to expand in scope from a focus on fields and farms to encompass whole agriculture and food systems. It now represents a transdisciplinary field that includes all the ecological, sociocultural, technological, economic and political dimensions of food systems, from production to consumption.	Gleissman 5 levels of agroecological transition		HLPE. 2019. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2019.		
Agroecosystem	x	x	x	organisms and environment of an agricultural area considered as an ecosystem	atural ecosystems that have been modified for the production of food and fiber. While they retain many of the characteristics of natural ecosystems, from a toxicological viewpoint they are characterized by the frequent presence of agrochemicals, including pesticides, fertilizers, and plant growth regulators. The nature and extent of the agrochemical contamination will vary considerably, depending upon the nature of the crops and/or livestock. In monocultures, the variety of chemicals will be smaller but the concentrations may well be higher while the reverse could be true in agroecosystems supporting the production of many crops.	opened/closed		Ernest Hodgson Progress in Molecular Biology and Translational Science		
Agroforestry	x	x		Agroforestry systems means land use systems in which trees are grown in combination with agriculture on the same land.	The minimum and maximum number of trees per hectare shall be determined by the Member States taking account of local pedo- climatic and environmental conditions, forestry species and the need to ensure sustainable agricultural use of the land.			Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 december 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005		Disadvantage: Does not include all agroforestry systems, e.g. bocage system. Shrub species are not included
Agroforestry 2	x	x		The practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions				Burgess et al. (2015)	article	This definition was used in AGFORWARD (EU FP7) project
Agroforestry 3	x	x		Agroforestry means land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel or land management unit without the intention to establish a remaining forest stand. The trees may be arranged as single stems, in rows or in groups, while grazing may also take place inside parcels and/or agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines).				Establishment of agroforestry systems. Measure 8. Article 21(1) (b) and 23 of Regulation (EU) No 1305/2013 of the European Parliament and of the Council on support for rural development by the European Agricultural Fund for Rural Development (EAFRD)		Definition (2) and (3) include "deliberately", expressing the importance of human intervention and both include also a shrub species. (3) indicates the variety of existing systems, such as hedge rows, etc.



CI	Ec	En	So	Definition	Expanded Definition	Measure	Indicator	Reference	Type of reference	Remarks
Agroforestry 4	x	x	x	The integration of trees in the agricultural landscape				UN Food and Agriculture Organisation	Institution webpage with examples	proposed
Agro-pastoral system				In addition to livestock production, involve some form of crop cultivation				UN Food and Agriculture Organisation	Institution webpage with examples	Tree growing by Human People
Agrosilvicultural system				combination of crops and trees, such as alley cropping or homegardens				UN Food and Agriculture Organisation	Institution webpage with examples	1 of 3 subdivisions of agroforestry
Agro-silvo-pastoral system				Three elements, namely trees, animals and crops are integrated	Both homegardens and scattered trees on cropland used for grazing after harvest			UN Food and Agriculture Organisation	Institution webpage with examples	1 of 3 subdivisions of agroforestry
Animal welfare 1	x		x	welfare refers to the state of an individual in relation to its environment; welfare is individual's state as regards its attempts to cope, that is how much has to be done to cope, and how well or how badly coping attempts succeed; welfare is characteristic of an animal; welfare will vary from very poor to very good (continuum); welfare can be measured directly.	Poor welfare often occur together with suffering (unpleasant subjective feeling), but welfare is somewhat wider term. Welfare, state of an individual, can be affected without suffering occurring (e.g. during sleep; an injury not felt by animal while injury itself is an indicator of poor welfare, etc.). (Desirable) high production is often associated with with increased likelihood of diseases and effect on life expectancy. '... After welfare has been measured, and the extent of the situation for an animal discovered, ethical decisions about whether or not this situation is tolerable can be taken.'	Welfare is poor when biological fitness of animals is impaired; direct measurements can be done on: 1) (reduction in) reproductive success (estimate in controlled conditions where animals kept in poor and good conditions), 2) body damage (broken bones, wounds, stomach ulcers), 3) disease level and susceptibility to disease, levels of adrenal products, hormones, enzymes, 4) behavioral responses (abnormal in pattern, frequency, context)	to obtain adequate assessment of animal housing and management systems it is essential to use variety of welfare indicators: life expectancy, responsiveness, stereotypes (route-tracing, bar-biting, tongue-rolling etc indicate that individual lacks control of its environment); the fact that one measure is normal does not mean that welfare is good.	Broom D.M. 1991. Animal welfare: concepts and measurement. J Animal Sci 68: 4167-4175	article	
Animal welfare 2 - positive welfare	x		x	Positive welfare: what should be provided to animals rather than what should be avoided. Two distinct views identified: 'hedonic positive welfare' arising from likes and wants and their positive outcomes on welfare, and 'positive welfare balance' - an overall positive welfare state based on the effects of positive experiences outweighing the effects of negative experiences, with 'eudamonia' possibly a third view. A variety of terms refer to positive welfare and related concepts: good welfare, happiness, quality of life, good life, a life worth living and others - often interchangeably used.	the two views differ in that they either consider only positive experiences, or the balance of positive and negative experiences; they lead into each other, as they both focus on hedonic experiences. '... there is a plurality of terms and perspectives in the literature on positive welfare'. Rault et al (2020) proposed a framework to structure research through empirical study of different facets of positive welfare.	centered around the question 'What are important aspects for positive welfare? -> facets were derived: frequency, duration, arousal, context specificity, previous experience, individual differences, sense of agency, long-term benefit, of behaviour / situation.	values to give the facets, between 1 - low, 10 -high	Rault J.-L., Hintze S., Camerlink L., Yee J.R. 2020. Positive welfare and the like: distinct views and proposed framework. Frontiers in Veterinary Sci 7, art. 370. https://doi.org/10.3389/fvets.2020.00370	article	This framework is meant for structuring research - can it be useful for farmers?
Anticipation				in preparation for something happening	to anticipate effects of global changes, including climate change, with its consequences for land use			cambridge dictionary, Caquet and al., 2020 : 'Agroecology Research for the transition of agri-food systems and territories'	book	
Biodiversity	x			species diversity. A measure of the number of different biological species found in a particular area (houghton)		species richness/unit or farm level.		Houghton 2009 Global Warming.	article	
Buffer strip	x			A linear landscape element of permanent vegetation introduced for diverse purposes, such as increasing biological diversity, soil quality or water quality of the system						
Carbon sequestration	x			Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide				https://www.uegs.gov/fqce/what-carbon-sequestration?qc-news_science_products-01q-news_science_products		
Carbon capture and sequestration				Carbon capture and sequestration involves the capturing of carbon dioxide from large commercial plant such as power plant, and transports them to geological storage site for long-term storage in geological formations such as basalt, depleted oil and gas field, coal seams, and saline aquifers.				Kazee O Rabu 2017 CO2 Trapping in the Context of Geological Carbon Sequestration		
Circular economy	x	x		The circular economy is most frequently depicted as a combination of reduce, reuse and recycle activities. Often, it is not highlighted that Circular Economy necessitates a systemic shift.	Circular economy is a possible way to improve autonomy and so resilience		It seems there is no holistic indicator available for agricultural sector, but for instance these indicators may help : % of close loop for N P K, % valorisation of coproducts, % of reduction of inputs (mineral fertilisers, imported animal feed...)	the reference below analyses 114 different definitions : https://reader.elsevier.com/reader/sd/pi/S0921344917302835?token=AAB2B9C530DA6EC81457C85DB8BC628F932D2DE02026F12EED34E3597304FD0C2BB3107D8558462A73570C3312D4438origInRegion=eu-west-1&origInCreation=20210423091723	scientific paper	
Circular agro-food system	x	x	x	Circular economy regarding the food system implies reducing the amount of waste generated in the food system, re-use of food, utilization of by-products and food waste, nutrient recycling, and changes in diet toward more diverse and more efficient food patterns. [...] 'three stages of the food system regarding circular economy: food production, food consumption, and food waste and surplus management (Jurgilevich et al. 2016). 'A circular economy for food mimics natural systems of regeneration so that waste does not exist, but is instead feedstock for another cycle.' (https://www.ellenmacarthurfoundation.org/explore/food-cities-the-circular-economy)	recirculation of resources and the regeneration of natural systems; opposes our current linear economic model - (take-make-waste) 'take materials from the planet, make products from them, and eventually throw them away' (Woolven J. https://medium.com/circularnews/a-new-measure-of-business-success-da53b7a5f1fa); 'linear' nature of modern food production, which extracts finite resources, is wasteful and polluting, and harms natural systems' (https://www.ellenmacarthurfoundation.org/explore/food-cities-the-circular-economy)			Jurgilevich A. et al. 2016. Transition towards Circular Economy in the Food System. Sustainability 8 (69); doi:10.3390/su8010069, https://www.ellenmacarthurfoundation.org/	scientific paper, website of Ellen MacArthur Foundation ANBI	To prevent further depletion and over-exploitation of the earth's resources, a system change is necessary. Instead of focussing solely on reducing the cost of production, we need to shift our mind set to reducing the use of raw materials through more efficient use within cycles. The question is, how can we transform the current linear supply chains into closed loops, with minimal unnecessary losses? How do we make the transition to a sustainable and circular agro-food system? https://www.oecd.org/agriculture/events/circular-approach-and-the-sustainability-of-the-agro-food-system-3-april-2019.htm
Climate				The average weather in a particular region				Houghton 2009 Global Warming.	article	



CI	Ec	En	So	Definition	Expanded Definition	Measure	Indicator	Reference	Type of reference	Remarks
Climate change				Climate change is a change in the usual weather found in a place. This could be a change in how much rain a place usually gets in a year. Or it could be a change in a place's usual temperature for a month or season.				NASA: https://www.nasa.gov/audience/forstudents/4-12stories/nasa-knows/what-is-climate-change-k4.html		
Climate risk, European typology	x	x	x	Climate-related risks are created by a range of hazards. Some are slow in their onset (such as changes in temperature and precipitation leading to droughts, or agricultural losses), while others happen more suddenly (such as tropical storms and floods).	Climate-related risks are created by a range of hazards. Some are slow in their onset (such as changes in temperature and precipitation leading to droughts, or agricultural losses), while others happen more suddenly (such as tropical storms and floods).	(indicator value) references to z-score; the mean (European average) has a z-score 0; climate risk indicator z-score values for regions and cities (NUTS3); the z-score above or below that baseline show how far the region is from European average (more/less vulnerable to predicted risk)	indicator tables for each European NUTS3 region	Carter, J.O. Hinks, S. Vastarás, V. Connolly, A. and Handley, J. 2018. European Climate Risk Typology. [ONLINE] Available at: http://europen-on.org/index.html (H2020 RESIN project – Climate Resilient Cities and Infrastructures). https://unfccc.int/topics/resilience/resources/climate-related-risks-and-extreme-events	interactive web page	offers users means to visualise, describe, compare and analyse climate risk in European cities and regions
Climate smart agriculture	x	x	x	Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. (FAO) Principles and mechanisms that allow agroecosystems to resist and/or recover from climate events (floods, droughts, hurricanes)	Wide array of management options and designs that enhance functional biodiversity in crop fields and consequently support the resilience of agroecosystems. The key here is that when environmental change occurs, the redundancies of the system allow for continued ecosystem functioning and provisioning of ecosystem services.	Risk = Vulnerability * Threat / Response Capacity		http://www.fao.org/climate-smart-agriculture/en/ + Alteri et al. 2015 Agroecology and the design of the climate change resilient farming systems		
Compensatory measures	x			balancing one action (or its effects) with another action, for instance trees plantations to compensate CO2 emissions.	These are a way to restore the environment and it is a way to reverse the environmental degradations.			Erillard et al., 2014 'Mesures de compensation écologique : risques ou opportunités pour le foncier agricole ? ', Commissariat général au développement durable, 2012	article	
Complementarity	x	x	x	relationship between two different -plant species enterprises or person- that is profitable for both or even for surroundings	Mixed farming, for example fruit trees can provide heat protection for poultry and poultry can help control fruit tree pests					
Complexity										
Conservation agriculture	x	x		cultivation system defined by minimal soil disturbance (no-till) and permanent soil cover (mulch) combined with rotations				Hobbs, P. R., Sayre, K., & Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1491), 543-555.	article	
Cover crops	x	x		A crop aimed at increasing soil surface cover and improving the soil, rather than production						
Echange(s) (of skills, of services, of products) = Barter		x	x	exchange (goods or services) for other goods (services without using money).	Mixed farming can be at a scale of several farms throughout the process of exchange: sheep grazing in vineyard for example					
Ecological corridors	x			An ecological corridor is an ecological continuum. It is a functional zone (or passage between several natural zones) for a group of species dependent on a single environment. This corridor therefore connects different populations and favours the spread and migration of species, as well as the re-colonisation of environments that have been disturbed.	These ecological corridors are a way for species to survive to a environment disturbance. It gives them the opportunity to escape and colonise another place.		to evaluate the quality of the ecological corridor : consider the presence of certain species	reference for possible indicator : "Using process-based indicator species to evaluate ecological corridors in fragmented landscapes"	scientific paper	
Ecopasture / Ecopastoralism				management of territorial space by herbivores	Use of herbivore for grass management in other productions (vineyards, fruit trees) or other spaces (urban agriculture for example, natural spaces)					
Ecosystem disservices				ecosystem functions that have harmful effects to human well-being				von Döhrn, P. and Haase, D. (2015) 'Ecosystem disservices research: A review of the state of the art with a focus on cities', Ecological Indicators, 52, pp. 490–497. doi: 10.1016/j.ecolind.2014.12.027.	Paper	
Ecosystem management	x	x	x	Ecosystem management is an approach to natural resource management that aims to ensure the long-term sustainability and persistence of an ecosystem's function and services while meeting socioeconomic, political, and cultural needs.				Brussard Peter, F.; Reed Michael, J.; Richard, Tracy C (1998). Ecosystem Management: What is it really? Landscape and Urban Planning. 40 (1–3): 9–20.		
Ecosystem services	x	x		The benefits produced by ecosystem functions and structures for human well-being	Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth					
Equity		x	x	Equity refers to the provision of varying levels of support—based on specific needs—to achieve greater fairness of treatment and outcomes	In essence, equity can be defined as a means of achieving equality					
External inputs				In Agriculture: Resources that come from outside the farm, usually those that have to be purchased by the farmer						
Fairness		x	x	Equality?	3 dimensions of social justice 'fair shares', or equality of outcome; 'fair play', or equality of opportunity; and 'fair say', or autonomy and voice					
Farming system								Giller K. E. 2013. Guest editorial: can we define the term 'farming systems'? a question of scale. Outlook Agric. 42(3), 149-153		



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Flower strip	x			Strips of flower rich vegetation integrated between or along crop fields	mainly used to provide pollinator habitat, and other beneficial organisms	square meter/hectare cropped land				
Food Insecurity		x	x	Food insecurity specifically includes the risk of people becoming hungry		Combination of data from multiple sources	FIES Food Insecurity Experience Scale	State of Food Security and Nutrition, FAO 2019		
Food justice	x	x	x	Food justice takes a structural view of the food system and states that (environmental) sustainability cannot be achieved without also challenging the unequal power relations that shape the production, distribution and consumption of food				Holt-Giménez and Shattuck 2011).		
Food security	x	x	x	'a situation that exists when all people, at all times, have physical, social and economic access to adequate, safe and nutritious food that meet their dietary needs and food preferences for an active and healthy life'		This is measured by calories per capita and doesn't include intra-country caloric distribution or nutrition	FIES Food Insecurity Experience Scale	State of Food Security and Nutrition, FAO 2019		
Food sovereignty	x	x	x	the right of peoples to define their own food systems	'the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems. It puts the aspirations and needs of those who produce, distribute and consume food at the heart of food systems and policies rather than the demands of markets and corporations'	Food sovereignty puts the people who produce, distribute and consume food at the centre of decisions on food systems and policies, rather than the demands of markets and corporations that have come to dominate the global food system.	1) Food as a right, not a commodity 2) Valuing producers 3) Localising food 4) Democratic control 5) Building knowledge and skills 6) Working with nature	Nyéléni Declaration 2007		
Forest	x	x		Land with tree crown cover (meaning all parts of the tree above ground level including its leaves, branches and so on), or equivalent stocking level, of more than 10 % and with an area of more than 0.5 hectares (ha)[1]. The trees should be able to reach a minimum height of five metres at maturity in situ.		Percentage of ground covered (%)		Eurostat		Definition used by European Commission, but also FAO
Functional diversity (biodiversity)				'the range and value of those species and organismal traits that influence ecosystem functioning'		species traits can be used to allocate species to functional groups		Tilman, D. (2001). Functional diversity. <i>Encyclopedia of biodiversity</i> , 3(1), 109-120.	Encyclopedia	
Functionality (of an ecosystem)										
Global warming				The idea that increased greenhouse gases cause the Earth's temperature to rise globally				Houghton 2009 Global Warming.		
Greenhouse gas emissions accounting										
Greening	x	x		'green payment - a direct payment rewarding farmers for farming practices beneficial for soil quality, carbon sequestration and biodiversity - was introduced in 2015, as a means to enhance the environmental and climate performance of the EU's Common Agricultural Policy'(1).	The European Commission has proposed a number of 'greening measures', including obligatory crop rotation, grassland maintenance, and more specific agri-environment measures, aimed at climate change mitigation and biodiversity conservation. / The reform of the CAP is a timely opportunity to provide a coherent set of interventions that address two key challenges simultaneously: 'greening' the agriculture sector (reducing environmental impacts) and ensuring food security (2).			(1) Special Report No 21 of European Court of Auditors 2017, https://op.europa.eu/webpub/eca/special-reports/greening-21-2017/en/richapter4 (2) European Environment Agency, Agriculture 2020. https://www.eea.europa.eu/themes/agriculture/greening-agricultural-policy	Report	
Heterogeneity (in space and time), landscape, cropping, ...										
Homeostasis										
Indicator				(1) This definition is also used by FAO.						
Intercropping				Intercropping is a multiple cropping practice that involves growing two or more crops in proximity.	Intercropping is the cultivation of two or more crops simultaneously on the same field. [1] The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources or ecological processes that would otherwise not be utilized by a single crop			Wikipedia		
Interdependence										
Land cover	x			refers to the bio-physical coverage of land (for example, natural areas, forests, buildings and roads or lakes)				https://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey#Defining_land_use2C_land_cover_and_landscapes		
Land Equivalent Ratio										
Landscape	x			refers to an area of land whose character and functions are defined by the complex and regionally-specific interaction of natural processes with human activities that are driven by economic, social and environmental forces and values.				https://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey#Defining_land_use2C_land_cover_and_landscapes		
Land use		x		refers to the socioeconomic purpose of the land. Areas of land can be used for residential, industrial, agricultural, forestry, recreational, transport purposes and so on	at any one place, there may be multiple and alternative land uses			https://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey#Defining_land_use2C_land_cover_and_landscapes		
Location-based serious games										
Low input (systems)	x	x			A transition towards innovative low-input systems (employing e.g. organic and precision farming techniques) appears on balance (...). Comparing managed grasslands: high-diversity low-input grassland communities had similar productivity as low-diversity high-input communities (2).			(2) Weigelt, A., Weisser, W. W., Buchmann, N., Scherer-Lorenzen, M. 2009. Biodiversity for multifunctional grasslands: equal productivity in high-diversity low-input and low-diversity high-input systems. <i>Biogeosciences</i> , 6, 1695–1706. https://doi.org/10.5194/bg-6-1695-2009		
Metastability										
Mitigation				Climate change mitigation: Reducing emissions of and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere				https://climate.nasa.gov/solutions/adaptation-mitigation/		



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Mixed farming 1		x	x	A mixed-farming holding is an agricultural holding where neither livestock nor crop production is the dominant activity - an activity is called dominant if it provides at least two-thirds of the production or the business size of an agricultural holding	Eurostat definition of a main type of farm holding.			https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Far_m_typology		This definition is used by Eurostat, so that data are available throughout Europe
Mixed farming 2		x	x	Mixed farming is the practice of deliberately integrating crop and livestock production to benefit from the resulting ecological and economic interactions	This is the 'Agromix definition', which mirrors the Agroforestry definition (Paul Burgess). In the sense of 'integrated crop livestock systems (ICLS)', a term used in North and South America.					
Mixed farming 3				Mixed farming is a system where livestock and crop production coexist with none of them having less than one third of the production (if trees are present, either permanent crops or other woody vegetation, it is considered an agroforestry system).						
Mixed type of farm		x		FADN (Farm Accountancy Data Network) classification: 73. Mixed livestock, mainly grazing livestock 74. Mixed livestock, mainly granivores 83. Field crops - grazing livestock combined 84. Various crops and livestock combined	Subdivisions: 731. Mixed livestock, mainly dairying 732. Mixed livestock, mainly non-dairying grazing livestock 741. Mixed livestock: granivores and dairying combined 742. Mixed livestock: granivores and non-dairying grazing livestock 831. Field crops combined with dairying 832. Dairying combined with field crops 833. Field crops combined with non-dairying grazing livestock 834. Non-dairying grazing livestock combined with field crops 841. Field crops and granivores combined 842. Permanent crops and grazing livestock combined 843. Apiculture 844. Various mixed crops and livestock			https://ec.europa.eu/agriculture/fadn/det/alt_en.cfm?TF=TF&Version=13185		
Multicropping				Practice of growing two or more crops in the same piece of land during one growing season instead of just one crop. Also called multiple cropping	Same meaning than intercropping					
Multifunctionality		x			increasing species richness might help to enhance multifunctionality in managed grasslands (L.J. ... biological mechanisms leading to enhanced biomass production in diverse grassland communities are as effective for productivity as a combination of several agricultural measures)	productivity (biomass) g m ⁻² y ⁻¹ measured in 78 experimental grassland communities of increasing plant species richness (both species and functional group numbers) in combination with mowing frequencies and fertilization levels (from 0 to 200 kg N ha ⁻¹ a ⁻¹)	higher diversity was more effective in increasing productivity than higher management intensity	Weigel, A., Weiser, W. W., Buchmann, N., Scherer-Lorenzen, M. 2009. Biodiversity for multifunctional grasslands: equal productivity in high-diversity low-input and low-diversity high-input systems/ <i>Biogeochemistry</i> , 6, 1695–1706; https://doi.org/10.5194/bg-6-1695-2009	article	
Mutuality		x	x	The principle of mutuality is a kind of voluntary anticipation of potential difficulties where individuals secure other individuals and vice versa.						
Natural grassland										
Nature based solutions		x	x	Actions that involve 'working with and enhancing nature to help address societal goals'				Seddon, et al., 2019		
Net Primary Production		x		yield of dry matter production of a plant community per area	takes into account the organic matter increase of all plant parts	kg dry matter per m ²		Larcher Physiological Plant Ecology		
Nutrient cycling										
Participatory research										
Permaculture		x	x	Permaculture is a global and systemic concept that aims at create ecosystems respecting biodiversity. It is a science to create agricultural system inspired from nature (diversity, stability sustainability and resilience are copied from natural ecosystems).	it is a way to be better resilient because once it is created, it is supposed to be persistent.			Dicoae : https://dicoagroecologie.fr/encyclopedie/permaculture/ (Agroecology dictionary from INRAE)		
Permanent grassland										
Permanent intercropping										
Persistence										
Perturbation										
Plant community				a unit of vegetation characterised by the composition of plants						
Production		x	x							
Productivity										
Profitability			x							
Reflexive innovative design										
Regenerative agriculture		x								
Regulating (ecosystem) services										
Relay intercropping or relay cropping				'Relay cropping is a method of multiple cropping where one crop is seeded into standing second crop well before harvesting of second crop.'				Tanveer, M., Anjum, S. A., Hussain, S., Cerdà, A., & Ashraf, U. (2017). Relay cropping as a sustainable approach: problems and opportunities for sustainable crop production. <i>Environmental Science and Pollution Research</i> , 24(6), 6973-6986.	review article	
Reorganization										
Resilience I		x	x	'A resilient farm can cope effectively with climate shocks such as droughts or floods, continuing to produce and sustain its capacity for future responsiveness and production'	Focuses on farm level			Oxfam 2008 Oxfam. (2009). People-Centred Resilience. Oxfam Briefing Paper 135.		



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Resilience II	x	x	x	Resilience is the ability of people, households, communities, countries and systems to mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth	Very general but spot on.			Usaid 2012 Building Resilience to Recurrent Crisis - USAID Policy and Program Guidance, 32. https://doi.org/10.1007/s13398-014-0173-7.2		
Resilience III	x	x	x	buffer, adaptive and transformative capacity	the three capacities together make a system resilient. Buffer: The buffering aspect of a system is about resisting pressures from outside the system. Adaptive: The adaptive aspect of a system is about making adjustment to the system during disturbances. Transformative: The transformative aspect of a system is about the ability to implement significant changes and new practices.			Darnhofer 2014		
Resilience IV	x			"the domain of response prior to an irreversible threshold change"	Resilience is not a unitary response to disturbance. Rather, the response of ecological systems following a perturbation can be summarized in sequential stages operating at differing levels of biological organization across scales of space and time. The more general emergent response of resilience is comprised of component processes of resistance, recovery, and reorganization.			Falk, D.A., A.C. Watts, and A.E. Thode. 2019. Scaling Ecological Resilience. <i>Front. Ecol. Evol.</i> 7(July): 1–16. doi: 10.3389/fevo.2019.00275.		
Resilience of a farming system	x	x	x	Ability of a farming system 'to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of robustness, adaptability and transformability.'				Meuwissen M. P. M. et al. 2019. A framework to assess the resilience of farming systems. <i>Agricultural Systems</i> 176, 102666	article	
Resilience in animals	x	x		'Resilience can be described as the capacity of the animal to be minimally affected by a disturbance or to rapidly return to the physiological, behavioural, cognitive, health, affective and production states that pertained before exposure to a disturbance.'	This broader characterisation of resilience can be considered to describe general environmental resilience to distinguish it from the narrower concept of disease resilience (the animal's capacity to resist (or recover from) the perturbation caused by an infection, measured as temporal deviations of production traits in within-host longitudinal data series)		Variance of deviations, the autocorrelation of deviations, the skewness of deviations, and the slope of a reaction norm, of selected variables measured over a period of time, taking into consideration the same indicators when microenvironment challenges (environmental disturbances) are not present.	Animal Production Science, 2016, 56, 1961–1983 Resilience in farm animals: biology, management, breeding and implications for animal welfare Ian G. Colditz and Brad C. Hine		Examples of variables: Core body temperature (normality of circadian pattern and dynamic range); heart rate and rate variability; Normality of circadian ethogram and expression of behavioural complexity; Feed intake; Growth rate
Resistance				the ease or difficulty of changing the system; how "resistant" it is to being changed.				Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. <i>Ecology and society</i> , 9(2).		
Resource use efficiency	x									
Self-organization			x							
Self-regulation			x							
Seminal habitat				a habitat which has been modified by human activities, but maintains high levels of biodiversity and is often considered of conservation value						
Shelter belt				is a windbreak. A planting of a row of shrubs or trees	It is a type of hedgerow, usually planted to reduce the effect of air flow, aimed at protecting soil against wind erosion or protecting crops					
Shock	x	x	x	A shock is an irregular, relatively large and unpredictable disturbance, such as is caused by a rare drought or flood or a new pest outbreak, or when slow onset disasters pass their tipping points and become extreme events				Montpellier Panel. (2012). Growth with resilience.		
Short food supply (SFC) chain		x		Different forms of SFC in Europe share common characteristic of reduced numbers of intermediaries between the farmer or food producer, and the consumer	Goals : SFCs can be seen as tool for improving farm incomes, and more broadly 'a means to restructure food chains in order to support sustainable and healthy farming methods, generate resilient farm-based livelihoods (in rural, peri-urban and urban areas) and re-localise control of food economies.' There is a need for business models whereby SFC enterprises can become financially viable and self-sustaining; obstacles include regulations, and dominance of large retailers and agro-food industries (p.29).			EIP-AGRI Focus Group Innovative Short Food Supply Chain management FINAL REPORT 30 NOVEMBER 2015, 80 pp	Report	
Short rotation coppice		x	x	Method of forest regeneration where the trees are cut periodically. In the periods between two cuttings the trees re-sprout from their stumps		length of harvest cycle		Rödl A. (2017) Short Rotation Coppice: Status and Prospects. In: Meyers R. (eds) Encyclopedia of Sustainability Science and Technology. Springer, New York, NY. https://doi.org/10.1007/978-1-4939-2493-6_988-1	Encyclopedia	



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Short supply chain		x	x	a supply chain involving a limited number of economic operators, committed to co-operation, local economic development, and close geographical and social relations between producers, processors and consumers'	The creation of short supply chains was among thematic sub-programmes 'the Member States should include in their rural development programs'. ... Support for horizontal and vertical co-operation among actors in the supply chain, ... should catalyse economically rational development of short supply chains, local markets and local food chains.'	-	-	Regulation (EU) No 1305/2013 of the European Parliament and of the Council on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) ... https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R1305&qd=1470747068369	EU Regulation	2013 CAP reform, concerns the policy for the period 2014-2020
Silvo-pastoral system		x		An agroforestry system with grazing livestock	A farm/territory where wooded species (shrubs and/or trees) are combined with grazing animals					
Silvo-pastoral system II				combine forestry and grazing of domesticated animals on pastures, rangelands or on-farm.			forest+grazing	UN Food and Agriculture Organisation	Institution webpage with examples	1 of 3 subdivisions of agroforestry
Soil quality										
Soil carbon concentration				Amount of carbon in soil (%). For the purpose of our project soil organic carbon is more important, i.e. not considering mineral carbon.	As a concentration it is usually expressed in % of soil. It is important to differentiate between total carbon and total organic carbon.	A standard measure of soil organic carbon is the Walkley & Black method. For total carbon the loss on ignition with 900°C				
Soil carbon stock				Total amount of carbon in soil (t/ha). We should use soil organic carbon	It considers the total amount of C in the complete soil profile and per unit area	It is necessary to know the organic C content at different depths, bulk density and soil depth.				
Soil fertility				fertile soil 'provides essential nutrients for crop plant growth, supports a diverse and active biotic community, exhibits a typical soil structure, and allows for an undisturbed decomposition'				Mäder et al., 2002 from ISOAPER D3.1		
Solidarity			x	mutual support within a group without obligation of reciprocity	It is maybe difficult to measure but is really important in case of disturbance					
Stress		x	x	<i>A stress can be defined as a regular, sometimes continuous, relatively small and predictable disturbance, for example the effect of growing soil salinity or lack of rainfall or indebtedness</i>				Montpellier Panel. (2012). Growth with resilience.		
Sustainability		x	x	meeting the needs of the present without compromising the ability of future generations to meet their own needs."				United Nation, Brundtland Commission. https://academic.oup.com/impact/advance-article-abstract/doi/10.1093/impact/ixi002/5555555		
Symbiosis		x		interaction between two different organisms living in close physical association, and benefiting both of this association.	This kind of association contribute to limit the external inputs and increase resilience			Cambridge dictionary		
Tolerance		x	x	An organism's capacity to survive variation in environmental conditions incl stress factors.		stability/adaption				
Transdisciplinarity										
Value chain		x		describes the complex interactions among agents from R&D to final consumption, including production, marketing, distribution and support to the final consumer. These activities can be contained into one firm or divided among different firms on a global scale.				Coe N. M., Dicken P., Hess M. 2008. Global Production Networks: Realizing the Potential. Journal of Economic Geography 8(3), 271-295. DOI: 10.1093/jpe/ixi002	Economic geography Research Group, Working Paper Series No 05.07	
Wood pasture		x	x	Treed landscapes in which livestock grazing co-occurs with woody vegetation (trees and shrubs). 'Their aesthetic, heritage and biodiversity values contribute to local economies through cultural tourism (ref. Beiling, Konold 2014). Intimately linked with farming system. Various terms applied across Europe to wood pastures, of which 'silvopastoral system' is more often used as formal and technical term (ref Mosquera-Losada et al. 2009).	Regular grazing and other management interventions are needed in wood pastures to maintain their often semi-open structure and the provision of ecosystem goods and services.' Scattered trees (c. 15-50 trees ha ⁻¹) do not compromise pasture yield (refs); buffer against extreme climatic oscillations in mountainous regions (ref. Gavazov et al 2009). 'The change from multifunctional management into (abandonment or) intensive mono-functional land use is the main driver of the shift to structural simplification and 'decrease in the richness and quality of the ecosystem goods and services' they provide.	binary - structural simplification has / has not taken place	undergo major structural changes as societies change; structural simplification => transformation into either closed forest or open agricultural areas	Hartel T, Plieninger T., Varga A. 2015. Wood-pastures in Europe. In: K.J. Kirby, C. Watkins (eds.) Europe's Changing Woods and Forests: From Wildwood to Cultural Landscapes. CAB International, pp.61-76	book chapter	Potential overlap with agro-silvopastoral and/or silvopastoral
Yield		x	x	crop production	production of any component on any ecotrophic level; agricultural output	kg per area per year				

