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

Deliverable D5.1 – Draft v.1*

[This is a draft deliverable, as there are still delays in receiving the FADN data from the EC]

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Deliverable 5.1	**Report on the assessment of the farm-level financial and socio-economic performance of selected MF/AF systems**
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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other
[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

Table of Contents

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

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 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.

The report contains both theoretical and empirical developments enabling understanding the drivers and performance of MF/AF.

The empirical analysis shows complexity in understanding the performance of AF due to difficulties in adapting definitions to the FADN data. The expanding attention to AF due to its contribution to CO_2 emission mitigation would require advances in the FADN data collection procedure. The report proposes a classification based on an integrated system that can be used to the convention on Farm Sustainability Data Network for AF/MF.

Note: This document is a draft of the develiberable. There are on-going delays in receiving the FADN data from the EC. The deliverable will be completed as soon as the FADN data will be made available to the authors.

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1 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. 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 focus on 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

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preliminary conceptual framework (CF) developed within this first task and the other relevant methodologies applied for the analysis of the FADN database follows.

Since the CF is expected not only to conceptually structure the T5.1 work but 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.

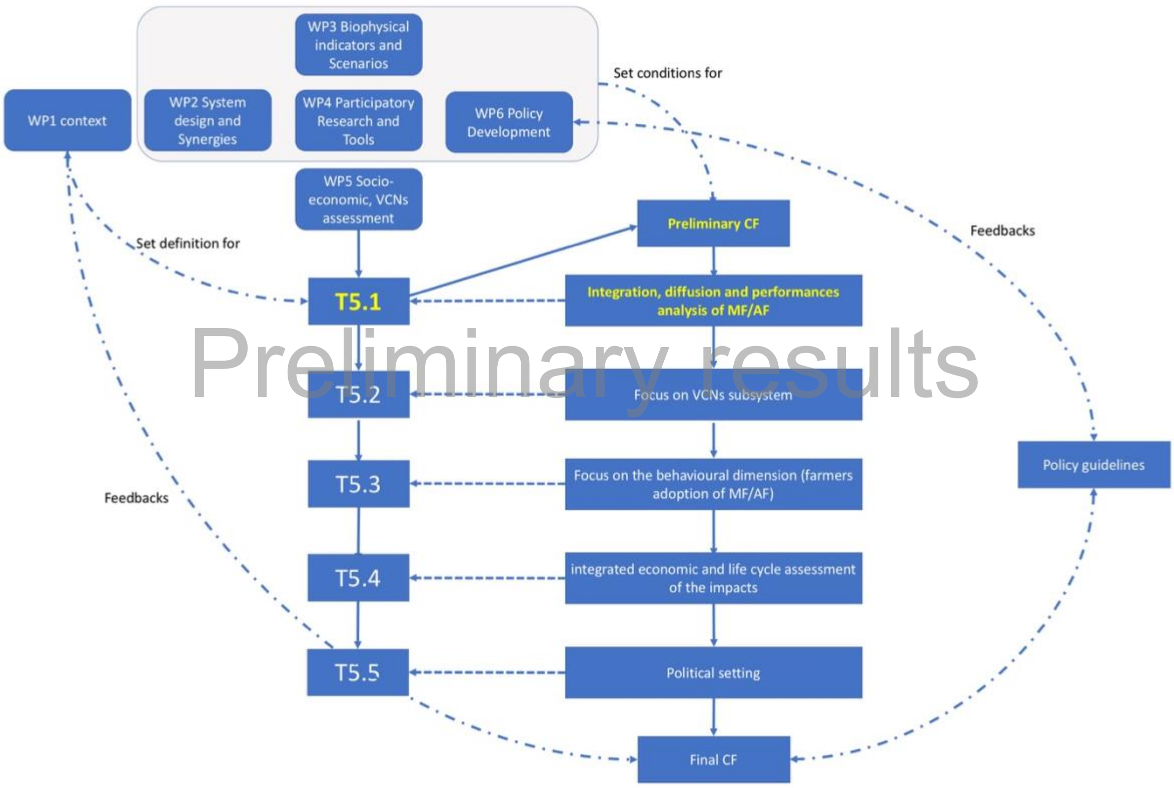

Fig. 1 Relation with CF components and WP5 tasks and linkages with other WPs

Feedbacks and exchange of information for the purpose of a mutual feeding of the concepts is also foreseen with WP2, WP3, and WP4.

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2 Conceptual framework

The Conceptual Framework (CF) is a conceptual 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 elaborate on the key concepts of AGROMIX (see T1.1) i.e. Agroforestry; Mixed-Farm; Value-chain; Transition; Agroecology; Resilience 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.

After the explanation of each concept, where relevant, we provide the implications for empirical analysis. 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 the tuned and refined version of the CF guiding the policy arena.

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

2.1.1 MF/AF practices

MF and 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).

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According to AGROMIX D1.1 Handbook of resilience and working definitions the term agroforestry defines a range of "*old 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 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: *agrisilvicultural* - combine crops and trees, *silvopastoral* - combine forestry and grazing, *agrosylvopastoral* - 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 Burgess et al. (2015) emerges both the theme of integration and dynamic interaction among

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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 D1.1 mirrors the AF definition of Burgess 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).

2.1.2 Defining VCNs

According to Moretti et al. (2021), the recent popularity of 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 - 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. 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);*

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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 (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 agroecological measures (MF/AF) that aim at 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 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****)*.

2.1.3 The Social-Technical-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, S. 2018; Ostrom 2007, 2009) to explore, model and assess such complex social-ecological interaction and related outcomes. The SES is

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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 here two main elements of novelty. 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 **VCNs** (Fig. 1).

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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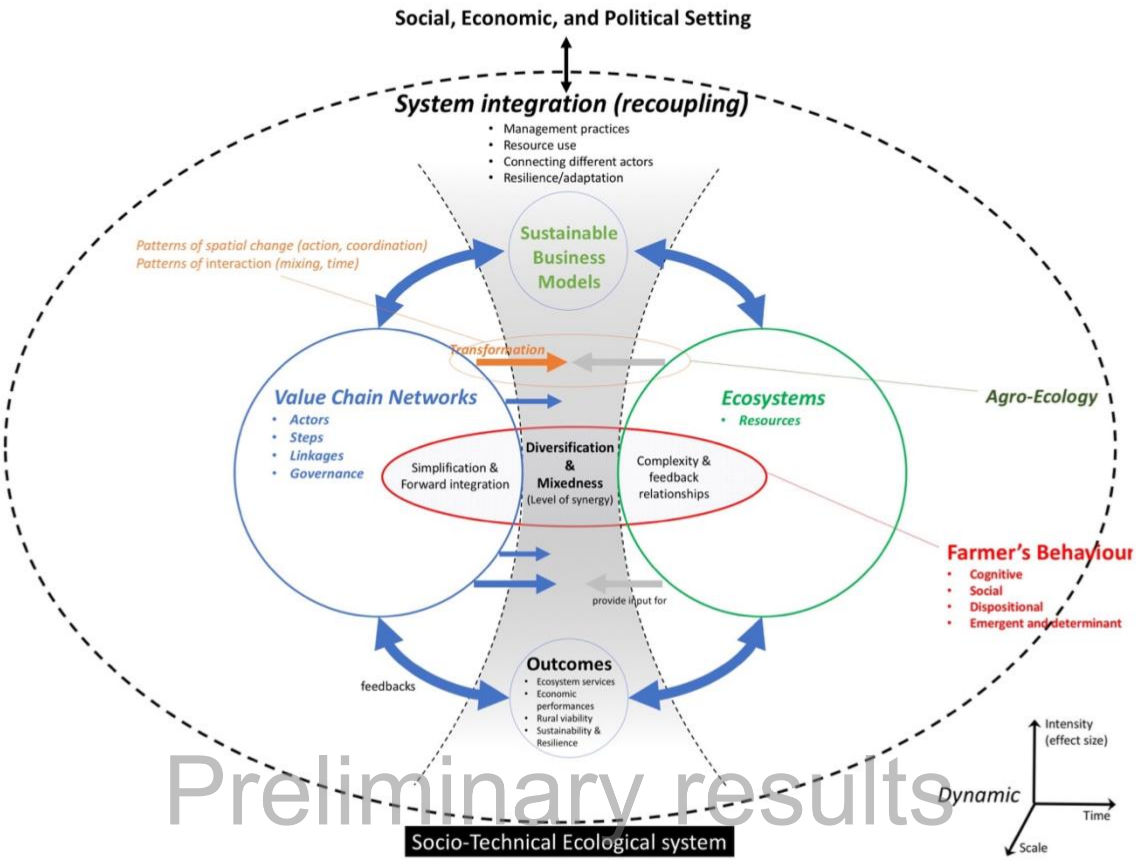

Fig. 1 The Socio-Technical Ecological system overview (authors' elaboration).

In line with the importance of human intervention in these 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.

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 through agroecology. 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

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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) 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. VCNs) 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 behavioral 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, 2017c, 2018a), 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) "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; E. Ostrom, 2007; Elinor 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

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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.

According to Dessart et al. (2019) we grouped the behavioural factors that exert a certain influence on farmers' adoption of environmentally sustainable practices 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 regard 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 supply chain networks, which is the ability, leaden by economic efficiency and localisation, technological, information and financial advantages, to relocate steps 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 social, environmental, and economic impacts (Wiedmann and

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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. 2 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.

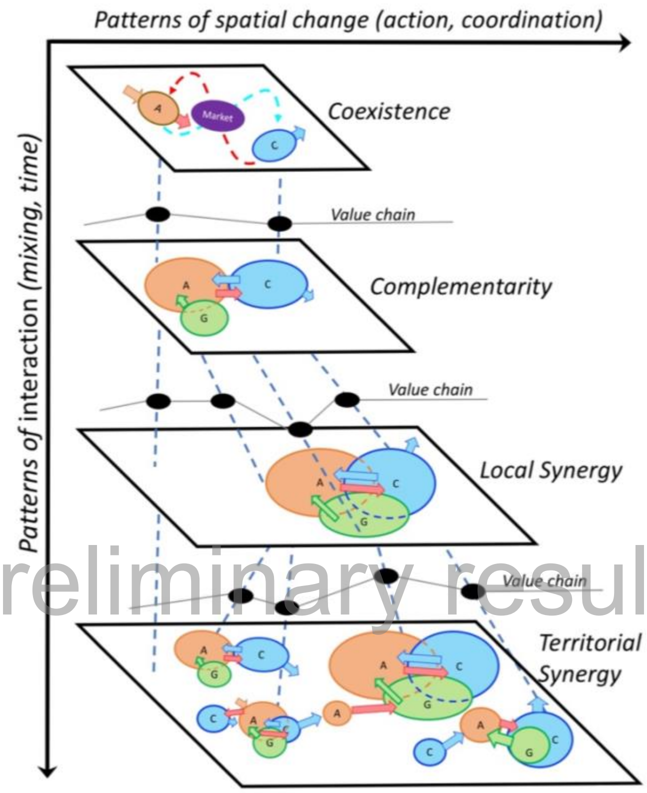

Fig. 2 Spatial configurations within the integration process of VCNs (authors elaboration on CANTOGHETHER project results).

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. 3).

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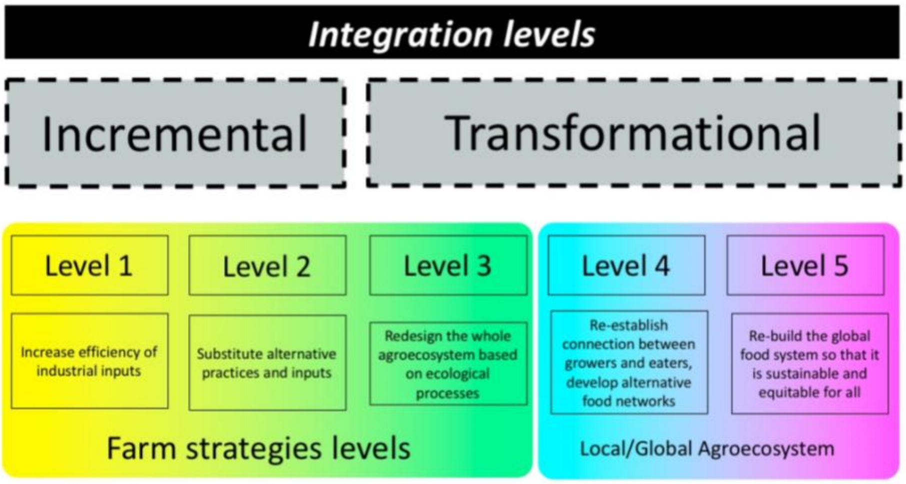

Fig. 3 Integration levels and farming/system changes (authors elaboration).

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 (ators 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.*

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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 and collaboration instances. At the DM level, the resulting coordination implies more interactions among the supply chain 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). With 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. At the spatial level (Fig. 2), we move towards the complementary model with increasing exchanges between the parts to fulfil their needs and manage resources. According to Heimeriks and Schreiner (2002), complementary resource use is key to supporting a successful collaboration (Dania, Xing, and Amer 2018). Then by increasing interaction, not only through the exchange but also due to an increase in the level of mixedness, the spatial coordination shift towards the local synergy. Finally, the integration arrives to a climax which delivers a deep interaction at the territorial level with territorial synergy. In such configuration, the sub-system has developed adaptation (ability to fine-tune new sustainable goals, tolerance to diversity and successful collaboration), increasing its overall resilience.

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3 AF/MF diffusion and socio-economic performance

Note: This section is incomplete. There are on-going delays in receiving the FADN data from the EC. This section will be completed as soon as the FADN data will be made available to the authors.

3.1 Overview

This section would understand the current diffusion of AF/MF and describe financial and socio-economic performance. In accord with the CF, we conduct both firm and territorial levels analysis of AF/MF, using FADN data.

3.2 Classification

The FADN is the main data infrastructure to provide macroeconomic data at a farm scale. The sampling procedure allows having data representative at the NUTS2 level. While MF is quite consolidated in literature and refers to existing FADN Farm typologies, the AF is challenged. In accord with Task 1.1, AF/MF definition overlaps. FADN data consider MF based on diversification of agricultural practices, in other words, the diversification is an external attribute to the agricultural system as often the definition of mixed farm refers to diversity or diversification of extra-agricultural activities rather than to a diversified development of livestock and crops. Based on that distinction, FADN provides a classification of Mixed versus Specialised farms using economic criteria (i.e. if a type of production has a standard output greater than 2/3 of the total farm SO[3] is classified as specialised). FADN provides three types of mixed farms: a) 60. Mixed crops; b)70. Mixed livestock; c) 80. Mixed crops and livestock. AGROMIX will refer to code 80 Mixed crops and livestock.

AF requires a definition that considers the synergetic aspects among different systems at the parcel level (tree, crops and livestock) and, therefore, is coherent with the mixed and extensive system. Such information can be obtained by databases that explicit overlap layers at the parcel level (i.e. LUCAS).

According to the lack of definition or the difficulties in providing one solution for both MF/AF, the important point is that. AGROMIX project could highlight such a gap, especially now that the interest is in promoting through Eco-Schemes the Agroforestry as a sustainable practice at the European level. In accord with that, a farm definition of AF will combine two dimensions: land use and economic:

[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.

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1) The land use criterion will be based on a threshold area allocated to trees/or wood. In accord with LUCAS definition, AF requires at least 10% of area allocated to trees or woods
2) The Economic will be based on a threshold on a measure of income diversification Herfindahl-Hirschman Index (HHI^{-1}) among the SO from crops, livestock and trees/wood.

3.3 Methodology

Note: This section is incomplete. There are on-going delays in receiving the FADN data from the EC. This section will be completed as soon as the FADN data will be made available to the authors. It will include methodology regarding the diffusion and performance of AF/MF systems.

3.4 Results

Note: This section is incomplete. There are on-going delays in receiving the FADN data from the EC. This section will be completed as soon as the FADN data will be made available to the authors. It will include results for the diffusion and performance of AF/MF systems.

3.5 Conclusion

Note: This section is incomplete. There are on-going delays in receiving the FADN data from the EC. This section will be completed as soon as the FADN data will be made available to the authors.

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