MIXED

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Summary

A framework is needed in the MIXED project to clarify base definitions and their inter-relations necessary to compare and analyse the possibility of achievement of mixed farming and agroforestry systems (MiFAS) in Europe. Such framework would serve two main purposes: (i) driving the coherence among parts of the project, promoting transparency in the definitions and making the unity evident out of the different tasks of the project; (ii) contribute to the international literature with a tool for promoting MiFAS at different levels. We got to the formulation of the framework starting from a very first proposition further enriched via a series of virtual workshop with project partners (from throughout the consortium, participating on a voluntary basis). As a first step, the framework includes the definition of MiFAS at different levels, *i.e.*, farm, landscape, value chain, country, Europe. Then, the framework is articulated on two axes: transition (the process leading from a current system to possible target systems), and evaluation (the quantification of a MiFAS performance along multiple dimensions). Concerning transition, the framework clarifies the concept in general and for the different levels considered; it also provides definitions and example of related concepts, such as barriers and enablers. Concerning evaluation, the framework clarifies the definitions of sustainability, efficiency, and resilience; it also provides example of functions that could be quantified for evaluating those properties. Evaluating serve mostly to compare MiFAS among themselves, MiFAS with non-MiFAS, and current system with hypothetical target systems; in addition to this, evaluating multiple performance dimensions highlights trade-offs and synergies among dimensions themselves. The framework constitutes a first step for clarifying and linking all the concepts relevant to the activities of the project, but it will be open to further discussion, that could lead to modifications and enrichments.

Contents

1 Introduction: why a framework?

The European agricultural sector is called, in line with the CAP objectives, to promote the provision of environmental, economic, and social functions, as well as to increase its efficiency and decrease its reliance on external inputs, fossil fuels and impact on natural resources. All of this should be achieved while coping with increasing challenges that the sector is facing, including adverse climate events, price volatility, frequent policy changes. In summary, the European agricultural sector needs to be sustainable, efficient, and resilient.

It is increasingly recognised that mixed farming, consisting of forms of crop-livestock integration and agroforestry (i.e., mixed farming and agroforestry systems, hereafter referred to as MiFAS) increases resilience and climate adaptation potential, promoting nutrient and carbon cycling, a diversified ecosystem services delivery and a more efficient utilisation of resources. In the scientific literature, studies have highlighted the multiple benefits of mixed crop-livestock and agroforestry systems (Martin et al., 2016). Among many others, these benefits include (see Kronberg and Ryschawy, 2019) the following: the option of feeding livestock with crops produced on the farm, the possibility to use excreta as source of nutrients for crops, the possibility of using livestock as weed control.

The goal of the MIXED project is to support MiFAS, facilitating the transition of current systems to more integrated systems or improving the current already integrated system, considering their resilience to challenges, their efficiency in the use of resources, and their sustainability. However, we also acknowledge that significant constraints exist for improving and promoting these types of systems and important trade-offs might occur among sustainability, resilience and efficiency. In order to operationalise the enhancement of MiFAS and the assessment of their performance, a theoretical framework is beneficial. Such framework is necessary for converging to a set of shared definitions of the most important concepts (e.g., what is a MiFAS at different levels? What is meant by “transition to MiFAS”? How are sustainability, efficiency, and resilience defined?) used along the project and relative to the facilitation of MiFAS.

In the MIXED project, a framework is needed to give a general context to all the activities, including participatory workshops, data collections, modelling, assessing the performance of or promoting the transition to MiFAS systems. This would promote general coherence among all the activities: it is important to have a common theoretical ground consisting of definitions of relevant concepts and explanation of how concepts are inter-related. In addition, this would promote transparency in some processes to be implemented in the course of the project, such as the quantification of sustainability, resilience, and efficiency. Revealing conceptual definitions and the processes behind assessments is fundamental for promoting interdisciplinary dialogue and communications with stakeholders (de Olde et al., 2017). These statements come with the awareness that definition and articulations of concepts might change during the course of the project, so the framework proposed in this report is a first version that might be modified during the project lifetime. Nevertheless, it is needed to bring all the project participant to a common ground and give the high-level project overview. In general, the framework might contribute to the scientific literature by conceptualizing the different aspects related to the transition to improved MiFAS

This report presents the different parts of a framework for efficiency and resilience assessment for MiFAS in its different parts, highlighting its rationale and explaining how it is operationalized in the

MIXED project. In order to test the solidity of the framework for the MIXED project, we mapped the tasks of the MIXED projects on the different parts of the framework. Perspectives and open questions are also remarked.

2 Activities that led to the framework

This framework is the outcome of Task 6.1. The task leader and the work package (WP6) leaders decided that it was pertinent to open to all the MIXED project participants the invitation to debate about the concepts linked to the framework. The reason behind this is because it is likely the framework and the definitions therein will impact the project future activities, therefore many different points of view from different project work packages and networks will need to be brought into the framework. On a voluntary basis and with different degrees of involvement some project participants took part in the discussions. Participants were from different backgrounds (e.g., agronomy, economics, social sciences) and assigned to different tasks of the MIXED project (including also network facilitation). The diversity of profiles involved undoubtedly contributed to the richness of the debate.

The task leader prepared a primary draft of the framework with some topics for the discussion. Three on-line meetings of two hours were organized. During the meeting the participants interacted with the support of a collaborative whiteboard. The meetings were about the following topics: 1) *defining MiFAS at different levels*; 2) *Addressing transition to (improved) MiFAS*; 3) *Evaluating MiFAS: sustainability, efficiency, and resilience*. Other than on-line meetings, participants could also contribute on the text of this deliverable.

This report presents the framework and the definitions out of a series of exchanges among experts involved in Task 6.1. Although we are aware that concept definitions can change along the course of the project, we believe that an initial framework design provides solid bases for further discussion and theoretical grounding of project activities and future improvements.

3 Description of the framework

3.1 General considerations

Before proceeding with the description of the framework it is relevant to make some considerations for preparing the ground for its configuration.

1) *Importance of accounting for sustainability*. We recognize that agricultural systems, and MiFAS in particular, are not only aimed at food production but provide a wide range of other functions of environmental, economic, and social type (OECD, 2001). For example, food systems can also contribute to ecosystem service provision (e.g., erosion control, nutrient recycling), provide habitat for biodiversity, contribute to rural vitality and economic viability (Cooper et al., 2009). In different studies it is acknowledged that environmental and social functions contribute to the resilience of a socio-ecological system: for example Altieri et al

(2015) remark that resilience to extreme climate events is higher for systems that enhance ecological processes via practices of diversification and organic soil management; other studies stress on the importance of social aspects (such as community self-organisation (Berkes, 2007), or good quality of life (Darnhofer, 2010)) to promote resilience. A balanced provision of functions on the environmental, economic, and social dimension resonates with the concept of sustainability. It is therefore important that the framework take into account the provision of different functions in all the sustainability dimensions by the system.

2) *Importance of accounting for different levels*. Promoting transitions to improved MiFAS and assessing their performance requires considering different levels, including farm, landscape, value chain, country and Europe. In this context, we prefer the use of the term “level” over the use of “scale”. While “scale” is mostly related to a spatial extent, the term “level” includes also organisational, administrative, and social aspects. In fact, the “value chain” level is not linked to any particular spatial scale, and when we refer to “farm”, “landscape”, “country” and “Europe”, we do not merely consider the spatial aspects but also the interrelations among e.g., components, actors, and policy. There are several reasons for considering multiple levels. First, each level has specific characteristics relevant for promoting MiFAS. Different levels correspond to different stakeholders (e.g., policy-makers at the country level, farmers at the farm level) requiring different outputs, different recommendations and levers, and characterized by different dynamics and social-ecological interactions. To give an example, at the farm level crop-livestock interaction is relevant, while at the level of a landscape structure, what becomes relevant is the interaction among farmers and other actors (e.g., policy-makers) and with non-agricultural land uses. Second, considering different levels makes it possible to “observe” phenomena and interactions that would not be visible at other levels. For example, the interactions among farmers are well observed at larger levels, therefore specialized but complementary farms do not identify a MiFAS at the farm level but make the MiFAS emerge at the larger levels. Third, different levels interact and are inter-connected, as shown in the concept of “panarchy” by Holling (2001). Farmers are the ultimate decision-makers on their land (although they can be influenced by e.g., markets and policies) and their action can play out at bigger levels. Knowledge and experience should be transferred among levels, policy-making should be based on insights gained at the small levels, recommendations to farmers should be coherent with bigger-pictures policy design at the country or European level. In light of the considerations about the importance of considering multiple levels, concepts and definitions will be provided for the different levels considered.
3) *Importance of defining systems*. A starting point of the framework would be the definition of MiFAS at different levels. This would imply delimiting boundaries, identifying the key actors and, above all, defining the elements that characterize “mixedness” as well as their interactions at different levels.
4) *Considering multi-dimensionality.* Sustainability, efficiency, and resilience are not concepts that can be described with a single metric. They are highly multi-dimensional and context-dependent. Sustainability is formed by different pillars (environmental, economic, and social) and sub-pillars. Efficiency can be observed under different points of view (e.g., production per unit of emissions or per unit of resource used). Resilience can be referred to different

specific challenges or can be generic (Carpenter et al., 2001; Meuwissen et al. 2019). It is therefore important to have a framework open to multi-dimensionality. This would also make it possible to create awareness about trade-offs and synergies among dimensions of sustainability, efficiency, and resilience.

5) *Distinguishing between services and disservices.* While the impact of MiFAS on the agro-ecological services they provide is often highlighted, it should be noted that these processes are not systematic. Depending on the context, the climate or the type and management of the development carried out, a MiFAS can sometimes cause undesired effects according to the years, generating costs and disservices. For example, in terms of biological control, pest control can be expressed to different degrees depending on the year, or even negative depending on the case; also, in a series of workshops about the perception of agroforestry in Europe, stakeholders remarked that some negative aspects can be related to the implementation of these systems, such as increased labour and complexity of work, management costs, and administrative burden (Garcìa de Jalón et al., 2017).

3.2 General overview of the framework

A scheme of the framework is depicted in Figure 1. The framework is based on two main axis: transition and evaluation. The transition axis conceptualizes all the elements playing a role in the passage from a current system (a MiFAS or a specialized system) to a (improved) MiFAS. Evaluation is centred around a set of concepts (sustainability, efficiency, and resilience) and provides elements useful for operationalising these concepts. The coupling among transition and evaluation is needed because on the one hand one aim is to analyse the pathway for achieving MiFAS (transition), on the other hand, it is important to make sure that MiFAS, in fact, perform better than specialised systems. Figure 1 also shows the importance of considering multiple levels when defining the concepts, as well as their inter-relation. The following section will provide definition to specific concepts.

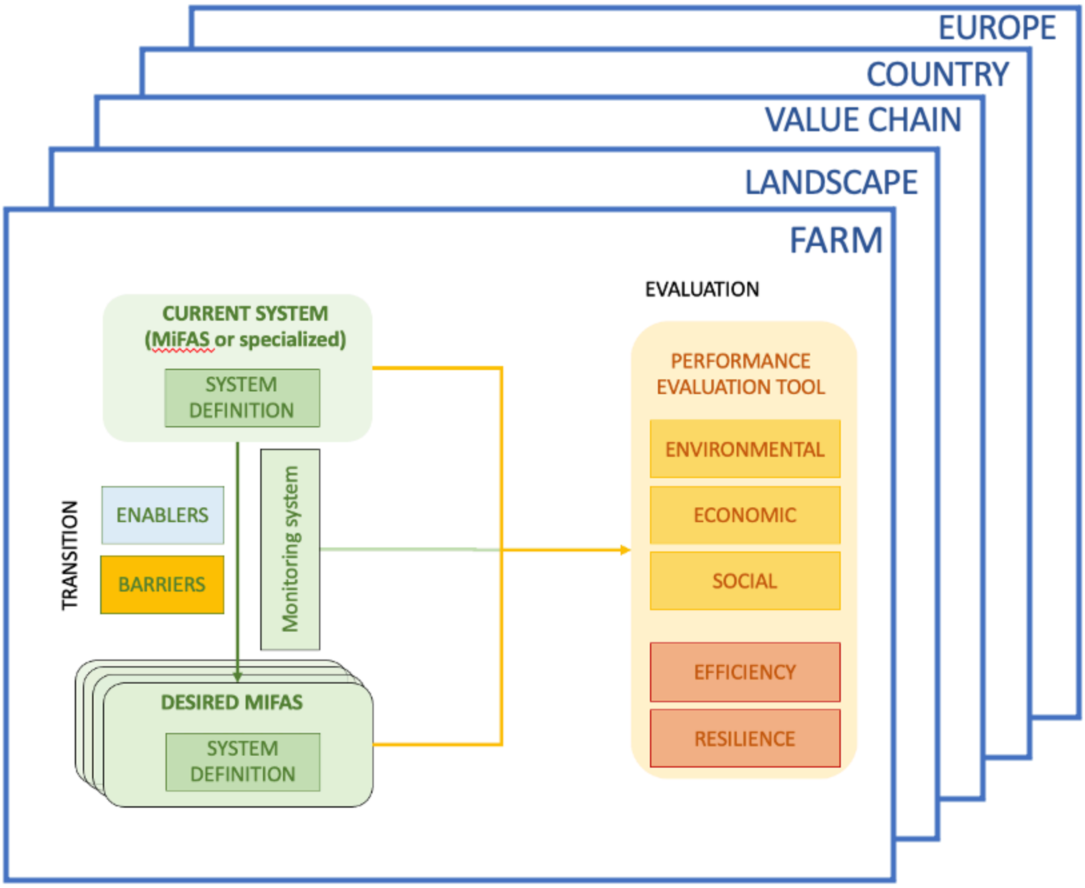

FIGURE 1 – schematic representation of the MiFAS framework at a generic level

4 Specific concepts of the framework

4.1 Defining MiFAS

Within the MIXED project different levels are considered, namely farm, landscape, value chain, country, and Europe. Some considerations can be valid beyond a specified level. The concept of "mixedness" implies a certain level of diversity (e.g., diversity of activities, actors, functions), however diversity *alone* is not sufficient: it is also important to consider the interactions among the diverse elements. In other words, a system can be considered a MiFAS if there are different activities interacting for improving the circularity and promoting synergies. With the term "activity" we mean a certain function executed by farmers producing certain outputs. Within the MIXED project we mostly focus on activities strictly related to agriculture, e.g., livestock rearing, forestry, cropping, with the possibility to consider also finer activities, such as pig rearing and cattle rearing. Other activities can be considered (see Meraner et al., 2015), which are not strictly related to agricultural outputs, yet make use of the resource of the farms, for example tourism and off-farm work or on farm processing, those types of activities are mostly related to economic or social outputs. For the MIXED project, we mostly focus the attention on the activities producing agricultural outputs, however, we keep possibility for other types of mixedness not strictly related to agriculture.

4.1.1 Concept of MiFAS at the farm level

A MiFAS at the farm level consists of a diversity of activities (e.g., crop, livestock, forestry) which are carried on promoting interactions among them. Interactions come in the form of shared resources, shared inputs, complementarity among fluxes with the overall aim of closing the N, C, P cycles. Complementarity can occur in different forms, for example by-products from an activity can be used as inputs for another (e.g., whey used to feed pigs); products of an activity can be used as input for other activities (e.g., grain used to feed pigs or manure to fertilize crops). Finally, complementarity can occur also among niches (e.g., co-grazing species with different preferences.

4.1.2 Concept of MiFAS at the landscape level

Among all the levels considered, landscape is the scale for which it is more difficult to put boundaries. From an ecological perspective, a landscape is a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout (Forman and Godron, 1981) For the context of our project we expand this definition to include the social system and focus on agricultural production, hence a landscape can be seen (i) from the point of view of the actors interacting as well as (ii) from the point of view of the ecosystems composing it (iii) from a point of view of governance and policies shaping an area. In the first case (i), a landscape can be conceived as a "farming system", which is a local network of farms and other actors that interact formally or informally in a specific agro-ecological context (Giller, 2013). In the second case (ii), a landscape can be considered as a region occupied by a farming system. In the third case(iii) a landscape can also be understood as an area with homogenous governance with similar policies and can be delineated as through administrative boundaries such as NUTS3 or NUTS2. In all three cases, the important characteristics of a landscape are the spatial continuity and a type of homogeneity under a desired point of view. At the landscape level a MiFAS can be defined as a system of farms in which farmers interact among themselves and with other actors, resulting in improved circularity at that level. We recognize that it is not easy to define thresholds for delimiting the level of "interaction" that could constitute a landscape, also, different geographical areas might have very different and specific socio-ecological dynamics, which make it very difficult to set rigorous definitions. However, we keep it as an open question which might be better answered in the course of the project. Mixedness at the landscape level might also be achieved with specialized (but different) farms that interact. Interactions might occur in different forms, for example exchange of matter (field, manure), livestock, workforce or information. Importantly, a condition for interaction is the coordination and the trust among farmers that, although they might be specialised, look for complementarities with other farmers and cooperate, leading therefore to a better closure of nutrient cycles in the landscape. It is also important to consider that at this level the interaction among agriculture and natural resources gains relevance which is at the base of ecosystem service provision (Power, 2010).

4.1.3 Concept of MiFAS at the value chain level

The concept of MiFAS at the value chain level refers to the capacity of the value chain to promote on the marked and add value to the products of MiFAS, making them more competitive with the products of specialised systems.

4.1.4 Concept of MiFAS at the country level

The concept of MiFAS at the country level could be referred to the extent to which a certain country promotes, via policy or in interaction with other actors (e.g., NGOs) the achievement of MiFAS within its boundaries. At the country level the concept of MiFAS can be related to a set of policy goals. A first policy goal is food and nutritional self-sufficiency. Within a country's boundary food and nutritional security are achieved if a multitude of food groups are provided, therefore requiring the presence of different agricultural activities. We remark that food and nutrition self-sufficiency can be a relevant issue also at other levels (e.g., farm, landscape), but it is more often formulated as a policy objective at the country scale. If the concept of food self-sufficiency implies a diversity and completeness of functions within a country's boundaries, this does not necessarily imply the integration and proximity of complementary activities that would be required by MiFAS. Another goal at the country level is to avoid the depletion of the environment and of the biohazards which are caused by the progressing specialisation. In addition, MiFAS usually require higher engagement of workforce and can therefore contribute to rural vitality and help to reduce rural unemployment and depopulation of rural areas. The promotion of MiFAS within a country, might also be in line with other policy goals, such as increasing carbon sequestration and promoting soil health. Therefore, policy goals at the country level are often in line with the promotion of MiFAS. The achievement of MiFAS within the country's boundary could therefore be in the core of policy, and each country would target the optimal level and spatial extent at which to promote the MiFAS, depending on internal geographical conditions.

4.1.5 Concept of MiFAS at the European level

The main concepts applicable for MiFAS systems at the country level can be applicable to Europe, i.e., promoting the achievement of MiFAS within the boundaries (at appropriate levels and spatial extents) in order to answer to policy goals (i.e., food self-sufficiency, protect natural resources, promote rural vitality); with the difference being made in the policy-making. An additional role of Europe could be the promotion of learning about MiFAS across different parts of Europe, as some knowledge can be shared beyond specific contexts. Also at European level, impacts of promoting MiFAS on the rest of the world is important. Most European countries, import more food when production gets less intensive at home, creating tele-coupled effects in other regions of the world.

4.2 Transition

Transition refers to the pathway of transformations required for moving from a current configuration to one of possible improved target configurations. The starting point of the transition (current configuration) is an observed system. This can already be a MiFAS that needs to be improved, or a specialized system that needs to be integrated. Likely, specialized or already mixed systems undergo very different processes of transition. The end point of the transition is something that does not currently exist, therefore multiple alternative configurations can be envisaged for a given current system. A set of possible desirable target configurations can be conceived by setting some criteria, principles and goals. While at a general level we can affirm that an improved MiFAS increases the closure of the N, P, C cycles, some research needs to be done on more specific principles. More in particular, goal setting also raises questions about who sets the goal and how to deal with the diversity of goals of different actors (policy-makers, farmers, and researchers might have different visions). Importantly transition implies a shift in vision from a short-term to a long-term perspective, as some elements (e.g., planting trees) need time for being integrated and bring to a benefit after years.

4.2.1 Transition to MiFAS at the farm level

At the farm level, transition to (improved) MiFAS implies a move towards the integration among crop, livestock, and trees towards the closure of the N, P, C cycles. Such a transition requires first of all a change in the mindset of the farmer as (especially for specialized systems) it is important to think and conceive their farm differently. The farmer needs to trust that a transition to a MiFAS will bring some benefits. In addition, a transition to a MiFAS at the farm level might require also changes the socio-technical environment of the farm, e.g., feed sellers, advisors.

4.2.2 Transition to MiFAS at the landscape level

At the landscape level, transition to MiFAS occurs through collective actions in which different actors collaborate (more or less intentionally) for achieving a common good. In this situation decisions are taken by farmers considering what other farmers or other actors do. Transition at this level requires the building of trust among actors. In the literature there are many remarks about the need of building trust in the cooperation with other farmers to obtain overall societal improvements in the context of farming systems composed by small scale farmers (Marcysiak, 2011; Baur et al., 2016). In addition, managing natural resources is important for promoting ecosystem services. Challenges can be different depending on the current configuration. If the current configuration consists of complementary activities already present in a landscape, transition would consist of boosting their integration; if the landscape is specialized, the challenge would be to introduce a complementary activity (e.g., introducing livestock in arable regions).

4.2.3 Transition to MiFAS at the value chain level

Transition at the value chain level refers to giving a certain value to mixedness (e.g. through using labels for mixedness). This would likely be achieved if the additional products of MiFAS are venued on the market. This is most likely be obtained with smaller and more distributed infrastructures which would allow for the valorisation of local and small-level production. Besides this, a fair distribution of profit along the value chain would likely support MiFAS as all actors involved would likely feel they are well (or relatively well) considered.

4.2.4 Transition to MiFAS at the country level

At the country level transition refers to the improved ability of a country to promote MiFAS within its boundaries. This passes through identifying systemic enablers and barriers and acting on promoting the former and mitigating the latter. This also requires finding the best level to promote mixedness within the boundaries (also considering different geographical contexts), defining policy principles for how to distribute subsidies (also supporting the already existing MiFAS), and facilitating the transfer of information at lower levels.

4.2.5 Transition to MiFAS at the Europe level

What applies at the country level can be extended to the Europe level with adjustments related to policy (CAP). In addition, Europe can make links among different contexts and can therefore promote knowledge exchanges (e.g., organizing summer schools).

4.2.6 Cross-level interactions and transition

Considering a framework that encompasses many levels brings to some reflections about the interplay among levels in the context of transition. Most importantly, some power relationships might exist among levels, for example farmers in many contexts need to adapt their decisions to the policy frame established at higher levels. Power relationships among levels consist of a level acting as a barrier or as an enabler for the stakeholders acting on another levels. An example of power relationship among levels consists of policy-making that affects the choices of the farmers. Policy can indeed act as a barrier or as a challenge in case it constraints some actions or if it changes too frequently (Buitenhuis et al., 2020). Interaction across levels can also be horizontal: for instance, distant levels can interact via trade and therefore cause tele-coupled effects, to give an example, a progressive specialisation in animal production of a landscape can force another landscape to specialise on crops for providing feed, therefore hampering its transition to a MiFAS.

4.2.7 Elements to consider concerning transition

A series of elements (depicted in Figure 1 in the transition dimension) need to be considered when discussing transition to (improved) MiFAS at all levels. First of all, the target should be defined. The transition is defined as a move from a current configuration to a hypothetical future improved one, not only one target system can be possible, but many: what is important it to define the rules and the principles to select the suitable alternative systems that could constitute a target. Once targets are defined, barriers and enablers need to be analysed. Barriers and enablers are exogenous or endogenous elements of different types (environmental, economic, social, institutional) that could hamper or facilitate – respectively – the transition (see Table 1 and 2 for examples of enablers and barriers, respectively, at different levels). The analysis of barriers and enablers could also account for the historical context (specifically, path-dependency could contain elements of inertia against transition or of momentum favouring transition). Last but not least, a timescale for measuring progress should be defined to monitor the transition. The definition of target system as well as the monitoring system of the transition could be linked with the performance evaluation tool of the framework.

Table 1. Example of barriers to transition to MiFAS at different levels (these examples are not linked to a specific case study but can be valid in general).

	Environmental	Economic	Social	Institutional
Farm	The biogeophysical context might not be suited for mixed farming (e.g., some crops cannot grow in some places).	Time needed for getting benefits from the implemented changes; Costs in changing the system and lack of profit in the short term; Increased cost of labour; Increased costs and machinery.	Reluctance to change; Absence of successors; Extra workload; Lack of the needed knowledge and technology; Adversion of the rural neighbourhood towards certain agricultural practices like animal husbandry (e.g., odour, noise, dirt)	Policy and legislation constraints; lack of advisory services; Excessive bureaucracy.
Landscape	Physical barriers might prevent the interactions among farmers (e.g., mountains); Low level of natural resources; Overexploited resources.	Unbalanced relationship among farmers and other actors of the value chain. Finance required for infrastructure; Transaction costs; Lack of skills and infrastructures in the landscape;	No trust developed in the other farmers and actors; Reluctance to cooperate and desire for independence in decision-making.	Policy context does not encourage cooperation
Value chain		The value chain is already specialized; Lack of infrastructures; Low willingness to pay higher prices for products of MiFAS; unbalanced relationship between value chain actors.	High power of retailers and supermarkets towards monocultures.	Tax issues with exchanges among farmers (e.g., who pays for the taxes that cooperatives pay for grain storage?)
Country/Europe	Greenhouse gas reduction objectives that require decreasing the livestock population.	Lack of infrastructures (e.g., slaughterhouses); Lack of subsides to support MiFAS. Competition with specialized systems.	Historic trajectories; Lack of infrastructures; Dominance of the way of thinking based on economy of scale and specialization	Lack of regulation that embraces MiFAS; Public perception of the importance of agriculture; Conflict with other policies; Biased information from AKIS; Lobbying of specialised agricultural systems.

Table 2. Example of enablers to transition to MiFAS at different levels (these examples are not linked to a specific case study but can be valid in general).

	Environmental	Economic	Social	Institutional
Farm	Biophysical conditions that favour mixed farming systems.	Grants and financial incentives; profitability of activities; availability of a suitable value chain and possibility of direct selling; capacity to invest. Labelling of products of MiFAS; Subsides for MiFAS;	Independence; knowledge availability; dynamic farmer groups; mind openness for MiFAS; Entrepreneurial mindset; Inclination towards an environmental-friendly agriculture.	Involvement of advisory services; Appropriate legal conditions.
Landscape	Sufficient ecosystem service provision; Improved soil health for arable system leading to better productivity.	Grants and financial incentives; Cooperatives and shared ownership of niche farm machines and/or bio-refineries; Availability of needed infrastructures.	Presence of similar initiatives in the landscape; experience exchange group among farmers; Social interactions; Cooperatives and organisations.	Cooperation is encouraged and rewarded; Presence of demonstration farms for exchange of good practices.
Value chain	Products with recognized delivery of environmental benefits.	Better distribution of profits along the value chain; Locally embedded value chain; Inter-professional organizations.	Growing consumer demand for products that can be delivered by MiFAS.	Labels recognizing MiFAS and providing added value to farmers; Farmer's' association and cooperatives; Committed processors.
Country/Europe	The climate in the country allows for multiple activities; EU and country's environmental goals.	Economic public support for MiFAS	Advisory board consisting of stakeholders from e.g., universities, farmers, organizations, companies, NGOs, who develop a shared framework for the development of MiFAS.	Public support for MiFAS (information, awareness of the importance of MiFAS); Effective system for monitoring the effect of policies.

4.3 Performance evaluation

The performance evaluation tool of the framework conceptualizes criteria for evaluating the performance of a MiFAS under a number of dimensions. Measuring the performance of a MiFAS is important for a number of reasons. First, it is useful to compare MiFAS among them (and also with non-MiFAS) and along a trajectory. Comparing MiFAS among them allows to create baseline and to understand the causes of a good or bad performance over some dimensions. Comparing the performance of a MiFAS along a trajectory constitutes a support for monitoring the transition: it makes it possible to understand which dimensions of the performance are improved and which dimensions, on the contrary, are worsened. Performance can also be assessed qualitatively for MiFAS that still do not exist. When some possible target MiFAS are discussed and compared, it is useful to have an idea of the estimated performances of those target systems, for a comparison among them and with the current system. Assessing the performance of target, non-existing, MiFAS can be done qualitatively through participatory or expert assessment or via modelling (for some dimensions). Second, it is useful for making trade-offs and synergies visible among dimensions of the performance. We expect that improvements might not occur across all the dimensions of performance, improvements along some targeted aspects might cause unintended negative consequences on some other aspects. Conversely, synergies consist in improvements on some aspects obtained by targeting improvements on other aspects. The different aspects of a MiFAS can be assessed quantitatively (models, data analysis) or semi-qualitatively (through participatory assessments) (see Accatino et al., 2020): this would make trade-offs and synergies visible, in order to put light also on possible disservices related to MiFAS and for exploring possibilities for softening trade-offs and enhancing synergies.

We believe that performance of a MiFAS is multi-dimensional. Specifically, we consider, sustainability, efficiency, and resilience. Sustainability comes from the acknowledgment that an agricultural system should not only merely serve to produce food, but also to produce a number of other public and private functions (Meuwissen et al., 2019) related to the dimensions of sustainability, namely environmental, economic, and social (OECD, 2001). These three dimensions of sustainability should be promoted over the long term. Efficiency comes from the acknowledgement that agricultural systems need to reduce their impact on resources and on the environment. Resilience comes from the consideration that agricultural systems have been and will be subject to challenges (known or still unknown and unexpected) and should be able to deliver their functions in spite of those. The main dimensions of a MiFAS performance (sustainability, efficiency, and resilience) are also multi-dimensional. Sustainability is composed by three pillars (environment, economy, and society), which can be composed by other sub-pillars, e.g., the environmental pillar is composed by the emissions, soil quality, effects on biodiversity. The multitude of dimensions considered in the performance evaluation of a system makes it possible to consider the widest number of possible aspects of a MiFAS and to have a full view on them and on the interconnections among them.

4.3.1 Sustainability

Sustainability can be conceptualized as the achievement of environmental, economic, and social functions over the long term. Examples of these functions are the provision of ecosystem services (environmental), ensuring economic viability (economic), and promoting good quality of life (social). A MiFAS should not only perform well in these dimensions but should also promote synergies and reduce trade-offs. The three pillars of sustainability are included in the framework of Figure 1.

4.3.2 Efficiency

Efficiency can be conceptualized differently according to different disciplines and points of view. On a generic level, it might express the extent to which economic, environmental, and social resources are not wasted. Importantly, this definition is thus conceptually in line with sustainability as it goes beyond the economic aspect. For a given quantity of output, a system is more efficient if less waste is produced, less resources are used, and less side effects and redundancies are allowed. What is exactly included in “output”, “resources”, “waste”, “side effect” or “redundancy” depends on the objective of the assignment. In the same way as sustainability, efficiency also has different dimensions. One way to do so is by having a partial outlook on efficiency. For example, different dimensions of efficiency could be “the amount of output produced per unit of nitrogen synthetic fertilizer application” or “the amount of output produced per unit of workforce”.

Alternatively, one may have an integrated outlook on efficiency, which attempts to integrate the various economic, environmental and social resources into one measure. To assess what amounts to inefficiency, it is here key to compare the performance of the observation to that of a “benchmark”. Understanding the production relationship between the various resources is in this light essential for accurately determining such a benchmark. This yields a measure that can most often be expressed in dimensionless percentages or ratios. For instance, one may assess the extent to which an observation can simultaneously increase production as well as decrease nitrogen pollution in terms of a percentage. Common approaches to operationalise this integrative approach include stochastic frontier analysis and data envelopment analysis (Coelli et al., 2005).

4.3.3 Resilience

Resilience can be defined as the ability of a MiFAS to provide the functions of sustainability over the long term despite challenges and disturbances (Meuwissen et al., 2019). Resilience can be *specific*, i.e., referred to a specific challenge, or *general*, i.e., referred to the unknown, uncertainty, and surprise (Walker et al., 2004; Anderies et al., 2013). Following a number of papers conceptualizing resilience for socio-ecological systems (see Folke et al., 2010, Meuwissen et al., 2019) we distinguish three resilience capacities: *robustness*, i.e., the capacity to withstand perturbation without configurational changes; *adaptability*, i.e., the capacity to change configuration in response to perturbation but without changing the main structure and feedback mechanisms; *transformability*, i.e., the capacity to significantly change the internal structure in answer to a perturbation. In addition, a set of resilience attributes identified in the literature (see Cabell and Oelofse, 2012; Tittonel, 2020; Paas et al., 2021) characterize the generic resilience. Resilience attributes consist of characteristics of a system that enhance the likelihood of a system to be resilient. Examples of resilience attributes are the following: “*Coupled with the local, natural capital*”, meaning that a system more reliant on ecological feedback mechanisms, own natural resource – rather than imports – has more probability of being resilient; “*socially self-organized*”, meaning the robust social connections improve the capacity of reorganization after a shock. The concept of resilience involves multiple dimensions: resilience to different specific challenges, and different resilience attributes. It is important to notice that MiFAS have intrinsically some resilience attributes, for example “*spatial and temporal heterogeneity*”, “*functional diversity*”, “*response diversity*”.

4.3.4 Operationalisation of the evaluation component of the framework and interactions among dimensions

In order to operationalize concepts presented in the evaluation component of the framework, it is important to define functions and elements to observe in order to investigate the different aspects of a system performance (sustainability – divided into its environmental, economic, and social dimensions – efficiency, and resilience). These functions and elements should be eventually translated into qualitative or quantitative indicators, so to have an objective assessment of the system. Indicators allow the assignment of a value, which can be calculated by means of data, modelling, or participatory methods. Once (quantitative or qualitative) values are assigned to indicators, trade-offs or synergies among dimensions can be visible. Examples of trade-offs are given in Albanito et al. (2020): to illustrate one, the increase of compound feed in a Lithuanian case study brought on the one hand to benefits (e.g., increase in the net farm income and in labour productivity), but on the one hand led to a worsening in species diversity and water quality. Examples of functions that could be quantified with indicators are given in Tables 3 and 4 and possible indicators are in a dedicated MIXED deliverable (Zolltisch et al., 2021).

Table 3. Example of observable functions related to sustainability at different levels. Functions might represent costs or benefits. Costs (indicated in the table with (-)) represent quantities to minimize (the higher, the worse) to minimize; benefits (indicated in the table with (+)) represent quantities to maximize (the higher, the better).

	Environmental	Economic	Social
Farm	Soil water retention (+); Soil carbon (+); greenhouse gas emissions (-); nutrient losses (-); pesticide use and toxicity (-); biodiversity (+).	Making loans that are future-oriented (+); Net Present Value (NPV) (+); Return on Investment (ROI) (+);; profit of the farmer (+).	Animal welfare (+); work-life balance (+); average working salary (+); women empowerment (+).
Landscape	Ecosystem services provision (+); Nutrient circularity (+); Landscape connectivity (+); Nutrients in water (-); Manure transferred outside the region (-). *Also the functions related to the farm apply here.*	Increased exchange of resources among farmers and other actors (+); shared ownership between farmers and stakeholders (+); locally embedded production relations (+).	Creation of skills and know-how in the region (+).
Value chain	Environmental footprint of the whole value chain (-).	Integration of the value chain (+).	Adaptation to consumer demand (+).

Country/Europe	Ensuring a production within the planetary boundaries (and restoring them); Nutrient spillovers (-); water quality (+).	GPD per capita (+); supporting circular economy (+), food sovereignty (+)	Equity in income distribution (+); labour conditions (+); social freedom index (+); securing good labour conditions (+); improved aesthetic conditions in landscapes and secure local communities (+).

Table 4. Example of observable elements related to efficiency and resilience at different levels. Functions might represent costs or benefits. Costs (indicated in the table with (-)) represent quantities to minimize (the higher, the worse) to minimize; benefits (indicated in the table with (+)) represent quantities to maximize (the higher, the better).

	Efficiency	Resilience
Farm	Profitability (+); the extent to which resources are not wasted (+); Diverse economically profitable production per input unit (+)	Ability of the farm to cope with disturbances (+); feed self-sufficiency (+); perception of the farmers about their own resilience (+).
Landscape	[Same as above but transferred to the landscape level]	Diversity in farming types (+); feed self-sufficiency at the landscape level (+); connectivity among actors in the landscape (+).
Value chain	Minimization of waste (+)	Flexibility/adaptability (+); easiness for the farmers to change outlets (+); Capacity to face certain supply issues (+); level and quality of relationships among actors including with farmers (+).
Country/Europe	Extent to which resources are not wasted at the country /Europe level (+); Securing economic development and support of current and future MiFAS (+)	Ability to create an environment that facilitates resilience at lower levels (+); Ability to understand the relationships among actors (e.g., among farmers and value chain actors) (+); capacity to adapt the policy to new situations (+).

5 Mapping the MIXED project in the framework

The internal coherence of the framework within the MIXED project was tested during the second MIXED annual meeting held in September 2021. The framework was presented to all the consortium and then, all the participants were invited to map the project tasks on the framework. The procedure was facilitated with a virtual board. All the tasks of the project (except some which are related to other project activities) could find their place in some parts of the framework, either on the transition or in the evaluation dimensions. This good outcome served to confirm the robustness of the framework in relation to the MIXED project and the procedure served to the consortium for familiarizing with the framework.

Results of the procedure are exposed as follows. The parts of the framework were numbered as in Figure 2, specifically: zone 1 referred to defining current systems; zone 2 referred to assessing the transition to desired systems, including the discussion or identification of enablers, barriers, as well as strategies to reach desired systems; zone 3 referred to the conception and definition of possible alternative systems; zone 4 referred to the application of the evaluation tool (with different methods) to current systems; zone 5 referred to the application of the evaluation tool (with different methods) to possible target systems; zone 6 referred to making the evaluation tool operational, i.e., defining methods, procedures, indicators for evaluating different dimensions of sustainability, efficiency, and robustness. Tasks were often related to more than one part of the framework. In addition to this, we also recorded the level(s) addressed for each task as well as the main method(s) implemented. Also in this, tasks could be referred to more than one level and could implement more than one method.

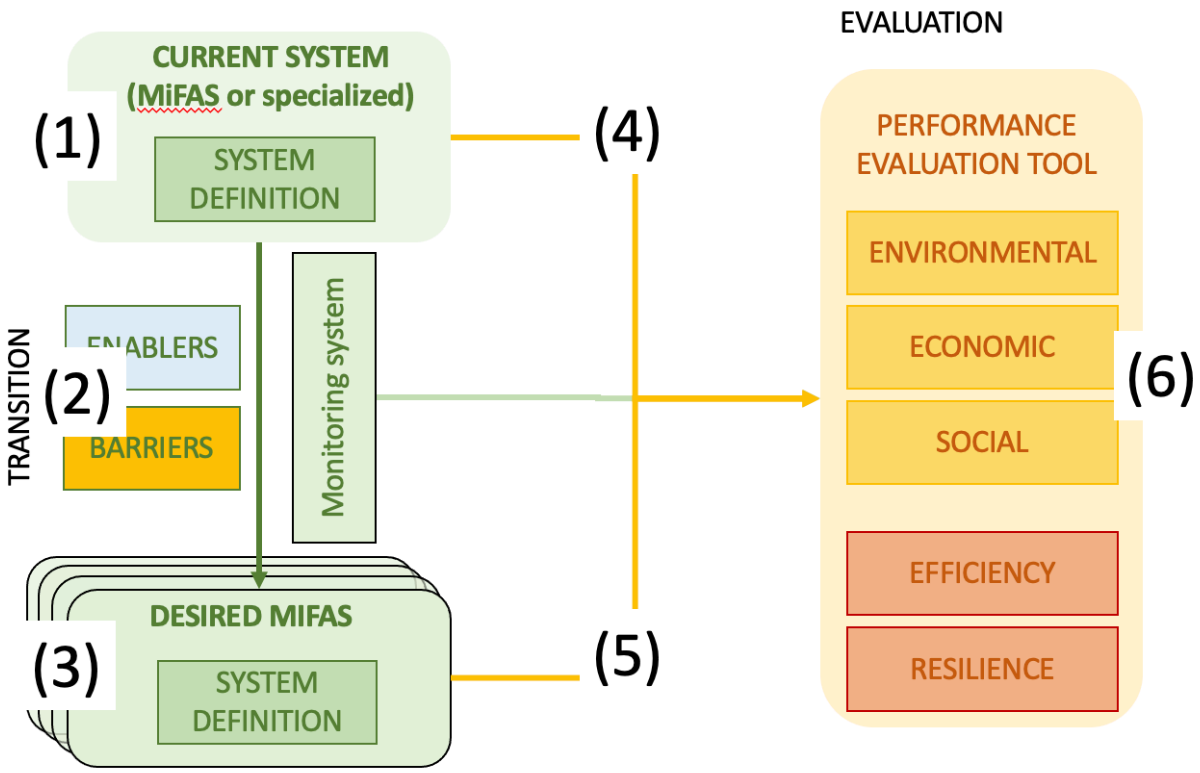

FIGURE 2 - Framework with the different parts identified for the task mapping exercise.

Some tasks are not specifically referred to the framework as they act on a more abstract level or on non-related topics: T1.1 and T1.5 are about facilitating and monitoring workshops of all the project; T3.1 is about organizing a workshop with sister projects and doing a literature review; T6.1 is focused on building and defining the framework itself; all the tasks of WP7, WP8, and WP9 are not related to the framework.

Table 5. List of the different tasks of the MIXED project in relation to the framework (see legend in footnotes).

Task n.	Task description	Zone[1]	Notes	Level[2]	Dimension[3]	Method[4]
T1.2	Backcasting workshops,	1;2	Assessment of current situation of MiFAS in Europe and identifying barriers and enablers to MiFAs at the national/regional level within countries.	Country	-	P
T1.3	A dynamic learning agenda	2;3	Identifying existing problems towards desired MiFAS. It is a bottom-up process that matches solutions from other contexts to the problems that form barriers.	Farm	-	P

T1.4	Solving open problems	2	Discussing strategies for moving towards desired systems. As T1.3, it is about identifying solutions and creating enablers.	Farm	-	P
T2.1a	Participatory design of MiFAS systems	1;3	Within participatory workshops current systems will be characterized and possible target systems will be co-conceived.	Farm	-	P
T2.1b	Quantitative and qualitative analysis of the scenarios designed	5;6	Performance will be evaluated in co-designed scenarios with the help of a modelling tool and qualitative assessments.	Farm	All	P;M
T2.2	Handbook of indicators	6	The handbook of indicators makes the ET operational	Farm	All	DC-N
T2.3a	Farm management data collection and collation	4	Semi-structured interviews to collect farm management, technical, and economic data.	Farm	ECO	DC-L
T2.3b	Quantitative and qualitative analysis of MiFAS at the farm level	4	Uses network data to characterise MiFAS in relation to ecosystem services provision	Farm	ENV	DA-L; DA-N
T2.4	Field testing strategies for increased integration	2,4	Collects data from innovation studies (existing MiFAS), this will lead to increased understanding of relationships among dimensions of the ET. In addition, the task helps to identifying and understanding interactions in systems that enable the transition.	Farm	All	DC-N
T3.2	An agent-based model of farm interaction in a landscape	1;5;6	A set of landscape scenarios are defined and simulated (different degrees of interactions among farms), with evaluation of results (5,6) and with also results at the farm level. The model serves also as system representation of the current situation (1).	Landscape; farm	All	M

T3.3	Mapping mixed landscapes in Europe using existing data.	1;4;6	Representation of mixed landscape in Europe using spatially distributed data. It is about system definition. Some evaluation can also be done.	Landscape	-	DC-N; DA-N; M
T3.4	Lansdcape scale impact assessment and solution scenarios	1;5	Application of the agent-based model to some networks and evaluation of performances under future scenarios.	Landscape	All	M
T4.1	Adapting the LCA methodology including integration of carbon sequestration	6	Focused on making the evaluation tool for value chain under environmental aspects.	Value chain	ENV	LCA
T4.2	Environmental impacts of products in the MiFAS value chains.	4	Focused on evaluating existing value chains on the environmental point of view, including carbon sequestration.	Value chain	ENV	LCA
T4.4	Governance in the value chain	2;4;5	Social network analysis in current value chains and discussion about scenarios. Also deals with drivers and barriers, pros and cons in terms of the social collective action.	Value chain	SOC	P
T5.1	Farm level assessment of MiFAS within networks	4;6	Uses data to assess strengths and weaknesses of farm performances	Farm	All	DA-N
T5.2	Specific labour demands and availability within MiFAS	2	Targets the identification of labour specific challenges in MiFAS and solutions for overcoming.	Farm	-	P
T5.3	Landscape level participatory game development	2;3;5;6	The participatory game will make the ET operational (6) and, at the same time it will make it possible the conception of possible target systems (3), with the discussion of the transitions to them (2) and their evaluation (5).	Landscape	All	P
T5.4	Modelling and assessment of the performance of future MiFAS systems.	5;6	Simulating and evaluating scenarios of MiFAS	Farm	All	M
T5.5	Development of an agro-forestry decision support tool	6	Focused on making the ET operational for agro-forestry systems for future scenarios in order to support decision-making.	Farm	All	M

T6.2	Efficiency and resilience assessment at farm level	3;5;6	The task focuses on defining resilience and efficiency assessment at the farm level and application to case studies. This will lead to identification and evaluation of optimized future farm configuration.	Farm	RES; EFF	M
T6.3	Upscaling of efficiency and resilience analysis to community, regional, national and EU level	3;5;6	The same concepts of T6.2 are brought up to larger levels.	Landscape; Country; EU	RES;EFF	M
T6.4	Assess the role of policy instruments in transition scenarios	5	Focuses on assessing the performance under different policy scenarios	Farm; Landscape; Country; EU	All	M

[1] Zones of the framework are represented in Figure 2 and better described in the text

[2] Levels could be Farm, Landscape, Value Chain, Country, EU.

[3] The column refers to the dimension of the performance evaluation tool. The cells are filled as follows: “All” in case the task does not refer to a particular dimension; “ENV” for environmental; “ECO” for economic; “SOC” for social; “EFF” for efficiency; “RES” for resilience. The cell is left blank if the task is not focused on the evaluation.

[4] The column refers to the method(s) used in the task. The cells are filled as follows: “DC-L” for Data Collection (quaLitative); “DC-N” for Data Collection (quaNitative); “DA-L” for Data Analysis (quaLitative); “DA-N” for Data Collection (quaNitative); “M” for Modelling; “LCA” for Life Cycle Analysis; “P” for Participatory approaches (workshops or interviews with stakeholders or experts).

6 Conclusions and next steps

Comparing and analysing the possible transitions to MIFAS in Europe at different levels requires transparency in the main concepts as well as in the interrelations among them. The framework presented in this deliverable is a first attempt of putting the necessary theoretical concepts useful for the MIXED project in relation with one another. Among the originalities of the framework there is the effort of defining MiFAS and conceptualising transition and performance at different levels as well as putting in relation the concepts of transition with the concept of system evaluation accounting for the different dimensions. This framework was the outcome of a series of discussions internal to the MIXED project, bringing views from multiple disciplines and multiple parts of the project. We acknowledge that the definitions given here and their inter-relations might change along the course of the project and the framework can be enriched with additional concepts. We also acknowledge the existence of a set of open questions, such as the definition of landscapes. As a first step, this framework is a very useful tool for promoting the dialogue within the project, but it will be kept open to further discussions and modifications.

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