Handbook of resilience and working definitions

Deliverable D1.1 – v2

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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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1 Executive Summary

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 and long-term stresses caused by climate change.
This document is one amongst the earliest documents delivered in the AGROMIX project, produced by Task 1.1. Our primary aim is to help the consortium in synchronizing the interpretations of conceptual elements and framework the consortium is dealing with throughout the project. The objective is to speak 'the same language' among the consortium partners in terms of definitions, usage of terms, and how we see the order of relevance of concepts and their linkages. The Work Packages starting later or currently working will have a handbook within-reach while working on their specific Tasks. This also incurs that the framework is building up during the course of the project, developing as the Work Packages obtain more in-depth knowledge from practical situations they tackle during the progress of their work. In the last phase of the AGROMIX project the Task 1.5 will have a chance to evaluate and correct the initial framework by looking back to the activities, experiences and results the Work Packages have achieved.
The most eminent and frequent keywords for the project are resilience of farming systems, climate change, agroforestry (AF), and mixed farming (MF). The main hypothesis being that the agro-food systems are more resilient to the impacts of climate change when they integrate complexity, agroforestry and mixed-ness of farming system being useful practices with old traditions. While the AF and MF can be rather different systems, complexity is a common assumption in both systems, including environmental and socio-economic dimensions inherent in their structure and functioning, when we compare with mono-systems.

- **Resilience** – resilient farms have greater capacity to recover from disturbances. Farms as social-ecological and economic systems, are complex and dynamic, continually changing due to interactions in multiple temporal and spatial scales, thus resilience is performed as a process. Resilience thinking means embracing change. In AGROMIX we look at resilience of farming systems to **climate** change induced disturbances to what the systems can respond either by buffering the impacts, adapting to changes and maintaining or transform and create a new system.
- **Agroforestry** and **mixed farming systems** are different and can be defined along a broad scales, while their common feature is complexity. Structurally inherent diversity of these systems, either in ecological or socio-economic sense, allow them to use as models to improve resilience in farming systems. Agroforestry systems can provide all main types of ecosystem services, important in restoring functionalities in agro-ecological landscapes. Mixed farming can be seen as suitable alternative for specialization, resulted from agricultural intensification. This is important as the share of mixed farm holdings is continuously declining in Europe.
- **Measures** to take to **increase resilience** of farming systems could be application of ecological principles, promoting heterogeneity of habitats and heterogeneity in agricultural landscapes, control of nutrient budgets (to avoid losses and environmental damage), support productivity by biodiversity (ecological services), balance lower yields by increased supporting, regulating and cultural services, practice regenerative agriculture and shift towards circular economy, development by diversification of production and economies of scope.

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Different definitions of terms, linked to AGROMIX topics, are available in scientific literature and public documents. We have gathered relevant terms and working definitions into a table in Annex, and explained the definitions of the most relevant terms in text, as we have agreed to use them in AGROMIX. In the Table of the Annex the dimension(s) to which a term is mainly related, either ecological, economic or social, are marked and its relevance distinguished by colours - important conceptual, general terms are in yellow; less important, not conceptual, branch / sub-terms of a conceptual term in green; not relevant in blue.

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2 Expected impact

This Deliverable is the report of Task1.1 (WP1, Work Package 1). The main objective of this document is to provide definitions and conceptual framework for the AGROMIX consortium as a handbook. The text analyses elements of conceptual framework, their linkages, and provides figures to illustrate the concepts. It indicates the elements relevant for farming systems to enhance their resilience to climate change. It shows that agroforestry (AF) and mixed farming (MF) practices can act in reducing negative environmental impacts. The Annex contains multiple working definitions. All other WP-s can benefit from this document, as they can address it with their questions about interpretation of concepts. The attempt is state of the art of resilience framework of agroforestry and mixed farming.

This is one of the most theoretical Deliverables and its primary purpose is to serve the AGROMIX consortium in their more practical Tasks and working at their further Deliverables. But the public should benefit from it as well when inquiring about AF, MF and capacities of farming systems to survive in ongoing climate change and impacts of crises.

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3 Complexity and resilience of agricultural systems in climate change

3.1 Complexity and resilience thinking

The concept of ecological resilience (Holling 1973) has evolved towards a broader framework of *resilience thinking* that brings together many concepts (resilience, multiequilibria, threshold, scale, feedback interactions) and include socio-ecological systems, unpredictability, uncertainty and adaptive management (Desjardins et al. 2015). According to generalized definition, farming systems are resilient when their productivity and organization sustains challenges by disturbancies or stresses due to adverse variability of climate (Altieri et al 2015, FAO 2018). Resilient farms have greater capacity to recover from disturbances (extreme weather events, resist disease and pest attacks, suffer less erosion, experience lower economic loss (FAO 2018) compared with farms practicing conventional monocultures. In brief, complexity and adaptivity make a system more resilient (Desjardins et al. 2015) while no single mechanism can assure maintenance of resilience (Gunderson 2000).

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." For farm management it is relevant 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.

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. Therefore resilience is performed actively and creatively when confronted with disturbance and stress, and cannot be 'reduced to automatic response directly deriving from the properties of the system' (Darnhofer 21014). Full prediction and control of continuously changing systems is very limited, thus raising methodological challenges.

As the agricultural systems are dynamic complexes comprising intertwined ecological, economic and social components, these three domains prevail in the literature analysing resilience of farming systems. Further, the holistic and broad concept of resilience split into capacities (buffer, adaptive and transformative) of the systems featuring their response scenarios to perturbations, is helpful for operationalizing purposes. Interpretation of the buffer and adaptive capacities in socio-ecological systems may vary but the underlying meaning is similar. The buffer capacity (robustness, resilience, persistence, cf Folke et al. 2010; Meuwissen et al. 2019) is a capacity of a system to continually change yet remain within critical thresholds, maintaining the same regime. Adaptability allows development within the current regime, by adjusting the system's responses to changing external drivers. Transformability is a capacity to cross thresholds into a new path of

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development, creating new domains. Indeed, resilience thinking is required for making use of crises as new opportunities (Folke et al. 2010).

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

In certain situations we need to ask resilient to what? Folke et al (2010) distinguished between specified and general resilience in social-ecological systems. *Specified resilience* applies in concrete situations requiring responses to questions 'of what and to what', as in Carpenter et al. (2001, cf Folke et al. 2010). *General resilience* is about coping with uncertainty in all ways. Resilience thinking suggests to reevaluate situations, recombine experiences and knowledge, open up to innovation (Folke et al. 2010).

Three main types of perturbations challenge resilience of agro-food systems: fluctuations (e.g., annual climatic variations), long-term chronic perturbations (e. g., rising average temperature) and short-term acute perturbations such as extreme weather events (Bullock et al. 2017). Extreme evens, large-scale and of irregular character are also called shocks, and regular, sometimes continuous relatively small predictable disturbance called stresses (Montpellier Panel 2012). By the latter definition fluctuations and short-term acute perturbations are shocks and long-term chronic perturbations stresses.

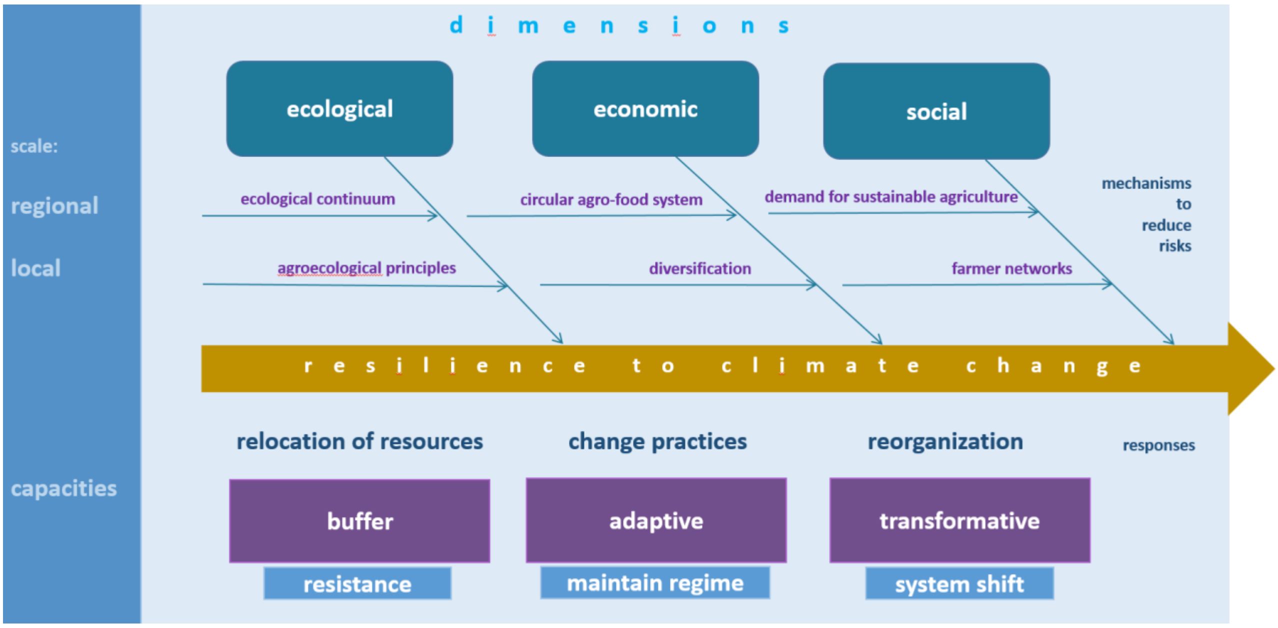

Figure 1. Resilience of farming systems encompass ecological, economic and social dimensions at all levels, from farm over landscape and regional. Numerous tools can be applied to minimize risks from perturbations. Capacities indicate multiple way systems respond; either bouncing back, staying in the same regime, and buffering the impact; adapting by making adjustments to the system; bouncing forward to change the system (Darnhofer 2014).

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Obviously agricultural systems need to be resilient to survive (alternative would be collapse). To enhance resilience, complementary approaches at different scales, from field (ecologically based interventions) to farm (adaptive management, diverse crop rotations etc.) to global/regional scale based approaches (socially based, policies etc.) should be considered (Bullock et al. 2017). We present a schematic resilience framework in Figure 1. A scheme is a simplification for visual purposes, thus the scale of mechanisms of minimizing risks can be more diverse while some relevant concepts in AGROMIX project are depicted.

The resilience concept, linked to the theory of adaptive cycles, is also useful to describe a dynamic interdependence of supply chain and its environment where change in one part can cause considerable change in other part. In the light of current ongoing crises (covid-19, geopolitical conflicts, climate) the old approach of static and controllable supply chains no longer work (Wieland 2021). Supply chains can be understood as social-ecological systems, fluid and interwoven with political-economic phenomena, their resilience similarly to that in ecological sense potentially measurable by the magnitude of disturbance a system can absorb before change (Wieland 2021).

The AGROMIX project focusses on complexity elements in farming systems in ecological, economic and social dimensions and aims at indicating mechanisms to minimize risks in facing shocks and stresses of climate change. The main attention is on resilience related to agroforestry (AF) and mixed farming (MF), inherently complex systems. We keep in mind that resilience thinking (for agroecological management) is to embrace change (Desjardins et al. 2015).

3.1.1 Resilience and / 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).

In the AGROMIX project the **concept of resilience** is considered **within sustainability** (the first item), based on the reasoning that sustainability is a broader concept, while resilience being a characteristic of a system. Thus achieving / pursuing resilience makes a system more sustainable in the long-term.

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3.2 Components of resilience in farming systems

3.2.1 Agroecological principles

Agroecology is an old concept itself but its theoretical framework is still disputed and not unequivocally established (cf Martin, Isaac 2018; Dumont et al 2021). The scope of agroecology is broad, it studies the whole food system, with all actors, flow of energy and materials from their sources through to the consumer, and the potential to return nutrients to the field (Francis et al 2003). In brief, agroecosystems are ecosystems controlled by humans (Doré et al 2011).

Homogenization of modern agroecosystems (genetic homogeneity and growing monocultures in large areas) makes the industrial agricultural systems very vulnerable to variability in climate (Altieri et al 2015). Small-scale traditional farming systems were diversified, practicing resource-conserving management while contributing to agrobiodiversity conservation and food security. Understanding agroecological features will help to design climate resilient agroecosystems. Higher biodiversity enhances compensation capacities in agroecosystems, since different species can buffer against (climatic) failures and persist ecosystem functions (Altieri et al 2015).

In its applied branch, agroecology promotes principles (rather than technical recipes) which set in motion ecological interactions to drive key processes such as nutrient cycling, pest regulation, productivity etc. (Nicholls e al. 2016). It has become inevitable to apply agroecological principles when we aim towards transition to ecologically sound and socially just agricultural systems (Nicholls et al 2020). 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. Making better use of biological regulation mechanisms would assume that they play the same agronomic role as chemical or physical inputs, without external costs (Doré et al 2011).

Redesign of farming systems by enhancing functional biodiversity can emerge from the application of well-defined agroecological principles by way of various practices and strategies (Nicholls et al 2016). Agroforestry via inherent characteristics already implies several agroecological principles, such as enhancing functional biodiversity, improving soil conditions (nutrient and water cycling in the network of root systems with different structures and distribution profiles), and creating synergistic effects among components of agrobiodiversity.

3.2.2 Complex structure of agricultural landscape

Agricultural landscape includes natural environment and the activity of farming systems. While the perception of agricultural landscape can be enjoyable public goods, it is as also the result of farming practices (Andersen 2017).

The current model of *agricultural intensification*, produces high yields resulting from monocultures (of high-yielding varieties) coupled with chemical and mechanical inputs, its key consequence being landscape

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simplification and concurrent loss of biodiversity, ecological function and critical ecosystem services. Individual farms in intensified systems may be highly efficient while the landscape is losing functionality (Landis 2017). To reverse the process of losing species richness, ecological functionality and ecosystem services, the simplified agricultural landscapes are to redesign by (re)introducing structural complexity. When inserted in a complex landscape matrix, the agroecosystems will be more resilient (Altieri et al 2015). However, reasoned large scale design is necessary because uncoordinated individual farmer decisions will be insufficient to mitigate landscape-level negative aspects of intensification (Landis 2017).

Promoting **heterogeneity** in **farmed landscape** serves universal management objective across farming systems. Habitat heterogeneity is associated with higher biodiversity. Connected mosaic of different fields together with between-field heterogeneity such as non-crop habitats, field margins, linear woody boundaries, ditches, fallow land and other elements support biodiversity (Benton et al. 2003, Landis 2017) and ecosystem services. To alter landscape structure larger than individual farm requires coordinated action among stakeholders and scientists, analyses and planning of a particular landscape to redesign and alleviate its structural deficit (Landis 2017).

3.2.3 Balancing ecosystem services

Agriculture depends on ecosystem services. Agroecosystems are natural ecosystems, which have been modified and often intensively managed. In addition to loss of **biodiversity** (plants, mammals, birds, arthropods etc.) trait and functional diversity (pollination, pest suppression) accompany the decline. In less intensified landscapes lower agricultural yields can be **balanced** by **increased supporting, regulating** and **cultural services** (Landis 2017).

The way an agricultural system is managed, its production pattern, has profound effects on ecosystem services. The elements N, P and C, essential for plant growth, have dual role as there is trade-off between food production and environmental impacts (Le Noë et al. 2017). **Element cycles** have been markedly altered in the course of agricultural intensification in the 20th century and onward, related to the use of fertilizers, intensified livestock production and related manure excretion. Soil N and P surpluses in livestock and crop production systems have increased manifold, and reached respectively to 138 Tg*y^{-1} and 11 Tg*y^{-1} by 2000 globally (Bouwan et al 2013). Livestock production has been the primary driver of nutrient N and P cycling rather than crop production; with one third of arable land in total used to satisfy the accelerated demand for animal feed. The surpluses of N, P and C lost to the environment have negative effects on water quality (eutrophication), habitats, atmosphere and human health. Among ways to reduce nutrient flows are efficiently integrating manure in crop production and matching supplies of N and P to livestock requirement, that altering the management (Bouwman et al 2013).

Analysing nutrient budgets of agro-food systems can lead to better decisions regarding shifts in production patterns to improve environmental services. Production patterns compared in agricultural regions of France, the systems associated with the highest environmental loss of N and P and the greatest resource consumption per unit of agricultural surface, were those exercising intensive specialized practices, compared with mixed crop-livestock farming and extensive cropping systems. The trends turned around when expressed per production unit of animal or vegetal (Le Noë et al. 2017).

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The core of *ecological intensification* comprises two opposite aims - to achieve food production at high level, using biological regulation in agroecosystems, and to provide ecosystem services (Doré et al 2011). **Productivity** can be supported by diversity as species richness in ecological and agro-ecological systems can enhance multifunctionality and ecosystem services. For example in diverse grassland communities biological mechanisms can effectively lead to enhanced biomass production as much as combination of agricultural measures (Weigelt et al. 2009). This could be an option to reduce external inputs.
AGROMIX Task 1.2 analyses ecosystem services in various agricultural systems.

3.2.4 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, also in **regenerative** agriculture. Everything is recirculated in nature, without waste. From agronomic perspective regenerative agriculture focusses largely on restoration of soil health and reversal of biodiversity loss (Giller et al. 2021). Using methods of regenerative agriculture the amount of soil organic carbon increases, soil structure improves as well as water retention capacity, fertility, having effect on crop yields but also carbon bound in soil is withdrawn from the atmosphere.
Circular economy, self-replenishing system that minimizes material and energy input, environmental deterioration without negative influences on growth, is seen as a possibility in transition to higher sustainability (Geissdoerfer et al. 2018). Both agroforestry (AF) and mixed farming (MF) systems contain elements of circular economy (reduced external input, recycling of resources, etc.). **Diversifying** production by for example adopting mixed crop-livestock systems (MF) is a measure of reducing risks to market volatilities. Diversification and economies of scope contributed significantly to resilient pathways of development in European study carried out by de Roest et al. (2018).
In social dimension, knowledge transfer can be promoted in local and regional or global scale while policies can be shifted by efforts of collective actions.
Proposals on the Common Agricultural Policy (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). The new CAP 2023-2027 has set high green ambitions, payments linked to a strong set of requirements, for example 3% arable land dedicated to biodiversity and non-productive elements etc. (The new common … 2023-2027).

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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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4 Agroforestry and mixed farming – diverse agroecological systems

4.1 Concepts of agroforestry, mixed farming: extent, diversity and management 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). By integrating trees, shrubs and other perennials to agricultural landscape many harmful management effects can be mitigated (Wilson et al. 2016). Environmental benefits include soil quality, carbon sequestration, regulation of run-off and erosion, biodiversity protection, improved wildlife habitat etc., bringing a renewed interest in integrating trees with agriculture into focus in EU policies (Wilson, Lovell 2016; 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 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), resulting > 15 million ha.

Agroforestry systems can be resilient to severe effects of climate change. Heat waves in southern Europe featured by extreme temperatures and fires are becoming common. The traditional (silvopastoral) AF systems resist wildfires more successfully than forests because of their savannah like structure and grazing animals reducing shrub growth. The mountainous mosaic landscapes with agroforestry, like it was in the past would be most protective. Wildfires are much more damaging in forests, particularly with pine trees, than in silvopastoral landscapes. In the conditions of climate change open [managed] spaces in between the forests would set boundaries for the spreading fires.

Mixed farming (MF) is an old practice as well. Mixed character of farms where combined crop and livestock husbandries occur on the same farm was widely practiced in Europe earlier (Robinson, Sutherland 2002; de Roest et al. 2018). Approaches of what is mixed farming however, depend on analysis or on the profile of the survey system. Farm Accountancy Data Network (FADN) monitors farms' income and business activities and provides regular data based on economic classification of farm types. Biophysical approach of elements included in mixed farming systems can be found in Land Use and Land Cover Survey (LUCAS) data but the

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understanding of what is mixed farming relies on the user, as this type is out of the scope of LUCAS classification focus.

There is a mosaic of farm structures and farming strategies in Europe. Overall, Eurostat results have indicated a trend towards specialized farming and decreasing number of agricultural holdings in the European Union. New data will be published in the end of 2022 while the previous period 2005-2016 was characterized by increased share of crop-specialists or livestock-specialists, that having happened mainly at the expenses of decreased share of mixed farming (Eurostat, Agri-environmental indicator). On average only 16 % of the utilised agricultural area in the EU (28 member states) lay under mixed holdings.

Farm modernisation including technical capacities, production based on intensification, high use of chemicals, and targeted agricultural policy schemes of subsidiaries since the end of 1960s have driven the trend towards higher efficiency and specialization. Specialist farms facilitated to reduce production costs and satisfy demand for lower food prices (de Roest et al. 2018). The agricultural intensification during the 20th century and onwards has been characterised by the trend of lowered production costs (cf Bouwman et al 2013). The cost of intensification and specialization has been detrimental on environment and made farms dependent on commodity markets (Ryschawy et al. 2012; de Roest et al. 2018). Market liberalisation since the last twenty years has resulted in increased economic vulnerability and weakened (economic and environmental) resilience of the specialised farms (de Roest et al. 2018).

Mixed framing has been seen as suitable alternative to specialisation. The agricultural European Innovation Partnership EIP-AGRI Focus Group on Mixed farming systems (2017) saw the negative effects of intensification in the separation of livestock farming and cash crop production. Resources can be used more efficiently in MF systems, grasslands and crops for feed and manure to fertilise them in turn.

Agroforestry and mixed farming are diverse agroecological systems which enable better use of resources and improve resilience to climate change compared to specialized farming. EIP-AGRI works to promote sustainable farming and forestry. They investigated case studies and i) identified key factors to enhance the increase of agroforestry in the EU agricultural landscape and ii) assessed sustainability of MF, suggested to use multicriteria analysis and specific indicators on economic, environmental and social dimensions. There is a need of better understanding how to manage complexity and interactions, adopt multidimensional design (above- and belowground), handle risks and barriers related to social dimension, and others.

Broadly seen, AF and MF systems are integrated systems. When an agricultural system combines two or more, out of three possible components – crop, livestock, forest, into a synergistic relationship we can define it integrated agricultural system (Gil et al. 2017).

4.1.1 AF and MF systems and AGROMIX project

According to the EU[3], 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

[3] *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.*

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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.

The AGFORWARD project used a triangular conceptual scheme where elements in the corners - trees (and shrubs) with crop (arable) and/or livestock systems are integrated essentially in two-component production systems (Figure 2a). A common share in this triangle encompasses mixed farming where livestock is integrated with arable practices or trees, and agroforestry with livestock or arable component. AGROMIX adapted conceptual representation of agroforestry and mixed farming systems, using the corresponding terms silvopastoral, arable agroforestry, mixed farming and agrosilvopastoral for integrated systemss (Figure 2b.).

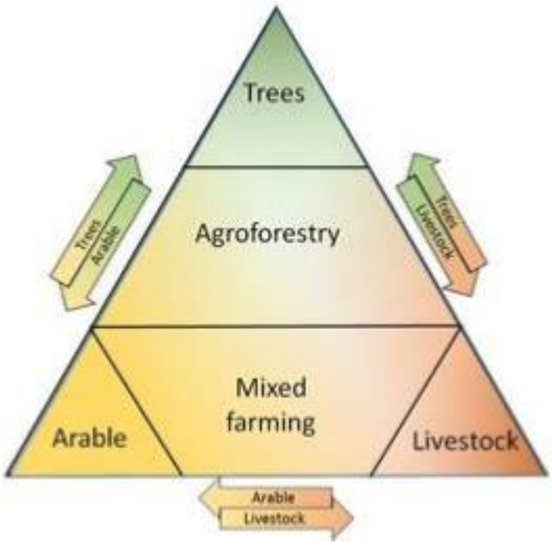

FIGURE 2a. Adopted conceptual scheme from the AGFORWARD project, integrating trees-livestock-arable practices, where agroforestry-mixed farming systems share common features in its core. Dynamics among the corner components allow development of a variety of possible internal designs of the AF/MF systems, depending on local conditions and demands of market.

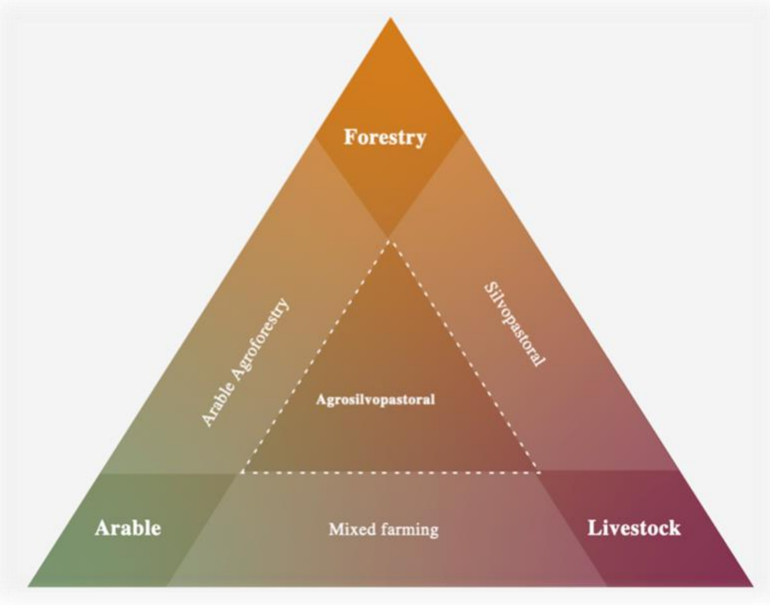

FIGURE 2b. Adapted conceptual representation of agroforestry and mixed farming systems.

The AGROMIX Task 1.4 maps the distribution and diversity of AF/MF systems in Europe. It also characterizes the diversity land use including an estimation of the extension of MF/AF systems by regions and climatic zones (spatial distribution). The Task makes a classification of agroforestry and mixed farming systems in Europe; attempting also to include for example, bocage (widespread in France), high nature value (HNV) farming, non-agricultural practices (such as hunting, collection of mushrooms, leisure, tourism, educational activities). A revised version of LUCAS database is used as the basis. The classification scheme as agreed in AGROMIX project, is presented in Figure 3. Whether the class of mixed farming would extend to being combined with permanent crops (left part in the scheme), either grazed or intercropped, was discussed. That would have overlapped with agroforestry as woody elements are involved (in agreement with FADN classification). In real farms mixed farming and agroforestry can both found in a farm structure. As the project is addressing both systems, for clarity, the clearly distinguished schematic definition is used.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 862993.

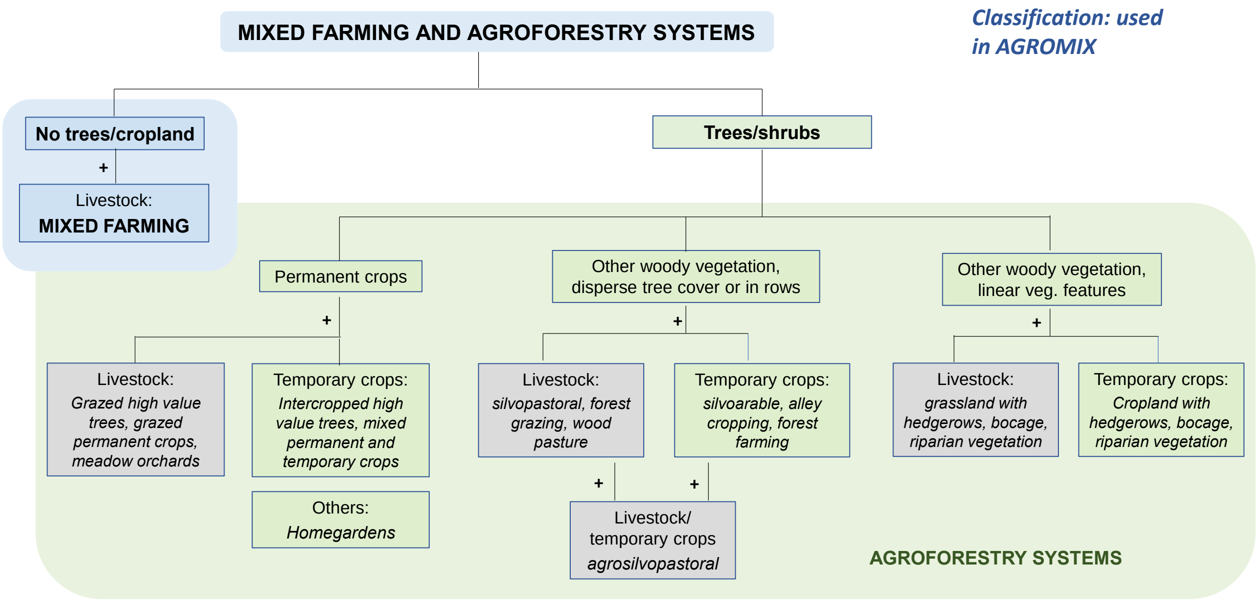

FIGURE 3: Classification of agroforestry and mixed farming systems used in AGROMIX.

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6 Annex

The Annex is a collection of definitions that are relevant in the conceptual framework of resilience in agroforestry and mixed farming systems. Alternative definitions were provided for several terms in pursuit of eventually selecting a suitable working definition.

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)		individial/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 etal (2020) listed agroecological principles 'for the design of biodiverse, energy efficient, resource-conserving and resilient farming systems (Table1): 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' undetaking 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 sponsering 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 enivronment 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 (silvoarable 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 shrub species. (3) indicates the variety of existing systems, such a hedge rows, etc.

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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						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 variery of welfare indicators: life expectancy, responsiveness, stereotypies (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 69: 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 "eudaimonia" 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 feed 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 reserach 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.	vales to give the facets, between 1 - low, 10 -high	Rault J.-L., Hintze S., Camerlink I., 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			cambidge dictionnary, 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.usgs.gov/faqs/what-carbon-sequestration?qt-news_science_products=0#qt-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 Rabiu 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 inicators 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 différents definitions : https://reader.elsevier.com/reader/sd/pii/S0921344917302835?token=AAB2B9C53DDA6EC81457C85D8BBC82BF832D2DE0D28EF12EEED3AE3597304FDFC2BB3107D85584A62A73570C3312D443&originRegion=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/circulatenews/a-new-measure-of-business-success-9e53b7aafafa); '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	

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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/k-4/stories/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).		(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 averge (more/less vulnerable to predicted risk)	indicator tables for each European NUTS3 region	Carter, J.G, Hincks, S, Vlastaras, V, Connelly, A and Handley, J. 2018. European Climate Risk Typology. [ONLINE] Available at: http://european-crt.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 enchance functional biodiversity in crop fields and consequently support the resilience of agroecosystems. The key here is that when environmental change occurs, theredundancies of the system allow for continued ecosystemfunctioning and provisioning of ecosystem services.	Risk = Vulnerability * Threat / Response Capacity		http://www.fao.org/climate-smart-agriculture/en/ + Altieri et al. 2015Agroecology and the design of the climate change resilient farming systems		
Compensatory measures	x			balancing one action (or its effects) with another action. for instance threes plantations to compensate CO2 emissions,	These are a way to restore the environnement and it is a way to reverse the environmental degradations.			Etrillard 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 surrundings	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 or services without using money.	Mixed farming can be at a scall of several farms throughout the process of exchange : sheep grazing in vienyard for example					
Ecological corridors	x			An ecological corridor is an eological continuum. It is a functional zone of 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 Döhren, 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 ecosystems 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 equalityof outcome; 'fair play', or equality of opportunity; and 'fair say', orautonomy 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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CI	Ec	En	So	Definition	Expanded Definition	Measure	Indicator	Reference	Type of reference	Remarks
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. *Encyclopedia of biodiversity*, *3*(1), 109-120.	Encyclopedia	
Functionality (of an ecosystem)										
Global warming				The idea that increased greenhouse gases cause the Earths temperature to ris 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/#chapter4 (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. 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_use.2C_land_cover_and_landscape		
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_use.2C_land_cover_and_landscape		
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_use.2C_land_cover_and_landscape		
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, Biogeosciences, 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:Farm_typology		This definition is used by Eurostat, so that data are available throughout Europe
Mixed farming 2	x	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/rica/detailtf_en.cfm?TF=TF8&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' /.../ '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	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, Biogeosciences, 6, 1695–1706, https://doi.org/10.5194/bg-6-1695-2009	article	
Mutuality	x	x	x	The principe 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	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 persistant.			Dicoae : https://dicoagroecologie.fr/encyclopedie/permaculture/ (Agrocecoly dictionnary 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 harvestingof 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. *Environmental Science and Pollution Research*, *24* (8), 6973-6988.	review article	
Reorganization										
Resilience I	x	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. Front. Ecol. Evol. 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, enviroenmental 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. Agricultural Systems 176, 102656	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 varables: Core body temperature (normality of circadian pattern and dynamic range); hear 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. Ecology and society, 9(2).		
Resource use efficiency	x									
Self-organization			x							
Self-regulation			x							
Seminatural 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 calatyse 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&qid=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 differenciate between total carbon and total organic carbon.	A standard measure of soil organic carbon it the Walkley & Black method. For total carbon the loss on ignition with 900ºC				
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 conten 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 ISQAPER 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	x	*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*				Montpellier Panel. (2012). Growth with resilience.		
Sustainability	x	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://academicimpact.un.org/content/sustainability#:~:text=In%201987%2C%20the%20United%20Nations,development%20needs%2C%20but%20with%20the		
Symbiosys	x			interaction between two different organisms living in close physical association, and benefiting both of this association.	This kind of association contribue to limit the esternal inputs and increase resilience			Cambridge dictionnary		
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/jeg/lbn002	Economic geography Research Group, Working Paper Series No 05.07	
Wood pasture	x	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. Bieling, Konold 2014).'intimately linked with farming system.' Various terms applied across Europe to wood pastures, of which 'sylvopastoral 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-funtional 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				

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