Report on the assessment of the farm-level financial and socio-economic performance of selected MF/AF systems

Deliverable D5.1 – v.4

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

Actors within the agri-food systems face risks due to changes in the climate, market, regulation, and socio-ecological conditions. The portfolio of functions maintained within Mixed Farming and Agroforestry (MF/AF) systems should help minimise risks. The objective of T5.1 is to understand the current diffusion of MF/AF as well as their socio-economic performance by using secondary data (i.e., FADN), giving the first characterisation to what extent MF/AF can contribute to the sustainability of agri-food systems at farm-level across Europe.

The theoretical model framing the MF/AF into the socio-technological system will be able to describe the simplification VS complexity decision making.

Our data show that de-mixing (a reduction of complexity, diversity, and mixed systems) is ongoing in many parts of Europe. The picture is, however, itself more diversified than assumed, with some areas getting still de-mixed, which were previously highly mixed (Eastern Europe), while others are, according to our data, not de-mixing and, on the contrary, gaining complexity and diversity, e.g., parts of Greece, Northern Portugal, Alpine/mountainous regions, certain European islands.

Our empirical analysis shows difficulties in classifying the MF/AF using the FADN data due to: a) adaptation of existing economic criteria to the system complexity of MF and b) the lack of data on the integration of forestry and agricultural practices; c) the lack of data to better understand forward supply chain integration. Due to their contribution to sustainability and CO_2 emission mitigation, expanding attention to these systems would require advances in the FADN data collection procedure. The report proposes a classification based on an integrated system that can be used for the convention on Farm Sustainability Data Network for MF/AF.

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2 Expected impact

The D5.1 is developed in task 5.1. The D5.1 Report on assessing the farm-level financial and socio-economic performance of selected MF/AF systems aims to generate several impacts that can be summarised in the following points.

Macro and micro-level variables have been identified to conceptualise diversification and Mixedness. Simplification VS Mixedness have been conceptually framed within a timeline (past, present, future), specific contexts, and socio-technical-ecological systems. This is relevant input as the knowledge on key performance and diffusion of MF/AF and their socio-economic performances. This conceptualisation is useful to frame all tasks of WP5 and to expand AGROMIX D1.1 (Püttsepp et al., 2021) with the inclusion of supply chain elements and dynamics of socio-technological systems.

The empirical analysis has described the different patterns of evolution of MF/AF. On the one hand, details of Value chain aspects affect the diffusion and performance of MF/AF, but the results need to be integrated with local knowledge. Through stakeholder interaction within 12 in-depth pilot projects across Europe and the policy workshops the AGROMIX project can provide further insight into how to in-depth interpret the data coming out of the FADN analysis.

Policy strategies, analysis, and discussions about sustainability have been enriched by contributing to the improve existing FADN infrastructure. The deliverables have also identified existing data needs to support the transition to FSDN. These data needs require better data collection to understand integration and complexity in the farming system. The analysis claim that to better understand the evolution of the Mixedness of farm need to integrate spatial data analysis (i.e. LUCAS) with structural and productive factors information as well as better understand the income information. Our results have been used to submit evidence-based comments on the EU initiative "Have your Say: Conversion to a Farm Sustainability Data Network (FSDN)"

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3 Context and objectives of WP5

The AGROMIX research project provides practical agroecological solutions for land use in Europe, focusing on two main agricultural systems: mixed farming (MF) - i.e. annual rotational crops and livestock - and agroforestry (AF) - i.e. trees and crops and/or livestock. The project has six specific objectives:

1. To identify solutions (through participatory research) that unlock the full potential of synergies between crop, livestock, and forestry production (fruits, biomass) at the farm level, and/or between farms (local, landscape-level), including a better understanding of those factors that can contribute to increase the environmental resilience of MF/AF systems and implement effective on-farm climate change mitigation and adaptation strategies;
2. To analyse the complexity of obstacles (e.g. infrastructure gaps) and enabling factors (e.g. governance) and develop, refine, and promote MF/AF-adapted value chains and infrastructure solutions that will ensure income stability and increase socio-economic and environmental sustainability among different agri-environmental and socio-economic contexts;
3. To develop a toolkit and co-design approach for mixed systems that will allow for modelling, testing and assisting farmers, land managers and other actors in the implementation and monitoring of smart solutions for real farm and landscape management with recommendations for climate-resilient agroecological systems, including risk assessment, for conventional and organic systems in Europe;
4. To identify and model key transition scenarios and trade-offs in climate-smart land-use systems, value chains and infrastructure at different spatial (farm, case study, regional, system levels) and temporal scales to inform post-2020 CAP development and identify best policy options;
5. To develop policy recommendations and action plans for a successful transition;
6. To maximise the impact and legacy of the project for building low-carbon climate-resilient societies through participatory co-design of solutions and knowledge distribution.

Objectives 1, 2, 4 and 5 are key for the development of WP5, which focuses on the socio-economic analysis of MF/AF at the farm, landscape and, value chain level. Within WP5, D5.1 the farm-level financial socio-economic performance of selected MF/AF systems, D5.2 provides a report and EIP-style factsheets on the characteristics of successful Value-Chain Networks (VCNs), D5.3 is about the acceptance, institutional barriers and conditions to the adoption of successful and improved VCN approach, D5.4 reports integrated economic, and life cycle assessment of the impact of specific policy instruments to support MF/AF farming systems and VCNs, and D5.5 provide guidelines for successful MF/AS value chain networks to inform the policy debate.

This report (D5.1) assesses the pan-European diffusion of MF/AF and their socio-economic performance (in terms of income, income stability, efficiency, market stabilisation, and employment) by using FADN 201X-2020. A methodological section in which we introduce a preliminary conceptual framework (CF) developed within this first task, and the other relevant methodologies applied to analyse the FADN database follows.

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Since the CF is expected not only to conceptually structure the T5.1 work but to enlarge supply chain consideration to the farmer decision making, also the findings obtained by the subsequent tasks, providing also a backward link with T1.1 *Resilience framework and working definitions,* and a forward connection with T6.1 *Global inventory of current policy contexts, instruments, and operational means for the support of Mixed Farming and Agroforestry systems (MF/AF)*, we introduce here the overall preliminary conceptualisation and those components related with T5.1. At the same time, we will analyse and expand the remaining components in the other deliverable following task results.

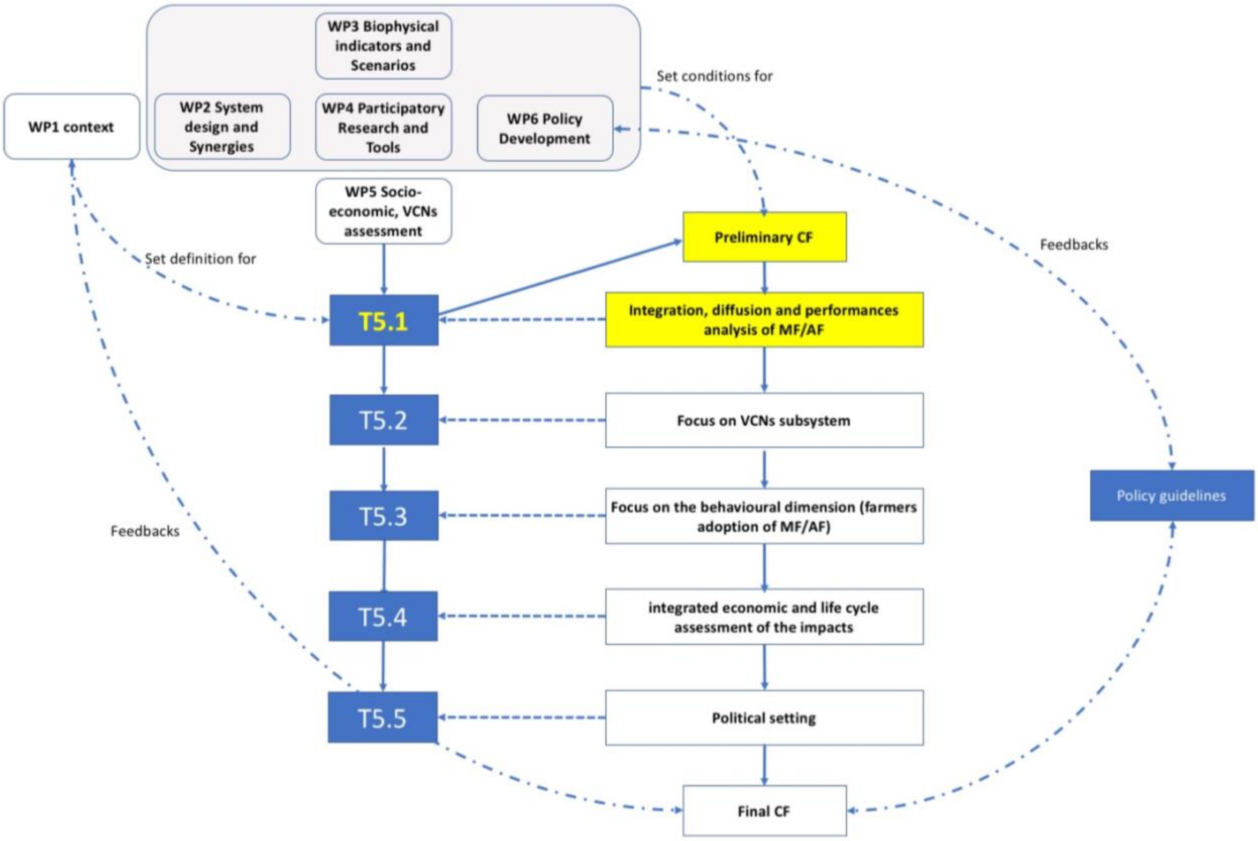

Fig. 1 Relation with CF components and WP5 tasks and linkages with other WPs

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4 Conceptual framework development

The Conceptual Framework (CF) is a preliminary map that provides the nexus for the financial and socio-economic implications of MF/AF and related VCNs at different scales (farm, supply chain, territorial) and practical guidance for researchers, practitioners and policy-makers interested in understanding the nature and complexity of different markets, business models as well as identify enabling factors, potential barriers, and infrastructure needed to co-create sustainable and resilient VCNs.

The CF builds upon the AGROMIX concepts and further elaborates on the T1.1 Resilience framework and working definitions, with relevant scientific literature through a systematic review process, and with findings from some other relevant AF/MF and resilience related EU research projects. These projects include (non-exhaustive): AGROFORWARD, CANTOGETHER, SUREFARM.

The CF will be one of the first attempt to integrate literature from ecological system with emerging concepts of farming system and supply chain relation. Therefore, we elaborate the CF on the key concepts of AGROMIX (see T1.1) i.e. Agroforestry; Mixed-Farm; Transition; with element of Supply chain at multiple levels on which it adds a new blending and distilling of ideas, concepts, and theories from multiple natural and social science disciplines with system integration, recoupling, individual and collective behaviour, patterns of interaction, spatial change (i.e. coexistence, complementarity, local and territorial synergy), redundancy, modularity and diversity. These concepts are set in relation to the adoption, implementation and performance evaluation of MF/AF practices and related VCNs. Therefore, the CF will be able to frame the rich literature of agroforestry, and mixed farming in a system perspective to identify how resilience is framed at the different levels (i.e. farm, landscape and value chain). Although the broad scope, the CF will be suitable to understand farmer perspectives by looking at different drivers enabling them to explain the core farm decision about simplification and forward integration with other supply chain actors versus the developed complexity of farming practices and Mixedness.
After the explanation of each concept, where relevant, we provide the implications for empirical analysis using FADN data. Thus, the CF becomes a basis to guide methodological decisions, data analysis and implementation of the WP5 activities. Indeed, we introduce here in this first deliverable a preliminary structure of the CF and the component related to the objective of the T5.1 analysis then the remaining part will be analysed in the further task and reported in the final deliverable D5.5 with a fine-tuned version of the CF guiding the policy arena. Accordingly, the CF is continuously updated and developed during the project lifetime.

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4.1 A Socio Technical Ecological System (STES) perspective for MF/AF and VCNs

4.1.1 MF/AF practices

MF/AF are land-use practices that combine - besides production - ecological (interaction between species, biodiversity, climate change regulation services, soil erosion balance, etc.) and cultural elements (landscape, recreation).

According to Püttsepp et al., (2021) Handbook of resilience and working definitions, the term agroforestry defines a range of "*land-use practices widespread in Europe where woody perennials, animals and / or crops are managed in one combined system*".

Two key elements emerge from the different definitions that populate the literature, the association of the term to a coupled human-natural system and the intrinsic diversity that links them, allowing the systems to provide all main types of ecosystem services, provisioning, regulating, cultural and supporting (MEA 2005).

The Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 defines agroforestry systems as "*land-use systems in which trees are grown in combination with agriculture on the same land*". This first definition sets the general scopes of the AF practices rather than delimiting the boundaries and functions of AF at farm level (operationalise the concept). In fact, the regulation then continues by defining that "*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*". However, the Measure 8, Article 21(1) (b) and 23 of Regulation (EU) No 1305/2013 "*Establishment of agroforestry systems*" shift the focus from agricultural systems, and introduces a spatial delimitation or a reference with the farm level by indicating the "*land management uni*t". Here 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). However, the boundaries of these land management units remain rather general, and the problem of a specific attribution of these systems or practices at the farm level, which is useful for applying policies in the various European territories, is therefore probably postponed to the national legislator. As we will deepen below in the analysis of the pan-European diffusion of MF/AF, such difficulties in defining these systems affect the needs of measuring and evaluating performances, at least with current European data sets like FADN.

The reference to a land-management unit is also employed in the FAO definition, where "*Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, ... etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. [...] there are both ecological and economical interactions*

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between the different components". While FAO mentions the technological dimension, however, it does not entail the same importance as the technical one, which is used to define at least three type of AF systems, namely: *silvoarable* - combine crops and trees, *silvopastoral* - combine forestry and grazing, *agrosilvopastoral* - integrate crops, scattered trees, animals (grazing).

In the extended definition of the FAO as well as the one applied for the EU FP7 AGFORWARD project by den Herder et al. (2015) emerges both the theme of integration and dynamic interaction among human-natural systems, considering respectively AF "*as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels*" and as "*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*". In particular the FAO in its approach to the topic introduces also a critical scale for this system qualifying a sort of optimal management unit (i.e. small farms) when states that "*agroforestry is crucial to smallholder farmers and other rural people because it can enhance their food supply, income and health*". All these definitions support the importance of human intervention in these systems. With regard to MF the AGROMIX definition provided in Püttsepp et al., (2021) mirrors the AF definition of den Herder et al. (2015), by defining "*integrated crop livestock systems (ICLS) to benefit from the resulting ecological and economic interactions*". Here we found again three key concepts: a) the complexity of a system that is expressed through diverse human-nature linkages, b) the integration and therefore c) the interaction between the components of the system. Although the MF boundaries appear even more blurred than in the case of AF, an exception exist and is represented by the quantitative attempt - at least from the economic point of view - to consider that in MF livestock and crop production should 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). This definition is in line with the definition provided by Eurostat, which indicates that a MF refers to an activity where neither livestock nor crop production is the dominant activity, where a dominant activity should provide at least two-thirds of the production or the business size of an agricultural holding (so one-third again qualify the MF).

The Püttsepp et al., (2021). describes MF/AF as an integration of different farming components and based on that we can consider as a simplification of the pursuing of a farming system based on a single farm specialisation which can be either livestock or arable or tree. Therefore, at the opposite, the complexity is due by a certain integration of different farming system toward a mixedness of specialisation such as arable agroforestry or silvopastoral or mixed farm or agro-silvopastoral system.

4.1.2 Defining VCNs

According to Porter's term, Value chain (VC) is linked to its multidimensional nature - i.e. through an intermediate perspective that allows grasping both the micro aspects and variables of firm and organisation processes and the macro level of the broader economic system - and versatility across different disciplines -

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i.e. in firm management and organisation literature the focus is on the analysis of competitive management and coordination in the supply chains, while in development theory it is used to frame structural or geographical changes and related policies (Moretti et al. 2021).
At the micro or local level, the concept is often associated with the organisation of various technological production "steps" to develop innovative products - e.g. high-valued by-products from traditional crops thanks to new knowledge and processing technologies. Accordingly, the VC can be defined as:

> *"series of steps from the initial production to the final consumption and the actors involved at each stage. The activities/operations of these agents are geographically localised. They identify products, financial and information flows between actors and areas" (European Commission, 2018)*

The concept is often declined between internal, local and global levels to frame new forms of organisation and coordination between companies of innovative food systems, i.e. short food supply chain (Galli et al., 2015). The point of convergence among these different backgrounds concerns the study of the "vertical" forms of coordination and trade between firms and networks of firms, from which a second definition can be deduced:

> *"the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer" (Christopher & Peck, 2004)*

Both definitions consider a different degree of combination (transformation) of the most relevant characteristics of the VC, like the actors (organisation), the operations (steps), and the linkages between them (flows of input, output, information, and values) qualifying the VC as a new object, the Value Chain Network whose ultimate purpose is to add (extract) value to the exchanges that can occur in both directions from downstream to upstream or vice-versa.

Since AGROMIX focuses on specific agricultural practices that have a positive impact on the natural environment, strengthening the sustainability and resilience of farmers and rural communities (Altieri et al., 2015), from now on, we refer to **sustainable business models**, where the social-economic, technical, and geographical dimensions are integrated and interact within the environmental one, allowing for new and complex configurations of land use and related resources, including culture.

The portfolio of functions provided by MF and AF systems and related VCNs can contribute to achieving a transition towards more sustainable land use and resource management models, as the main expected benefits – relative to conventional practices – are the provision of positive externalities on biodiversity, water, soil, landscapes and climate change, and a positive contribution to income stability and rural viability. Accordingly, we do not limit our analysis just to the vertical dimension (use of the resource-products-consumption) that in the VC literature leads to "specialisation", but we will try to understand: a) *how the VCs can be framed in a social-ecological system perspective (Turner, Matson, et al., 2003) among different **patterns of interaction and spatial change** generated by MF/AF practices at different scales following*

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horizontal models of complementarity, coexistence, and synergy, and b) *what are the main implications of this reorganisation in terms of sustainability and resilience for the whole system (**recoupling**)*.

4.1.3 Diversification and Mixedness in socio-technological and ecological system

With respect to the objects of our analysis, we can now stress some points of convergence, like the system perspective, the coupled human-nature system, diversity, integration, interaction, and the presence of multi-scale dimensions. All these characteristics urge us to deem it appropriate to build on the concept of **Socio-Ecological-System** (SES) (Partelow, 2018; Ostrom 2007, 2009) to explore, model and assess such complex social-ecological interaction and related outcomes. The SES is defined (Turner et al., 2003; J. Liu et al., 2007) by the coupled presence of human and natural systems, which are nested across different scales (Berkes & Folke, 1998). These complex and interdependent systems are formed by nested components (sub-systems) that are related to each other at different levels (McGinnis & Ostrom, 2014; Ostrom, 2009). The concept incorporates the dual relationship between people (the social system) and ecosystems: people shape ecosystems according to a set of norms and rules (Elinor Ostrom, 1990) but at the same time, they are dependent on the capacity of ecosystems for the services they provide for the achievement of societal needs (e.g. supply of food, fibre, energy, and drinking water).

Compared to the classic framework for SES, we introduce two main elements of novelty here. The focus on VCs that are considered as a backbone of new modes of production and organisation of the social system that largely interacts with nature, and the shift toward innovative practices such as MF/AF. Both generate enhanced connections with ecosystems, leading to a more diversified **Social-Technical-Ecological System** (STES) whose key component is represented by the **VCN** (Fig. 2).

Then, given the recent advances in exploring and modelling complex social-ecological interaction in coupled human-nature systems (Grêt-Regamey et al., 2019; Filatova et al., 2016), we extended our representation to combine concepts from different frameworks for analysing agroecological transition (Holling 1973; Gunderson et al. 1995; Ostrom's 2009), comprising resilience thinking (Meuwissen et al., 2019), a behavioural dimension that represents the actors' decision-making (DM) in the adoption of sustainable farming practices (Dessart, 2019), and the characterisation of the system integration through the transformation towards sustainable business models, which we define "recoupling" to emphasise the opportunity of re-design the close human-nature relationship by nudging savvy behavioural and organisational changes. The approach can also be considered as a first attempt to frame the linkages and dynamics between the social and environmental patterns of changes, and to unlock how such changes can influence the achievement of sustainability goals across different systems, levels, and scales (Berkes and Folke 1998, Liu et al. 2007, Fischer et al. 2015).

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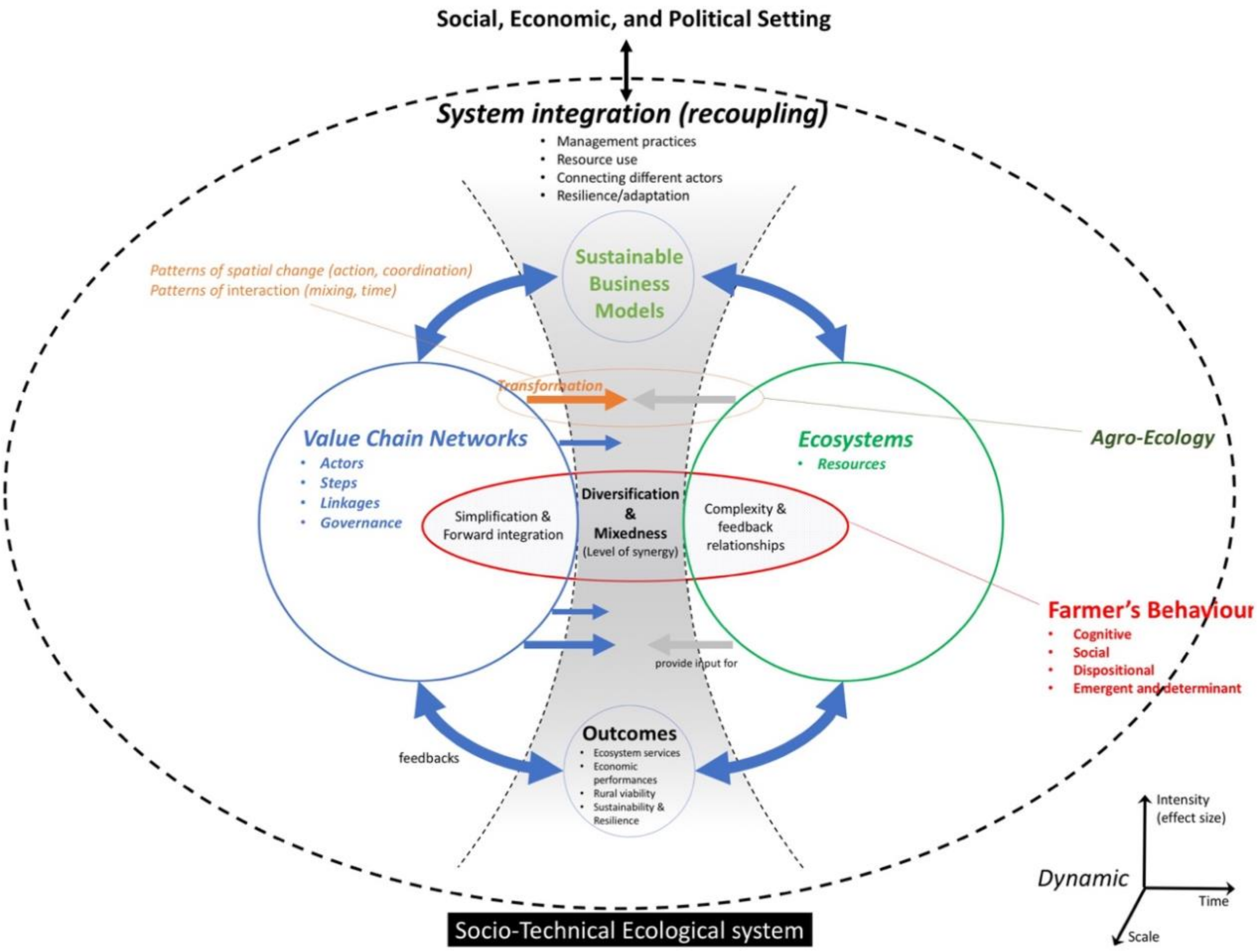

Fig. 2 The Socio-Technical Ecological system overview (authors elaboration).

In line with the importance of human intervention in this system, we assume a core position of the behavioural dimension through DM (red central set), representing the engine of the positive or negative transformation process of the whole STES.

The DM model, as well as the adoption choices, will be explored and deepened in T5.3, here, we just aim at introducing and framing the concept within the CF. It is worth stressing that with farmers' decisions to adopt innovative and sustainable practices (MF/AF) we primarily focus on those less frequent business decisions that involve large investments and long-term personal and economic commitment, including those extra efforts, and hence costs, to manage the increasing diversity and complexity introduced by the shift toward MF/AF.

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4.1.3.1 Behavioural factors

According to Dessart et al. (2019) we grouped the behavioural factors that exert a certain influence on farmers' decision toward Mixedness into four clusters:

- **Dispositional** (personality, resistance to change, risk tolerance, moral and environmental concern, policy options)
- **Social** (descriptive norms, injunctive norms, signalling motives)
- **Cognitive** (knowledge, perceived control, perceived costs and benefits, perceived risks)
- **Emergent and determinant** (observed patterns of change)

Moving forward, concerning the sub-system of VCNs that will be analysed in detail in D5.2 "characteristics of successful VCN", according to our definition this is made by actors under different steps providing linkages within different components of the social system and the ecosystem. Thus, just focusing on the sub-system characteristics (non-integration), with regards to the steps for Kumar and Kumar Singh (2021), there are five major components: farming, post-harvest activities, food processing, distribution, and retailing, and consumption. Tsolakis et al. (2014) provide a more specific design by including farming, processing/production, testing, packaging, warehousing, transportation, distribution, and marketing, while Ivanov (2020) includes in its framework for Viable Supply Chains also the 'governance level' and characterise the network components across organisational, informational, process-functional, technological, and financial structures.

Suppose we connect an optimal combination of these structures with the behavioural dimension (left intersection area of Fig. 1). In that case, we find two main strategies that can characterise the DM, i.e. simplification and forward integration. These strategies define a key feature of VCN, which is the ability, leaden by economic efficiency and localisation, technological, information and financial advantages, to relocate steps and services where marginalities allow for a greater added value, thanks to increased connectivity across phases, and control or limit the related organisational, coordination, information, and production costs.

- *Forward integration is a version of vertical integration that involves acquiring or adopting actors, functions or activities further downstream of the focal chain actor in order to reduce risk and generate higher income (Chang and Iseppi, 2012; Del Prete and Rungi, 2020). It involves an extension of production activities to other activities in the value chain, and advocates for large scale, and where the technical specificity can be covered by large capital investment, i.e. processing and packaging (Aneani et al., 2011; Barghouti et al., 2004; Kray et al., 2018).*

While the implementation of these strategies can drive an increase in the competitiveness and added value generated by the system (Gibbon, 2001; Humphrey and Schmitz, 2002; Sexton et al., 2007), it also leads to an intensified conversion of natural resources into simplified production phases, driving the displacement of

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social, environmental, and economic impacts (Wiedmann and Lenzen, 2018; Del Prete and Rungi, 2020; Traversac et al., 2011). Consequently, in this extremely specialised and simplified sub-system we assume the coordination among steps at spatial level to be characterised by coexistence across the VCN actors with the possibility of products exchange (see Fig. 3 below). This configuration is the most vulnerable due to lack of integration and the self-oriented interest of the actors or organisation of the VCN.

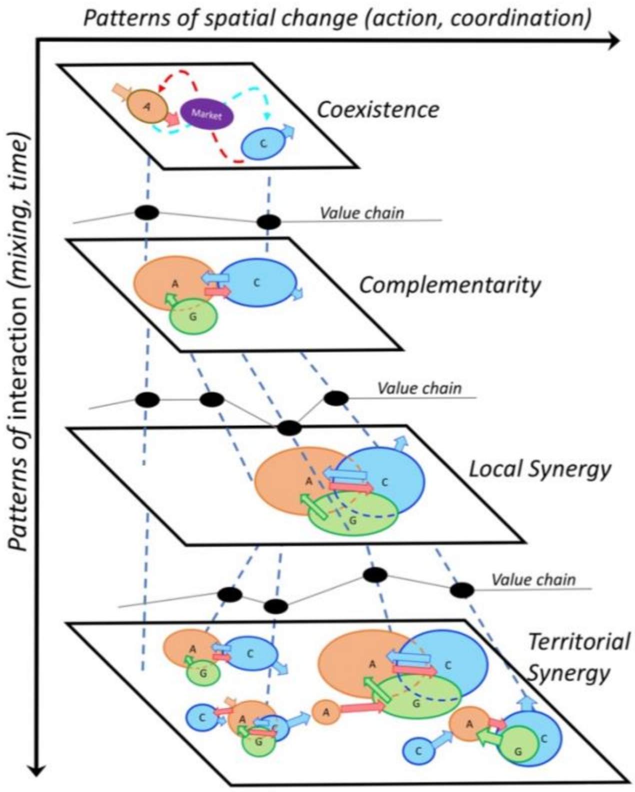

Fig. 3 Spatial configurations within the integration process of VCNs (authors elaboration on CANTOGHETHER project results).

4.1.3.2 Transformation and Resilience

While integration represents a property of the system, transformation represents a state of the system, because part of it is transforming, and according to our expectations, it can be desirable if towards greater sustainability. Both concepts are built to be correlated since we look at those transformations leaden by the integration process that occurs through the adoption of agroecological practices. Indeed, the strong conception of agroecology we refer to, requires extensive change and not just marginal technical adjustments to reach more sustainable agriculture (Ollivier et al. 2018). Such changes are related to agricultural practices, the organisation of production and distribution, the nature of technologies used, and last but not least a different consideration for the role and identity of "farmer" (Hill and MacRae 1996, Francis et al. 2003, Lamine 2011, Nicholls et al. 2016). In other words, it also implies cognitive aspects (IAASTD 2009)

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that can be considered only by shifting towards a different conception of the human-technology-environment situation (Plumecocq et al. 2018).

- *The object of transition is a Social-Technical-Ecological System (STES). This system is integrated because (parts of) it goes through a process of integration.*
- *The meaning of integration that we use in the CF goes beyond the purely economic concept of forward integration (a company buys another company of the type that it supplies goods or services) or vertical integration (a situation in which a company controls the supply of goods and services it needs by buying the company that supplies them).*
- *Here and after we use "system integration" or just "integration" with the meaning of a process that combines the social sub-system (i.e. VCN) with the natural one (i.e. the ecological system). By bringing multiple aspects of human-nature interactions together the result is increasing interconnectivity and complexity among sub-systems with a greater effort of actors, organisations and supply chains, and hence costs, in coordination and sustainable management of value flows (information, matter, and energy). With respect to a potential increase in costs, which is inevitable by embracing strong sustainability goals, the focus becomes how the final value generated can be granted and redistributed during the transition to a highly integrated STES. Equity and transparency are fundamental to secure the entire process.*
- *Accordingly, integration is meant along behavioural, organisational, spatial, and temporal dimensions to avoid that sustainability solutions in one system cause deleterious effects in other systems. Along the behavioural dimension, the integration occurs by nudging and influencing savvy and tailored behavioural change so that decisions are taken in order to reduce human impacts at local to global levels. Then, organisational integration can contribute to assigning value to natural components for humans, again reducing impacts, and promote fair exchanges. Spatial integration can foster landscape planning for ecosystem services, promoting synergies at the territorial level among different land use and allowing for coordination across space. Temporal integration is key to quantify the system boundaries, predict fluctuations in resource stocks and ecological processes or reveal legacy effects of prior human-nature interactions.*

Against this background, one key point distinguishes our framework from the SES literature (Ostrom, 1990). The actors are the fulcrum of our speculation but not as such, or for the type of stakeholder they represent, or for the degree of influence they exert on governance processes, but rather because we put in the foreground the role of cognitive dynamics in the human decision-making process. Although there is a relatively recent acknowledgement of the relevance of understanding behavioural factors at policy level, e.g. inclusion of behavioural evidence in the background documents of the European Union's Common Agricultural Policy (CAP) reform and in the related impact assessment (European Commission, 2017, 2018), at academic level there is an incomplete overview and limited theoretical understanding of the role of behavioural factors, i.e. how and why these factors affect decision-making (Prokopy et al., 2008) especially if we restrict the application on only those sustainable agricultural practices (Dessart, 2019). Thus, a further theoretical and empirically-grounded development of this field could benefit the future design of interventions that leverage the non-financial, behavioural factors that according with Dessart et al. (2019)

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"have a bearing on farmers' uptake of more sustainable practices". In addition, both the goal of greener, targeted and more effective (result-based) CAP (European Commission, 2017b, 2018b, 2018c) and the budgetary shift towards more voluntary approaches (i.e. Eco-schemes) could represent an opportunity that further justify a behavioural perspective. Therefore, instead of assuming a rational behaviour among actors to then analyse the role of incentives, organisations, institutions, as well as transaction costs and market strategies in explaining the interactions between farmers and their environment (current approach in most SES studies as well as other frameworks, and often statistically valid to account for producer choices), here we aim to a more refined understanding of actual (not hypothetical or normative) factors that influence farmers' adoption of sustainable business models such as MF/AF (Troussard and van Bavel, 2018).

- *We adopted the term 'behavioural factors' as in Dessart et al. (2019), where it is intended as synonymous of psychological factors – i.e. the cognitive, emotional, personal and social processes or stimuli underlying human behaviour (American Psychological Association, 2018c).*
- *The main idea is to harness behavioural insights (Dessart, 2019; Prokopy et al., 2008) within a much more realistic model of human decision-making to unlock how the social system can integrate with ecosystems, overcoming the current failure of conventional policy instruments (Shogren and Taylor 2008). Then, in line with SES literature, we aim at understanding how the condition and functioning in different sub-systems affect the actors' DM and consequently their performances (McGinnis & Ostrom, 2014; Ostrom, 2007; Ostrom, 2009).*
- *Since Human and natural systems interact in a multitude of ways along behavioural, organisational, spatial, and temporal dimensions, and also through their potential permutations, assuming human systems as solely responsible for the transformation (agency-based), the behavioural dimension becomes the centre of gravity for the entire integration process.*

In the STES, individual or collective choices shape the structure and functioning of organisations and related VCNs, and their objectives and impacts on natural resources. By understanding how behavioural factors affects the adoption of sustainable farming practices such as innovative business models like MF/AF we can design interventions that favour the conditions under which these models operate, leading to the improvement of land use, as well as to the provision of ecosystem services and ultimately increasing resilience.

By moving on the right of Fig. 1 on the behavioural set, we assume that the process of **integration starts** (grey area) where a **transformation** through a sustainable business model (MF/AF) occurs. For the VCN actors, this implies a change in management practices, resource use, and connections between the various players in the network. The behavioural change of farmers that adopt MF/AF is rooted in the ecological rationale through an incremental and transformational process that enhances functional biodiversity in crop fields and, consequently, supports resilience through the diversification of agroecosystems (Fig. 4).

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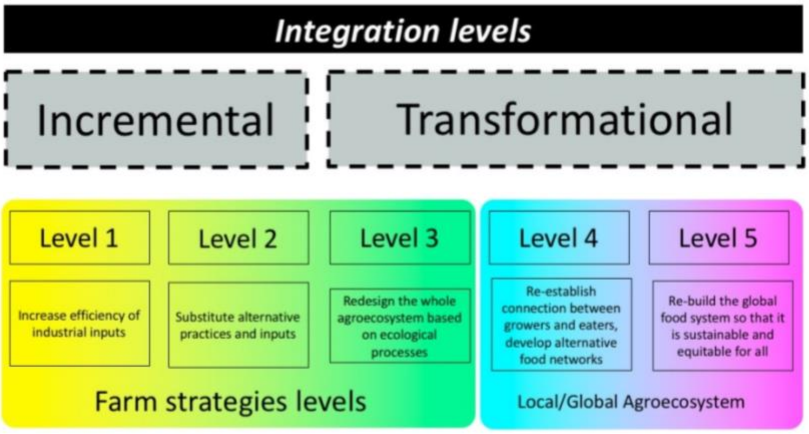

Fig. 4 Integration levels and farming/system changes (Based on Gliessman, 2016)

The diversification of the analysed sub-system (level of Mixedness) is regarded as more beneficial for increasing agroecosystem services (Kray et al., 2018) and is framed as an attribute of the integration process between the VCNs and the ecological system, resulting from the actors' decision-making process.

Diversification is intended here not only in economic terms (e.g. income diversification, market diversification, product and process diversification etc.), but rather as the result of farmers' actions within the VCNs that trigger specific combinations of the sub-system functional units (knowledge, technology, crops, animals, and trees) and leading to different patterns of spatial change (action, coordination) and of interaction (mixing, time).

- *Key determinants of the diversification process are the number of farms (actors richness) and the diversity of their behaviour expressed by the abilities and skills that characterise their management capabilities (actors' functional diversity).*
- *With behavioural factors, we can define actors' functional traits – i.e. farmers' management capacities, with their drives and motivations, and abilities and skills, characterising their DM and their interactions within the VCN.*
- *Biological diversity is known to enhance the resilience of ecosystems to environmental change. What we speculate is that a high diversity of socio-economical actors in the supply chain analogously can increases the capacity of STESs to maintain the provision of ecosystem services while undergoing socio-economic and climate changes. In analogy to the positive relationship between biodiversity and ecosystem functioning, several authors have demonstrated a link between the diversity of social actors and the resilience of coupled social-ecological systems.*

As the integration process takes place, there is a shift of the DM towards the acceptance of the greater complexity of the ecosystem (right intersection area). The transformation towards diversified agricultural systems that rely on biological processes rather than external inputs implies a re-design of the agroecosystem that affects the network with an increase in the number of intermediaries (Dania et al., 2018), coordination

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and collaboration instances. At the DM level, the resulting coordination implies more interactions among the VC partners to achieve the new (agroecological) goals by accomplishing the tasks jointly (Gulati et al., 2012). Coordination helps minimise the potential ambiguity associated with the change in routines, overcoming path dependency and lock-in effects by promoting effective problem-solving processes (Chounta et al. 2014), knowledge sharing, capacity enhancement, and information dissemination (Heimeriks and Schreiner 2002).

A growing body of academic literature deals with understanding farmers' resilience to cope with hazards (stress and shocks external or internal at farming system). The resilience concept, originated from ecological literature which explain changes in ecological systems, may have several interpretations: adaptation, robustness, exposure, vulnerabilities, among others (Cowan and Wright, 2014). Rose and Krausmann (2013) identify tree subsets of resilience pertaining to the economy: microeconomic (individual business model or household); mesoeconomic (individual industry or market); macroeconomic (combination of all economic entities).

There are two approaches in studying resilience "Bounce Back" and "Bouncing Forwards" (Darnhofer, 2014). The former uses resilience and transformation as two distinct concepts, while the latter considers transformability as the core of resilience. These concepts are operationalised in economic context by Rose (2004) distinguish static economic resilience to dynamics economic resilience. The former is the ability of the system to maintain function when shocked while the latter by hastening the speed of the system to recover the shock.

By mutating these concepts, Peerlings et al., (2014) build a theoretical model enabling to identify tipping point and to discern adjusting cost by adapting strategies. Peerlings et al., (2014) stress that farming is a complex adaptive system characterised by multiple interaction across system components and are affected by disturbances. In this context disturbances are defined as event that disrupt a farm business (Janssen and Osnas, 2005) and can be idiosyncratic (e.g. a farm family crisis) or structural (e.g. policy reform).

Thus, farmers have two possibilities to deal with an external disturbance: one adjusting internal activities based on adaptation costs (i.e. adjusting variable input and output resulting from price and subsidy changes; adjusting use of productive factor; leaving farm activities) and the second is based on adaptation strategies, which can include simplification VS mixedness strategy. Therefore, the functioning of complex farming systems (MF/AF) can be framed into an adapting strategy to cope with the risks associated to instable input or output market. Indeed, increasing Mixedness has two main effects. The first is relatively observable at spatial scale (Fig. 3), and it means that we are moving from complementarity model towards Local and Territorial Synergy with increasing exchanges between the parts to fulfil their needs and manage resources. The second rely on increasing collaboration in the VCN there is a shift towards **collective behaviour**, which enhance resource sharing (skills, assets, technology), co-creation activities, mutual understanding, trust, VC's relationships and reduces potential conflicts to get the collaborative benefits. According to Heimeriks and Schreiner (2002), complementary resource use is key to supporting a successful collaboration (Dania, Xing and Amer 2018). Within territorial synergy the integration delivers a deep interaction among parts. In such configuration, the sub-system has developed adaptation strategy (ability to fine-tune new sustainable goals, tolerance to diversity and successful collaboration), potentially increasing its overall resilience.

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5 MF/AF diffusion and socio-economic performance

5.1 Overview

This section would understand the current diffusion of MF/AF and describe financial and socio-economic performance at farm level. According with the CF, the analysis of MF/AF systems with FADN data is done at both farm and territorial scales.

5.2 Classification in the FADN

The FADN is the main data infrastructure to provide macroeconomic data at a farm scale. The sampling procedure allows data representative at the NUTS2 level based on farm size and type of farming. Both dimensions are computed using the Standard Output[3] in pre-defined farm types. According to Article 5b of Commission Regulation (EC) No 1217/2009: '*The type of farming of a holding shall be determined by the relative contribution of the standard output of the different characteristics of that holding to the total standard output of the holding*'. In accord with that principle the type of farming of a holding" *is the production system of a holding which is characterised by the relative contribution of different enterprises1 to the*

holding's total SO".

Therefore, a holding is a specialised farm when a given activity exceeds 2/3 of the total farm SO.
The five main groups of specialist agricultural holdings are:

- Field crops (general cropping),
- Horticulture (vegetables and flowers)
- Permanent crops (vines, olive trees and fruit trees including berry plantations),
- Grazing livestock (bovines, sheep and goats),
- Granivores (pigs, poultry and also rabbits);

While, for the non-classified as specialists (i.e. with no one activities higher than 2/3 of Standard Ouptut), FADN provides three types of mixed farms:

- Mixed crops;
- Mixed livestock;
- Mixed crops and livestock.

[3] The Standard Output (SO) is the average monetary value of the agricultural output at farm-gate price of each agricultural product (crop or livestock) in a given region (EU.,.

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The above-mentioned typologies refer to the upper level of FADN classification. Depending on the amount of detailed provided, the FADN provide three nested levels of type of farming:

- level 1: 8 general types; (i.e. specialist Filed Crops if total SO for Field Crops > 2/3)
- level 2: 21 principal types; (i.e. Specialist Cereal, Oilseed and protein crops if total SO for Field Crops > 2/3)
- level 3: 61 particular specialisation types.

Table 1. FADN classification – first and second levels

Level 1 (8 types)	Level 2 (21 types)
1. Specialist Field crops	Specialist cereals, oilseeds and protein crops
	General field cropping
	Mixed cropping
2. Specialist Horticulture	Specialist horticulture indoor
	Specialist horticulture outdoor
	Other horticulture
3. Specialist Wine	Specialist vineyards
4. Specialist Other permanent crops	Specialist fruit and citrus fruit
	Specialist olives
	Various permanent crops combined
5. specialist Milk	Specialist dairying
6. Specialist Other grazing livestock	Specialist cattle – rearing and fattening
	Cattle – dairying, rearing and fattening combined
	Sheep, goats and other grazing livestock
7. Specialist Granivores	Specialist pigs
	Specialist poultry
	Various granivores combined
8. Mixed	Mixed livestock, mainly grazing livestock
	Mixed livestock, mainly granivores
	Field crops – grazing livestock combined
	Various crops and livestock combined

5.2.1 Classification for AF/MF typologies

Mixed Farm

The application of Standard Output recognises the specialist farm (type 1-7) by non-specialised (mixed – type 8). Although the Standard Output criteria distinguish between specialised and mixed farms, the applicability to AGROMIX does not appear feasible as mixed farm are residual category for those that are non-specialised farm.

For example, a generic farmer with the agrosilvopastoral system with cork oaks, livestock, and pasture area (i.e. Montado system in Portugal) that sell only livestock products is classified as specialised livestock, which

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fails to highlight a clear representation of the synergies among the different component activities. This is a clear data limitation for those systems with one selling products (livestock), or for systems with activities without final commercialisation of any products or by products. *Viceversa* a farm that has been classified as mixed farm in accord with SO criteria does not ensure that the different activities are integrated, and it suggests that no one activities dominate the other.

Agroforestry

Following Püttsepp et al., (2021) definitions, agroforestry is "the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or livestock production systems to benefit from the resulting ecological and economic interactions". Although its relevance in the policy document for the new programming period, the agroforestry system is even not considered in FADN data, as data on the "wood area" is very rough. In fact, the FADN can have detailed information on permanent crops (i.e. vineyards; orchards, olives groves and other permanent crops) or on woodland area, but lacks in information on i) other woody vegetation, disperse tree cover or in rows (such as silvoarable, alley cropping, and forest farming), ii) woody vegetation, linear veg. features (such as cropland with hedgerows, bocage, riparian vegetation).

Table 2 details the variables used for trees and wood.

Table 2. details of tree and woodland variables

Name of the variable	Description
Vineyards	Area under vineyards. The variable includes area that belongs either productive vineyard or young plantations
Permanent crops	The variable includes: fruit and berry orchards (including tropical fruit), citrus fruit orchards, olive groves, nurseries and other permanent crops (osier, rushes, bamboos). Including young plantations and permanent crops grown under shelter.
Woodland area	Woodland area, forests, poplar plantations, including nurseries. The woodland area is not included in Usable Agricultural Area

Therefore, the next session presents the methodology used to provide a classification according to Püttsepp et al., (2021) and Schnabel et al. (2021) using farm structure instead of the SO.

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5.3 Methodology

The approach used to classify the farms is synthesised in Figure 4.

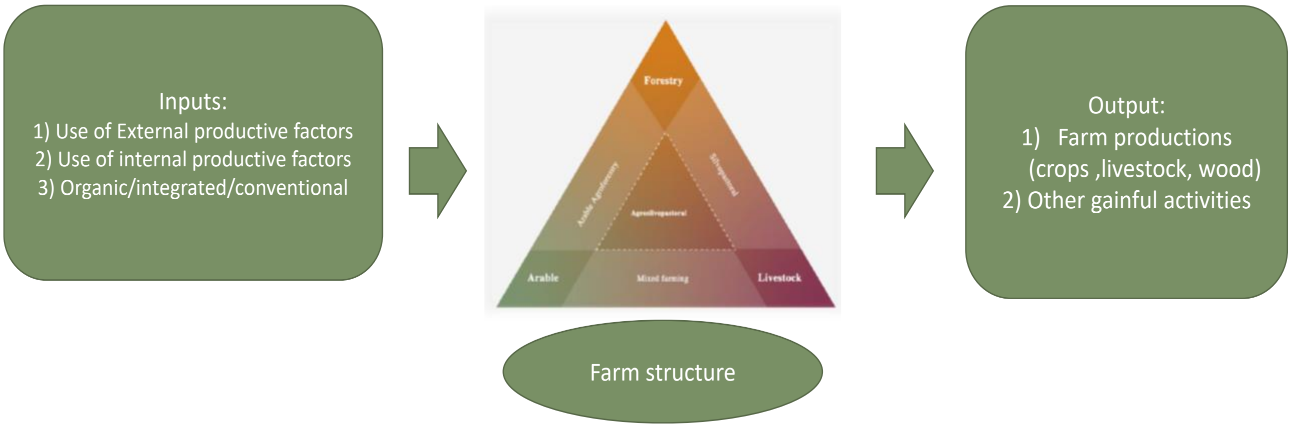

Fig. 4 Approach to FADN classification in AGROMIX what is other

As above mentioned, AGROMIX provides a different classification of farm typologies using the farm structure endowment. Figure 4 indicates that farm structure resulting from the combination of production outputs and its structure endowment will determine the farm outputs.

5.3.1 Typology of MF/AF in AGROMIX

As previously introduced, the theoretical background for the classification is provided by Püttsepp et al., (2021)and Schnabel et al. (2021), which expand MF/AF in four categories with the following working names:

1) MF/AF Type 1 – '**Arable Agroforestry' AP (Annual and Permanent crops)**
2) MF/AF Type 2 – '**Silvopastoral' PL (Permanent crops and livestock)**
3) MF/AF Type 3 – '**Mixed Farming' AL (Annual crops and livestock)**
4) MF/AF Type 4 – '**Agro-Silvopastoral' APL (Annual crops and Permanent crops and livestock)**

Example. A farmer type considered Arable Agroforestry (type 1) is given by the intersection of the arable crop/pasture and forestry/permanent crop sets. This means that this type of farm must have at least one parcel of arable or pasture and at least one parcel with woodland or permanent crops.

$Type\ 1 - ArableAgroforestry\ = \cap[\cup(Arable, Pasture), \cup(Woodland, Permanent)]$, with:

- $\cap$ represent the intersection of two or more sets, which contains all elements that are included in all the sets
- $\cup$ represent the union of two or more sets, which contains all elements.

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- *Arable* is a binary variable with a value 0 or 1. the variable has a value = 1 when a farm cultivates cereal crops OR other field crops OR energy crops OR vegetables and flowers; the variable has a value = 0 when not in arable cropland;
- *Pasture* is a binary variable with a value 0 or 1. the variable has a value = when a generic farm cultivates fodder crops OR temporary grassland OR permanent grassland OR permanent pasture OR grazing land OR fallow land;
- *Woodland* is a binary variable with a value 0 or 1. the variable has a value = when a generic farm has a wood area;
- *Permanent* is a binary variable with a value 0 or 1. the variable has a value = 1 when a generic farm has farmland area allocated to fruit OR olives OR wine OR other permanent crops[4].

A farmer type considered Silvopastoral (type 2) is given by the intersection of the livestock/pasture and forestry/permanent crop sets. This means that this type of farm must have at least one parcel of livestock/pasture and at least on the parcel with woodland or permanent crops.

$Type\ 2 - SilvoPastoral\ = \cap[\cup(Woodland, Permanent), \cup(Livestock, Pasture)]$ with:

- *Forestry* is a binary variable with a value = 1 when a generic farm has wood area;
- *Permanent* is a binary variable with a value =1 when a generic farm has farmland area allocated to fruit OR olives OR wine OR other permanent crops;
- *Livestock* is a binary variable with a value =1 when a generic farm has dairy OR cattle OR buffalo OR sheep and goats OR pigs OR poultry;
- *Pasture* is a binary variable with a value =1 when a generic farm cultivates fodder crops OR temporary grassland OR permanent grassland OR permanent pasture OR grazing OR fallow land.

A farmer type considered Mixed Farm (type 3) is given by the intersection of the livestock/pasture and arable/pasture crop sets. This means that this type of farm must have at least one parcel of livestock/pasture and at least on parcel with arable or pasture crops.

$Type\ 3 - MixedFarm = \cap[\cup(Arable, Pasture),\ \cup(Livestock, Pasture)]$ with:

[4] Technically this is not agroforestry in a narrow sense it is more and indicator that a farm has arable or pasture in one part and forestry or permanent cropping on another. Since agroforestry is not defined in FADN this Type 1 is only the best possible approximation. It does not mean there are trees in a field or pasture.

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- *Arable* is a binary variable with a value = 1 when a generic farm cultivates cereal crops OR other field crops OR energy crop OR vegetable and flowers; the variable has a value = 0 when not in arable cropland;
- *Pasture* is a binary variable with a value =1 when a generic farm cultivates fodder crops OR temporary grassland OR permanent grassland OR permanent pasture OR grazing OR fallow land;
- *Livestock* is a binary variable with a value =1 when a generic farm has dairy OR cattle OR buffalo OR sheep and goats OR pigs OR poultry;
- *Pasture* is a binary variable with a value =1 when a generic farm cultivates fodder crops OR temporary grassland OR permanent grassland OR permanent pasture OR grazing land OR fallow land.

A farmer type considered Agrosilvopastoral (type 4) is given by the intersection of the livestock/pasture, arable/pasture crop and forestry/permanent crop sets. This means that this type of farm must have at least one parcel of livestock/pasture, at least on parcel with arable or pasture crops and at least on parcel with woodland or permanent crops.

$Type\ 4 - AgroSilvoPastoral =$
$\cap[\cup(Arable, Pasture)\ U(Forestry, Permanent)\ \cup(Livestock, Pasture)]$ with:

- *Arable* is a binary variable with a value = 1 when a generic farm cultivates cereal crops OR other field OR energy crop OR vegetable and flowers; the variable has a value = 0 when not in arable cropland;
- *Pasture* is a binary variable with a value =1 when a generic farm cultivates fodder crops OR temporary grassland OR permanent grassland OR permanent pasture OR grazing OR fallow land;
- *Forestry* is a binary variable with a value = 1 when a generic farm has wood area;
- *Permanent* is a binary variable with a value =1 when a generic farm has farmland area allocated to fruit OR olives OR wine OR other permanent crops;
- *Livestock* is a binary variable with a value =1 when a generic rear dairy OR cattle OR buffalo OR sheep and goats OR pigs OR poultry in their farm;

It is worth noting that type 1 and type contain some farms classified as type 4. To avoid double counting of farms resulting from the intersection between type 1 and type 2 we have classified as type 4 the intersection of type 1 and type 2. Therefore, type 1 excludes the farm classified as arable agroforestry with livestock activities and type 2 excludes the silvopastoral farm that has also cereal or vegetable or other arable crops not used for livestock.

5.3.2 Mixedness Indicator

In line with the conceptual framework outlined in the previous chapter, we also define an indicator of complexity based on the count of different farm activities requiring differentiation in farm structure, inputs and technology that constitute farm income diversification (Mixedness).

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$Mixedness = \sum_{i=1}^{i=22} i$ considering all the following activities:
1) cereal; 2) other field crops; 3) energy crops 4) vegetables 5) flowers 6) vineyards 7) permanent crops; 8) orchards; 9) olives; 10) fodder crops; 11) temporary grassland; 12) permanent grassland; 13) meadows and permanent pasture; 14) grazing land 15) fallow land with or without subsidies; 16) woodland; 17) dairy; 18) cattle; 19) buffalo; 20) sheep and goats; 21) pigs; 22) poultry.

This indicator shows how farms integrate among their system different activities (*i*). A farm with high value indicates a high complexity of farming activities and larger interaction with VC Actors or with territorial synergies. In contrast, a low score shows a deep integration with only one supply chain actor and strong specialisation. The indicator is somehow linked with the income diversification strategy but it provides the share of income streams (see. for example, Vergamini et al., 2019) it provides the investment on different farm activities, including also these activities that do not generate any source of income.

5.4 Data description

AGROMIX asked for FADN data in August 2020, which we received in March 2022. The dataset contains more than 1 million farms across the EU 27 countries and it cover year 2007-2018 for all countries except for the United Kingdom and Croatia. The dataset is limited to year 2013-2018 for Croatia (as it joined the EU later) and 2007-2017 for the UK. Table 2 below shows the country and year coverage. All countries were included in the analysis.

The FADN data is reported using 14 different tables plus the “Standard Results”, which contain a synthesis of the main economic performance of the farms.

The tables are:

- Table A General information on the holding;
- Table B Type of occupation of agricultural land;
- Table C Labour;
- Table G Land and buildings, deadstock, circulating capital;
- Table L Quotas and other rights;
- Table H Debts;
- Table I Value added tax (VAT);
- Table F Costs;
- Table K Production (excl. livestock) [incl. Animal products and Other Grainful Activities];
- Table D Number and value of livestock;
- Table E Livestock purchases and sales;
- Table N Details of purchase and sales of livestock;
- Table K Production Table J Grants and subsidies;
- Table M Direct payments.

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Table 3. Summary of FADN data, showing years with data, countries and number of farms in the network per country.

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Belgium	1,168	1,196	1,195	1,201	1,252	1,251	1,229	1,208	1,297	1,078	1,070	2,088	15,233
Bulgaria	1,871	1,950	1,900	2,291	2,245	2,180	2,228	2,228	2,267	2,251	2,244	4,472	28,127
Cyprus	376	385	377	432	470	484	472	445	458	483	506	1,018	5,906
Czech Republic	1,323	1,340	1,417	1,429	1,417	1,369	1,401	1,363	1,366	1,351	1,343	2,746	17,865
Denmark	1,813	1,765	1,850	1,855	1,818	1,785	1,796	1,869	1,812	1,849	1,845	3,656	23,713
Germany	7,692	7,841	8,880	8,999	8,922	8,957	8,928	8,823	8,881	8,821	8,941	17,920	113,605
Greece	3,923	4,014	3,847	3,457	3,712	4,427	4,775	4,235	4,212	3,939	3,878	7,272	51,691
Spain	8,807	8,210	8,184	8,195	8,135	8,698	8,726	8,716	8,695	8,677	8,738	17,460	111,241
Estonia	499	498	498	659	657	655	660	658	659	659	663	1,318	8,083
France	7,191	7,264	7,307	7,438	7,401	7,531	7,510	7,557	7,552	7,471	7,487	14,916	96,625
Croatia							1,177	1,220	1,253	1,221	1,237	2,676	8,784
Hungary	1,953	1,936	1,932	1,918	1,918	1,978	1,974	1,982	1,961	2,142	2,171	4,292	26,157
Ireland	1,185	1,185	1,090	1,049	1,052	952	937	915	907	899	903	1,816	12,890
Italy	29,716	10,797	10,743	10,720	10,903	10,591	10,778	9,948	8,830	9,329	10,098	10,124	142,577
Lithuania	1,145	1,099	1,090	1,056	1,098	1,109	1,064	1,153	1,121	1,150	1,126	2,332	14,543
Luxembourg	445	446	445	445	443	447	446	446	446	445	445	896	5,795
Latvia	994	997	991	993	996	999	998	998	998	998	998	1,996	12,956
Malta	376	374	386	494	506	497	499	498	490	490	497	978	6,085
Netherlands	1,493	1,482	1,540	1,479	1,472	1,519	1,513	1,503	1,507	1,502	1,497	2,996	19,503
Austria	2,024	2,077	2,009	2,088	2,034	2,126	2,117	2,142	2,126	2,009	1,860	3,744	26,356
Poland	12,043	12,273	12,426	11,194	11,076	11,114	12,321	12,315	12,311	12,329	12,297	23,392	155,091
Portugal	2,206	2,166	2,187	2,270	2,298	2,246	2,215	2,084	2,163	2,065	2,046	4,112	28,058
Romania	1,008	1,869	3,346	5,616	5,729	5,687	5,885	4,031	4,670	5,968	5,987	10,170	59,966
Finland	931	927	933	926	888	854	846	830	817	792	763	1,444	10,951
Sweden	1,017	1,034	1,047	1,047	1,010	1,056	1,075	1,040	1,035	1,044	1,025	2,020	13,450
Slovakia	506	513	506	520	531	529	558	562	559	559	559	1,118	7,020
Slovenia	755	826	856	959	929	1,142	944	904	882	912	883	1,780	11,772
United Kingdom	2,795	2,829	2,835	2,739	2,723	2,763	2,813	2,756	2,793	2,832	2851	0	33,580

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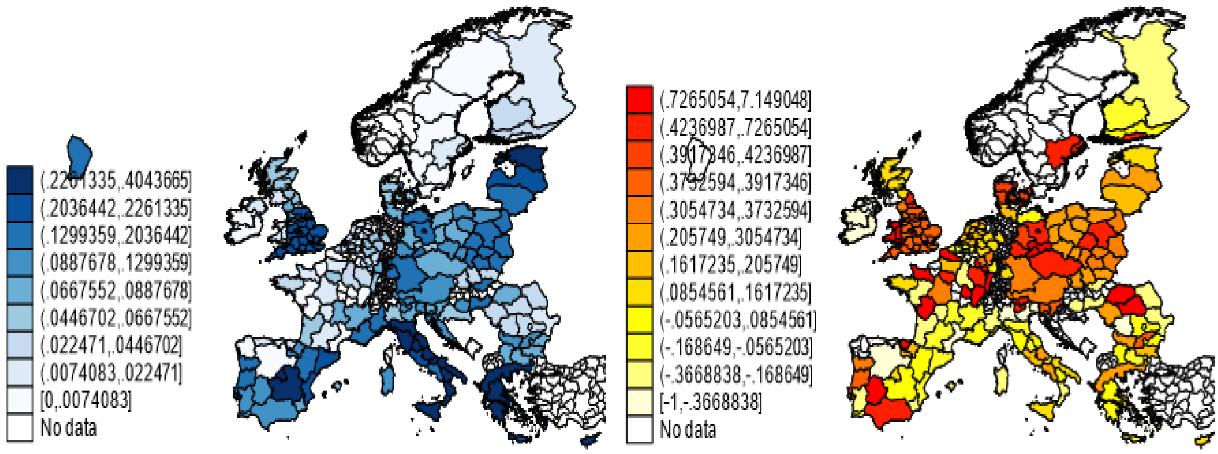
5.5 Results

5.5.1 Diffusion of MF/AF

This section provides an overview of the diffusion of the four typologies of MF/AF identified in AGROMIX. Each category is presented according to the current consistency (Panel A) and the evolution (Panel B).

Panel A contains the average share of each category in the years 2016-2018[5]; while Panel B the relative change in the share of category concerning the first period of the dataset (average value between years 2007-2009) [6].

5.5.1.1 MF/AF Type 1 – 'ArableAgroforestry'



Panel A Panel B

The darker color of Panel A indicates a larger share of farms classified as type 1 (arable agroforestry). The current distribution of arable agroforestry shows a clear spatial pattern across the EU. The share of this system is particularly high in the Mediterranean countries as the combination of permanent crops (wine and olive), and arable crops are highly widespread. In these countries, the average value in NUTS2 areas is higher than 25%. Panel A also shows that the arable agroforestry is relevant in Eastern Europe and Southern regions of UK, with a value of around 20%. The continental part of EU show low diffusion of the systems. The results indicate that Mediterranean agricultural system experienced the integration of the arable system with

[5] We limited the average for the UK to the years 2016 and 2017 due to missing data for the year 2018.
[6] Due to data limitation, we keep initial average between year 2013-2015 for Croatia

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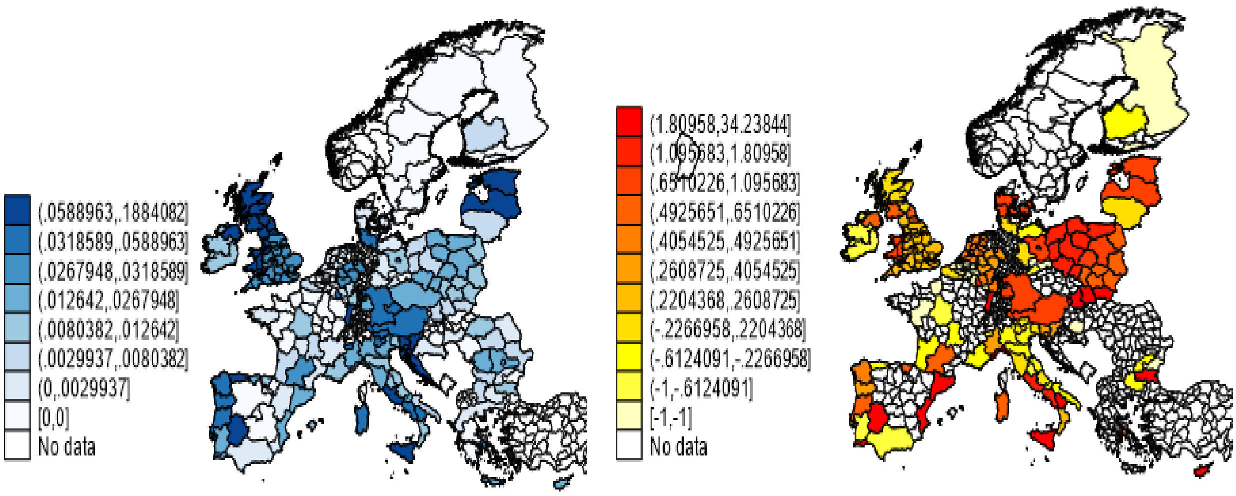
permanent crops while for the southern of UK this is due to the cultivation of arable crops with woodland areas or hedges in the fields.

Panel B presents the evolution of the average from 2007-2009 to years 2016-2018. The area in yellow shows a reduction, while the area in orange or red is increasing. The figure shows a clear pattern of change over time, with a general reduction in Mediterranean regions (except for southern areas of Spain and northern Portugal) and an increase in the continental and western regions of the EU. This can result from regulation for new vineyard crop plantations and the continuous abandonment of olive crops. Meanwhile, arable areas show an increase due to the introduction of area payments in the EU and decoupled payments (i.e. Single Farm Payments).

5.5.1.2 MF/AF Type 2 - Distribution of 'SilvoPastoral'



Panel A Panel B

While the darker color of Panel A figure indicates a larger share of farms classified as type 2 (silvopastoral), the Panel B presents the farm types evolution over time, and the area in yellow show a reduction, and in orange or red the increasing.

The silvopastoral system is less widespread than the previous one, with a share of less than 20% for all the EU region. UK and Austria, Slovenia, Croatia and Latvia regions show higher diffusion. The large majority of the country show low or no changes over time, except Poland and Austria with a strong increase (about the double of the previous period).

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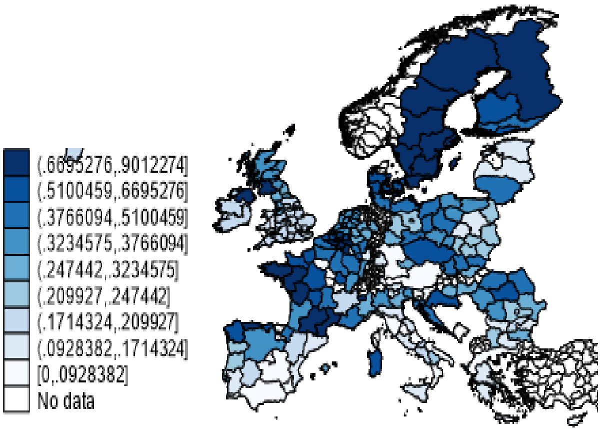
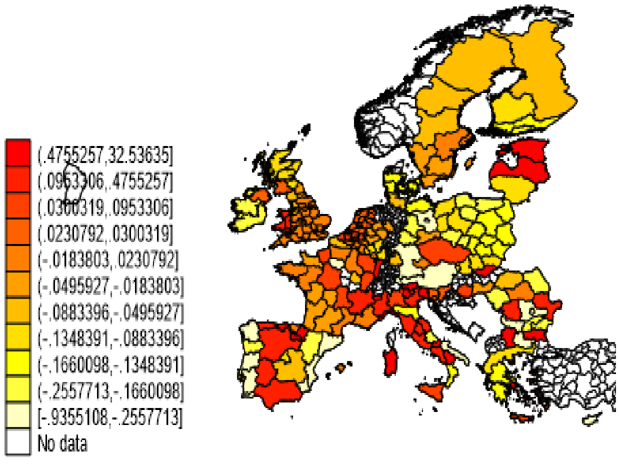
5.5.1.3 MF/AF Type 3 - Distribution of 'Mixed Farming'





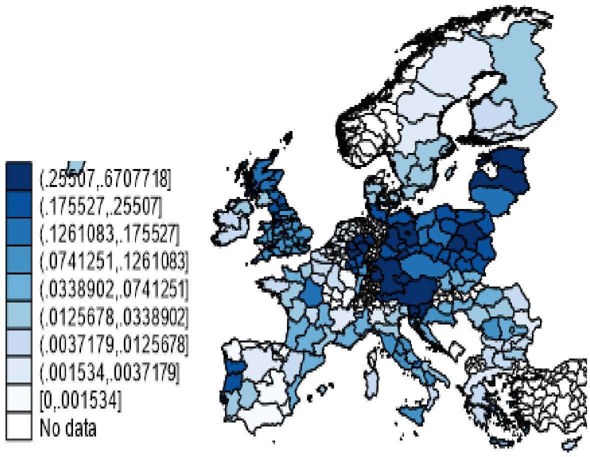
Panel A

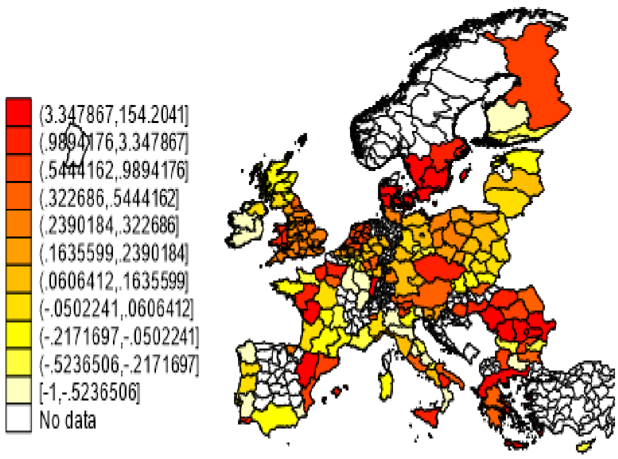
Panel B

While the darker color of Panel A figure indicates a larger share of farms classified as type 3 (mixed farm), the Panel B presents the farm types evolution over time, and the area in yellow show a reduction, and in orange or red the increasing.

Mixed farms are very widespread category of farm type. The map shows a high share of the system in Scandinavian Regions and the continental EU. At the opposite side, this system is less diffused in the Mediterranean countries. However, the system shows a general increase in the Western and Mediterranean areas of the EU with negative trends in the Eastern parts of the EU and specifically Poland.

5.5.1.4 MF/AF Type 4 - Distribution of 'AgroSilvoPastoral'





Panel A

Panel B

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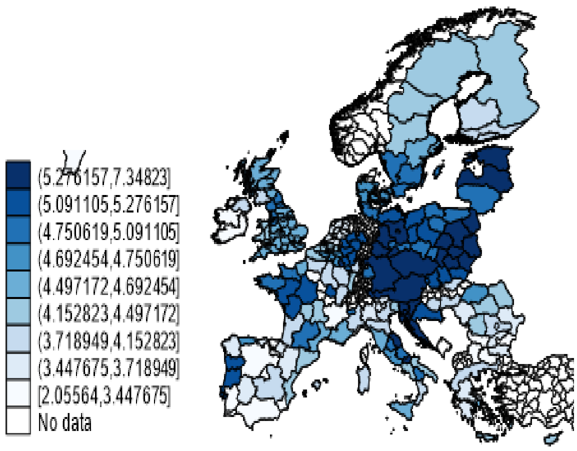
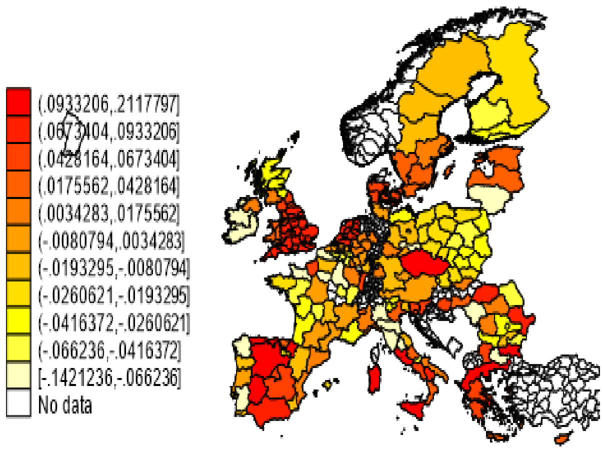
While the darker color of Panel A figure indicates a larger share of farms classified as type 4 (agrosilvopastoral), the Panel B presents the farm types evolution over time, and the area in yellow show a reduction, and in orange or red the increasing.

The agrosilvopastoral type represents the intersection between livestock, forestry (and permanent crops) and arable crops. Panel A shows clear spatial aggregation in the Eastern part of the EU, including Austria and Southern part of Germany. In addition, the north of Portugal, the UK (and especially Western Scotland) show a higher diffusion of the system. However, the tendency shows a general reduction in the diffusion of the system, except for the region from Romania to Greece, Denmark, Southern Sweden and Finland in the Scandinavian regions and Wales in UK, Catalonia in Spain and Sicily in southern Italy. It is worth to notice also France with some regions increasing and other decreasing. For the Balearic Islands of Spain, and other Southern Mediterranean islands such as Sicily and Crete Sardinia or Cyprus) the data show an interesting countertrend towards the increase. One potential explanation is due to persistence of dairy or cheese supply chain in these areas.

5.5.1.5 Mixedness in the farming system





Panel A

Panel B

Panel A provides the average value of the complexity indicator across all NUTS2 regions in the EU. The indicator can take values from 1 to 22 according to the count of different activities carried out on the farm.

The figure shows the extent of 9 different clusters spanning from an average value of 2 (white colour) to more than 7 (dark blue colour). As an average value, such changes describe very heterogeneous farming practices and can be interpreted as strong integration in the supply chain for the lower value or higher complexity in the farming system management due to the integration of different farming activities on the farm.

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Thus, diversity in farming system can be observed in the central and Eastern part of the EU (also high in Croatia and Slovenia that shows an average value higher than 5 with an average, five different activities that are carried out on the farm). Less complex but still integrated results can be observed in the Western part of France and Northern Portugal and parts of Italy and the UK. Panel B show a worrying trend of reduced diversity in former hot-spots like Eastern Poland and part of Romania. Also Eastern Scotland, Republic of Ireland and Southwest France, northeast Germany and the lowlands of Northern Italy are reducing diversity. All this are areas with more intensive, commercially driven production. Parts of Greece, central Spain, the Czech Republic stand out as retaining diversity although from a lower level as shown in Panel A.

5.5.2 Performances of MF/AF

The different performances over type of farm have been assessed against three main criteria: use of productive factors (Figure 5 to 7) economic performance (Figure 8 to 11), and efficiency (Figure 12). Each figure shows the average value for all FADN sample for each category. Each bar is an observed year. Then moving from the left-hand to right-hand side it is possible to observe the tendency over time.

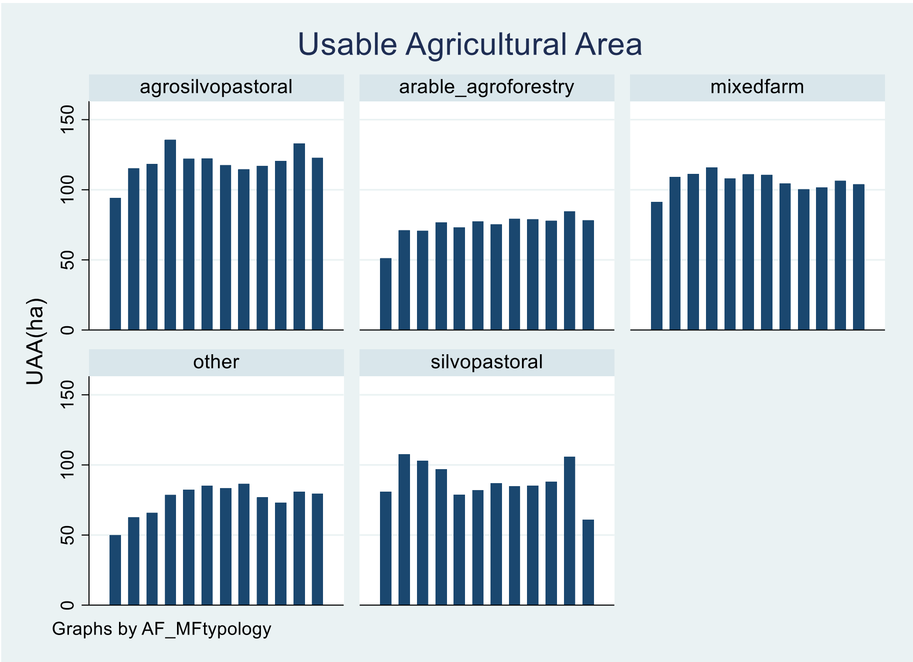

Fig. 5 Use of productive factors – Average Usable Agricultural Areas (ha per farm)

Figure 5 shows that 'agrosilvopastoral' type and 'mixed farm' has an overall large farm size, which is almost double with respect to the 'other type' and 'arable-agroforestry'. While the farm size is stable over time for 'mixed farm', the 'agrosilvopastoral' type highlight larger fluctuations. This structure can be explained by the extensive nature of 'agrosilvopastoral' system and by the commitment to the nitrogen directive (legislation

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against high animal stocking densities to reduce nitrogen leaching) for the mixed farm that affects the ratio between herd size and land used, leading to farms with larger UAAs.

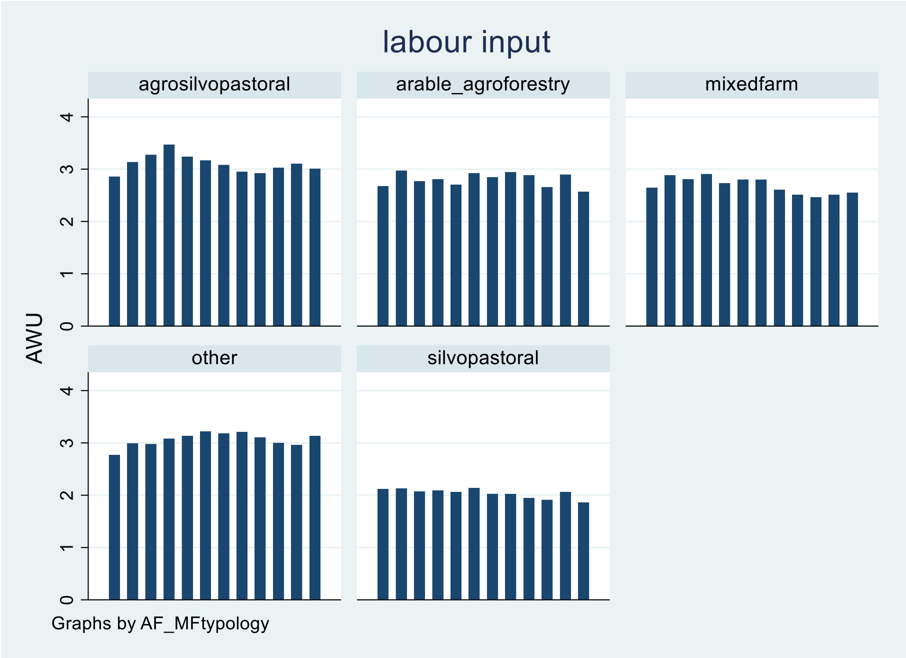

Fig. 6. Productive Factors- Labour used (# of Annual Work Unit[7])

Figure 6 shows the amount of labour used on farm. The variable measures the total worker units, including both family and external work. The results depict a similar picture for all farm typologies, except for the 'silvopastoral type' that uses one-third of labour less than the others indicating a more extensive land management in this system. Surprising there are few changes in the observing years, meaning labour input per farm is stable, it might be different per hectare as farms sizes have grown. This results can be further indicate the labour market rigidity, with low possibility of substitution between on-farm and off-farm work or.

[7] Eurostat defines Annual work unit (AWU) as "*is the full-time equivalent employment, i.e. the total hours worked divided by the average annual hours worked in full-time jobs in the country. One annual work unit corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis*".

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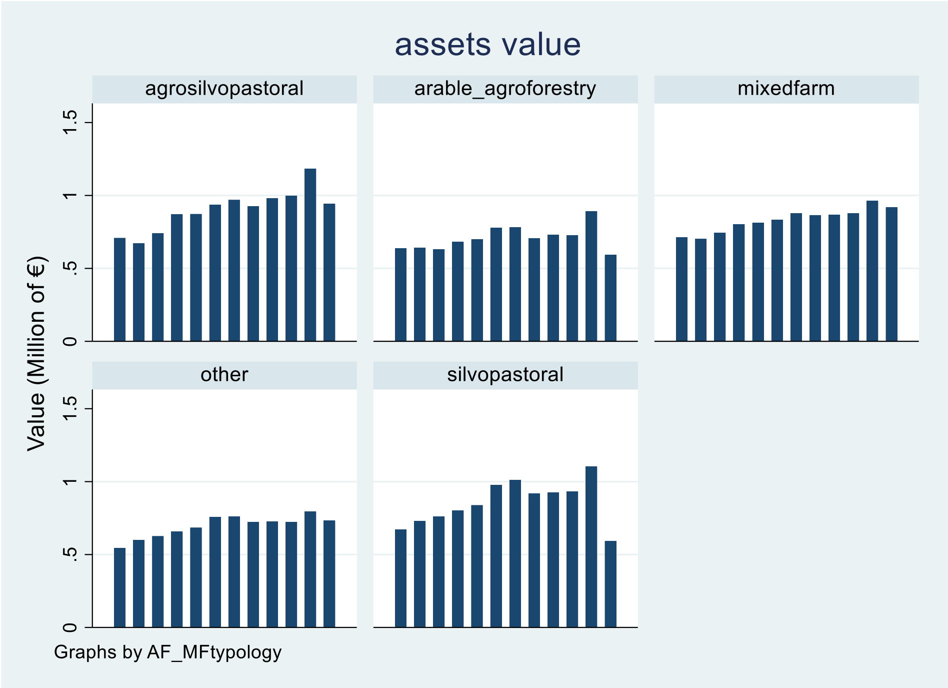

Fig. 7. Productive Factors – Assets value (Million of Euro)

Figure 7 presents the value of total assets owned by the farm. This capital indicators measure the value of fixed assets and the value of other non-fixed assets at closing value, and it indicates the value of agricultural land and farm building and forest capital, plus the value of machinery and equipment and breeding livestock. The results suggest that larger farmland increase with the total value of assets. Comparing the assets with land use results we can speculate on the relevance of land price increase for extensive farm typologies. The results show a general increase in the total assets by all farm typologies but with different slopes among the farm typologies. The 'other' type and 'arable agroforestry' have lower increase in the total asset value. Is worthy to note that agrosilvopastoral and silvopastoral show a stronger increase in the total asset value. General asset value increase might also be a function of inflation or recessions e.g. as in the final year of the analysis (2017-2018).

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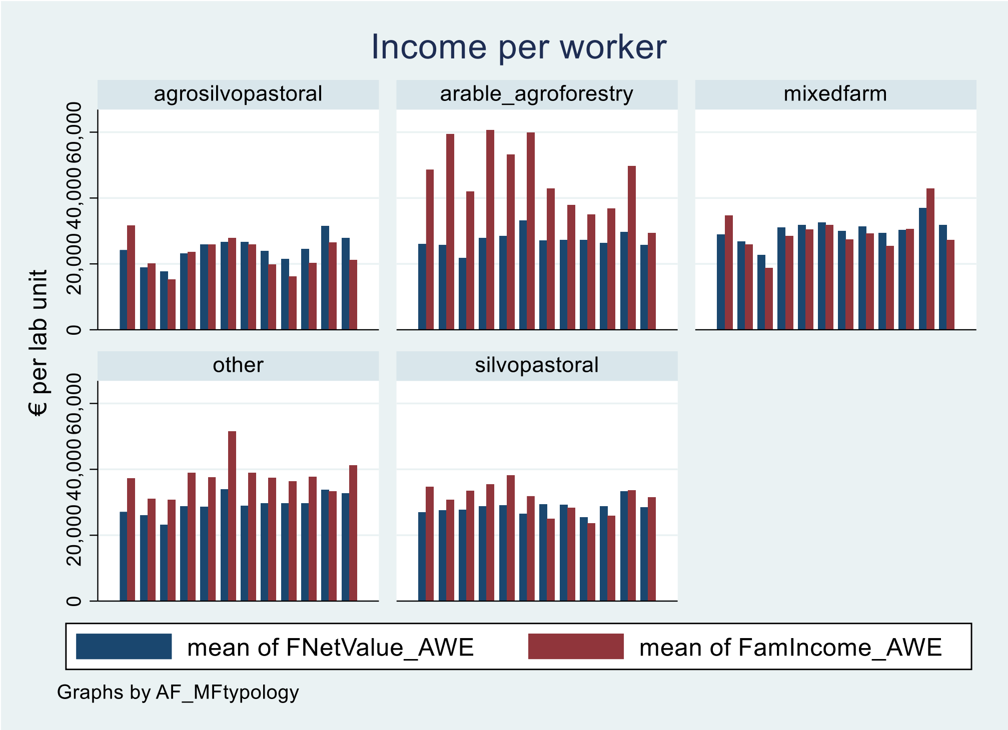

Fig. 8 Economic performance - Income per (Annual Worker Unit) considering the remuneration to the fixed factor used considering all sources (FNetValue) and considering only productive factors of the family (FamIncome)

present the economic performance per worker. We choose to use this indicator to better compare the different farming system. As mentioned before, it employs on the production system very heterogeneous amount of labour force. Furthermore, we used two different indicators that measure the remuneration of productive factors used: the **Farm Net Value per AWU (blue bar)** measures the remuneration to the fixed factor of production considering the source (i.e. external or family factor), and then the indicator is sensitive to the production system and can consider the intermediate consumption and depreciation (for example, in the livestock sector, if production is mostly without the use of land (purchased feed) or extensive (purchase and renting of forage land); the **Family Farm income per AWU (red bar)** indicator remunerates the fixed factor of production of the family (labour, land and capital) and remuneration to the entrepreneurs' risks.
Is worth to note that when the two indicators have similar values (i.e. agrosilvopastoral, silvopastoral and mixed farm) there is less intermediate consumption of productive factors (i.e. purchased feed).
The results show a slightly higher performance for arable forestry crops and for the other farm typologies, even if it appears very unstable over time.

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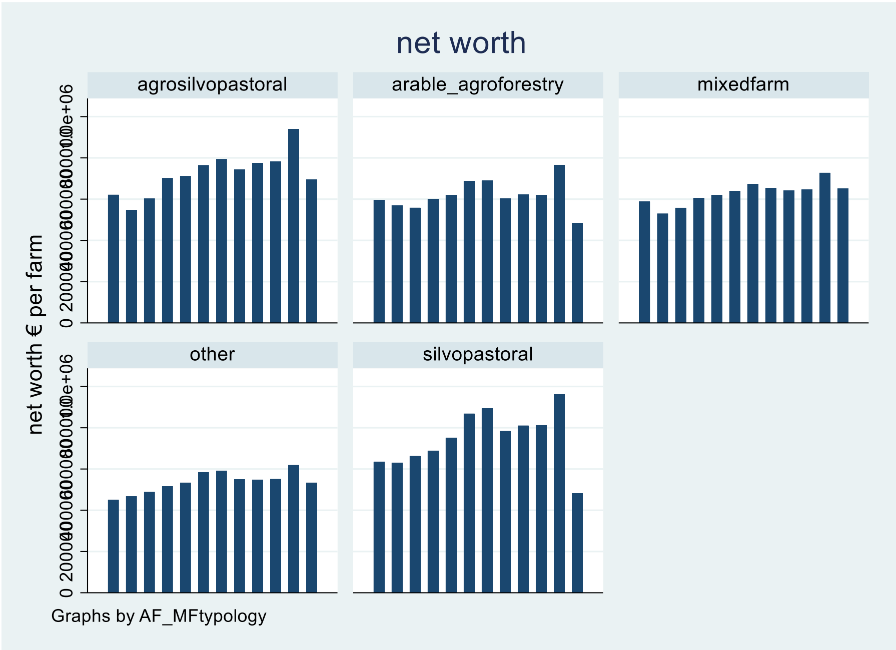

Fig. 9 Economic performance Net Worth – € per farm x-axis not readable

provides the net worth of the farm which is a relevant financial robustness indicator that has been calculated as **total assets minus all liability**: long- medium- or short-term loans still to be repaid. The figure demonstrates that extensive farming system have better financial performance when liability are considered, with a strong increasing. These are relevant results as the extensive system can be less risky and potentially more resilient to external shocks compared to the other farming typologies.

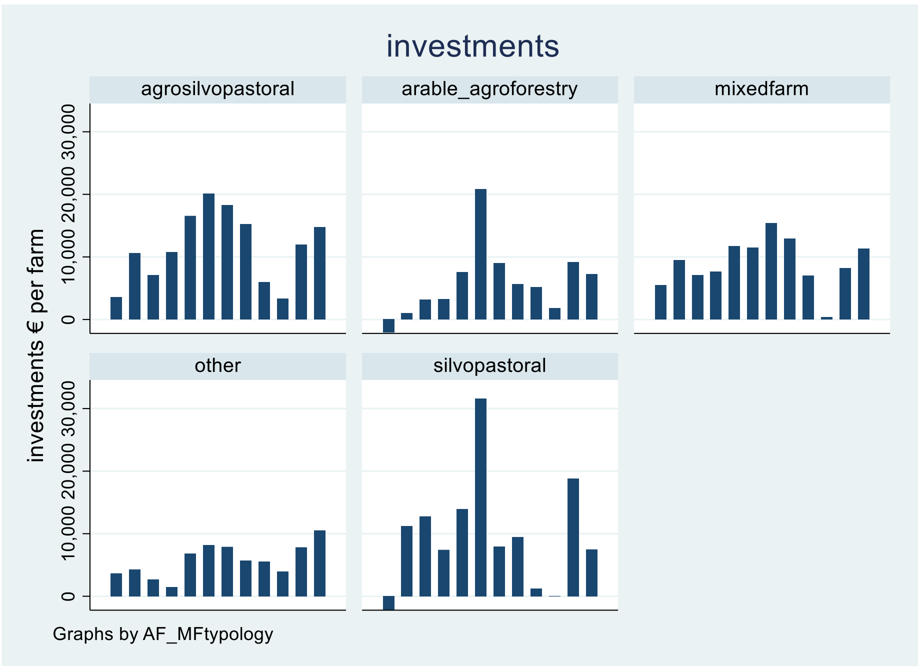

Fig. 10 Economic performance Net Investments– € per farm

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Figure 10 provides information on the net investment on fixed asset considering the depreciation. Results return an interesting picture, with very strong variability over time (indicating farms may select to make investments in good years, also to reduce tax burden, while deferring investment in less good years). Is worth to note that, contrary to expectations some may have, that the investments are higher to the more extensive farming system, which can be a consequences on the typologies of investment mainly in land rather than machineries and equipment. Another explanation could be that the Net investment is measures per farm and not per ha, maybe extensive farms are just larger to cope with the extensive management. Thus such a typology of investment has no depreciation.

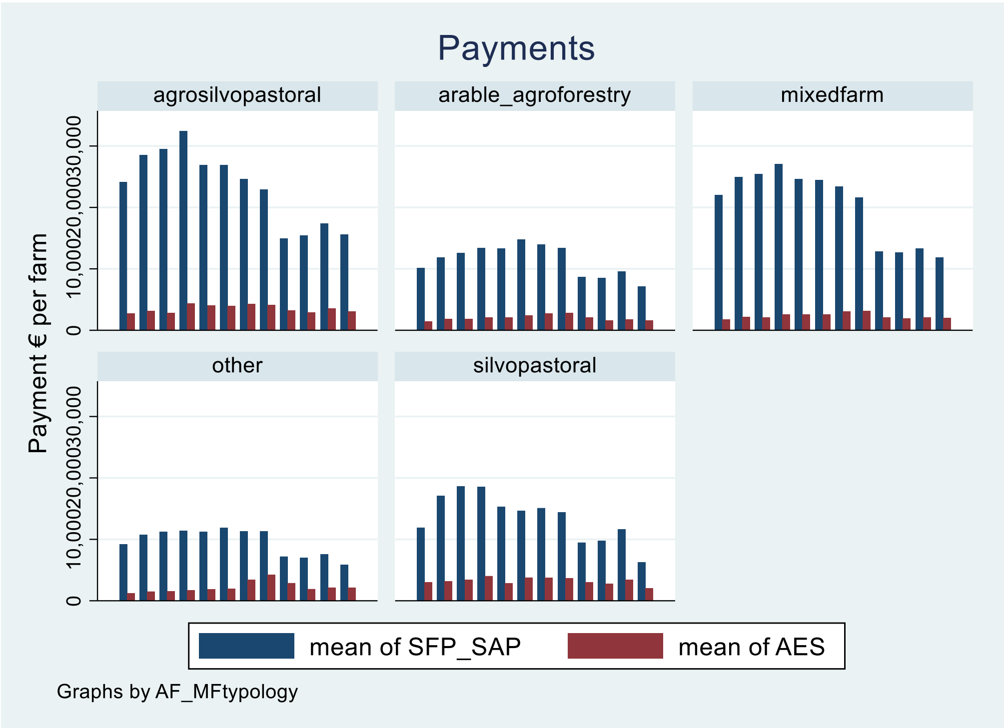

Fig. 11. Economic Performance – Payments received per farm SFP-SAP is Single Farm Payment AES is agri-environmental schemes

Figure 11 presents the average value of payment received per farm, respectively the direct payment (blue bar) and the agri-environmental payment (red bar).

Overall, the results confirm the significance of direct payment all farming systems with higher contribution for the most 'agrosilvopastoral' and 'mixed farm' types, while agri-environmental schemes have lower relevance. The results indicate a general reduction in the amount of payment received and it is worth note that this reduction is stronger for a farming system with livestock. This is due to the introduction of decoupling. It is also worth noting that despite reduced payment the net worth (Figure 9) in e.g. in the 'mixed farm' type has not reduced.

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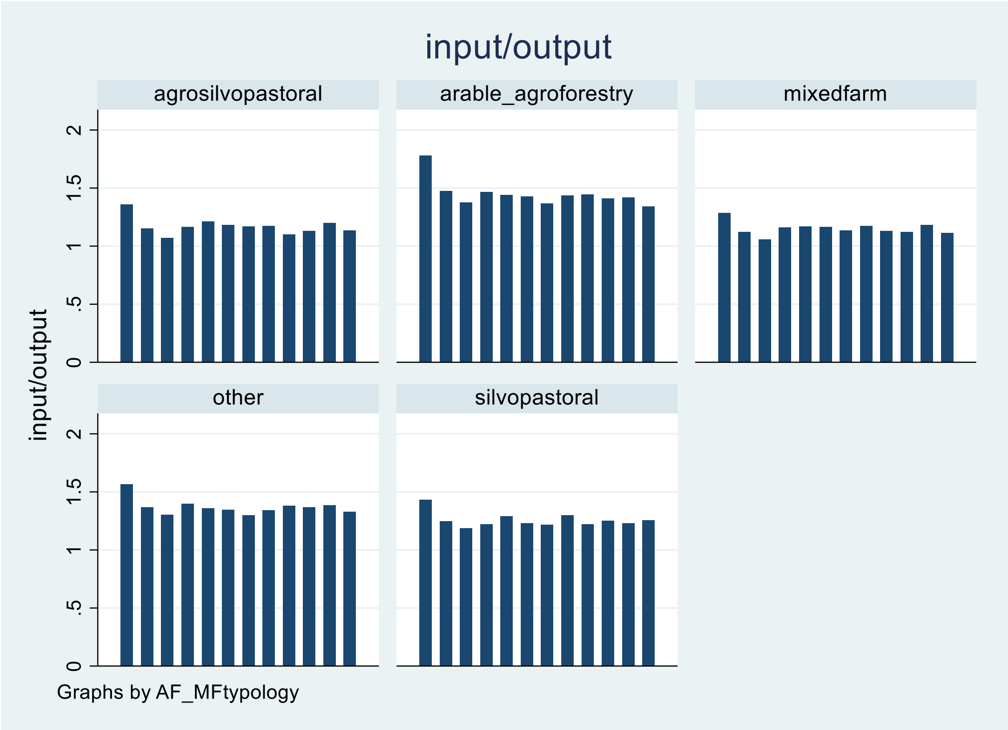

Fig. 12. Efficiency– input/output ratio

Figure 12 presents an indicator of efficiency, which is based on the ratio between monetary value input and outputs. The figure shows no major differences among the farm typology, with possibly the exception of 'arable agroforestry' category showing slightly more efficient than the others. The results also indicate a general slowdown in the efficiency compared with the first year, which can be attributed to the increasing the unitary production costs. Excluding the first year we can observe that for mixed farm type the fluctuation seems lower, which can suggest I haver ability to adjust productive factor use on the based on market price signals.

5.6 Conclusions

This deliverable presents both a conceptual and analytical analysis of MF/AF systems. Both conceptual and empirical analysis requires a deep understanding of the complexity of the integration among the different activities of the farm.

To our best knowledge, this is one of the first academic attempts to develop an empirical analysis of a conceptual and analytical analysis of Mixed farming and Agroforestry systems in Europe using FADN data.

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We conclude, while FADN is based on an “economic” definition of the farming system, this is not completely suitable to understand such complexity. This is a quite interesting result considering the purposes of the FADN to be expanded to a measure of sustainability performance at farm level.

According to the lack of definition or the difficulties in providing one solution for both MF/AF, the important point is that the AGROMIX project has contributed to identify data needs and support with evidence the public debate about the transition to FSDN. This is especially important currently as there is large interest in using agri-environmental and other ecological funding schemes (carbon credit) to promote especially Agroforestry and to a lesser degree mixed farming at the European level.

Our data show that de-mixing (a reduction of complexity, diversity, and mixed systems) is ongoing in many parts of Europe. The picture is however itself more diversified then assumed, with some areas getting still de-mixed, which were previously highly mixed (Eastern Europe), while others are, according to our data, not de-mixing and on the contrary gain complexity and diversity, e.g. parts of Greece, Northern Portugal, Alpine/mountainous regions, certain European islands. This gives hope, that the de-mixing trend in agriculture can be stopped and ultimately reversed, leading to potentially more resilient, diverse landscapes with many more trees mixed into it.

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