A framework for assessing mixed farming and agroforestry systems in agricultural value chains: A review

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Abstract

Mixed farming and agroforestry systems (MiFAS) are widely proposed to deal with ecological, economic, and social challenges that are associated with specialised farming systems. However, little is known about how MiFAS are integrated in food value chains and how value creation in MiFAS is rewarded by value chain partners. We here review the broad literature on mixed farming and agroforestry system (159 papers) with a particular focus on implications for food value chains. We use thematic analysis to code existing evidence and categorize these codes into the four major themes *Farm-level value creation, Impacts of the farming environment on value creation, Ecosystem service valuation, and Supply & value chain integration.* From here, we produce meta-narratives to summarise the literature within each theme. In a second step, we use these literature insights to develop a conceptual framework on possible value chain configurations that visualize MiFAS in food value chains. Our research delivers important implications for future research on MiFAS, that should focus more on value chain implication of this emerging food production system.

1. Introduction

The global agricultural paradigm is increasingly typified by specialised-intensive farming systems, characterised by their intensity of production, large scale, and specialisation (Lüscher et al., 2014; Moraine et al., 2014). On the one hand, thanks to the advancement of machinery, agrochemicals, breeding programmes, and globalised supply chains, the world is producing food in unprecedented quantities leading to the gradual diminishing of the threat of global hunger and malnourishment since the Green Revolution of the 1950s (Dalgaard et al., 2003; Evenson & Gollin, 2003). However, a growing scientific consensus charges specialised and intensive systems with the rapid depletion of nutrients in global soils (Borrelli et al., 2017), the excessive use of industrial chemicals to restore soil fertility and to combat resistant pests and diseases (Pingali, 2012), and increasing vulnerability to extreme weather (Olesen & Bindi, 2002). Economically, they are also increasingly susceptible to price risks (Tothova, 2011) and are associated with the widening dissonance across supply and value chains (McCorriston & Sheldon, 2007). Underpinning these accumulating ecological, economic, and social challenges are specialised farming's limited resilience capacities in the face of increasing uncertainty and shocks in agriculture (Meuwissen et al., 2019; Paas et al., 2021).

Mixed farming and agroforestry systems (MiFAS) present an opportunity to reduce some of these symptoms. The MiFAS design emerges from the principles of agroecology, which aims to increase the sustainability and productivity of agriculture while maintaining the environment (Francis et al., 2003; Kremen & Miles, 2012), and seeks to do so by incorporating scientific concepts from the disciplines of agronomy, ecology, sociology, and economics (Dalgaard et al., 2003; Gliessman, 2007). MiFAS capture synergies formed through the integration of different and multiple farming enterprises – arable, livestock, and forestry – in order that resources are more effectively utilised fostering more stable profits through diversification (Kirkegaard et al., 2014) and better environmental and ecological stewardship (Moraine et al., 2014; Ryschawy et al., 2012; Soussana & Lemaire, 2014). MiFAS have yielded promising results with respect to socio-economic (Bell et al., 2014; Darnhofer, Bellon, et al., 2010; Havet et al., 2014; Peyraud et al., 2014; Wilkins, 2008) and environmental sustainability indicators (Duru et al., 2015; Hendrickson et al., 2008; Horlings & Marsden, 2011; Kremen & Miles, 2012; Power, 2010; Russelle et al., 2007; Ryschawy et al., 2012). However, research on the value chain impacts of transitioning towards and employing MiFAS is missing, leading to uncertainty about their viability in the wider food production environment.

Our review of the literature will address how different MiFAS create, receive, and transmit value, and how these value chain processes fit in the wider food production environment. As products or inputs pass through the chain of activities performed by a MiFAS – such as though the integration of farming enterprises – value is created. MiFAS research highlights two chief discrepancies with regards to value chain implications. Firstly, the literature is disparate across different socio-economic regions, production systems and ecosystem processes, disciplines, and study designs, causing the limited value chain research to be particularly anecdotal. Secondly, existing research has conceptualised MiFAS by fusing biological, agroecological, and – to an extent – economic processes with spatial, temporal, and organisational integration between farming enterprises (Martin et al., 2016; Moraine et al., 2014). While these can be sufficient for the farming-level, no conceptual frameworks exist to associate MiFAS with upstream and downstream value chains actors. As such, the comparative advantages and deficiencies of different MiFAS have rarely been compared and contrasted. In essence, providing insight on MiFAS value chains is concurrent with the broader discussion surrounding the reconciliation of sustainability and resilience in agriculture.

2. Principles for conceptualising value chains in mixed farming and agroforestry systems

2.1. Mixed farming and agroforestry systems

A MiFAS can be described simply as a farming system that integrates different farming and agroforestry enterprises, wherein the multitude of processes and interactions between enterprises "create opportunities for synergistic resource transfers" over space and time (Martin et al., 2016). This general description broadly overlaps with other definitions in the literature for similar farming or agroecological systems, including those that more particularly identify with specific synergies, inter-species relations, or processes. In essence, we can therefore ascribe MiFAS to any combination of cropping/arable, livestock, and forestry enterprises (Figure 1). It should be noted that we do not give attention in the research to other integrated farming systems that are diversified intra-enterprise (for instance mixed cropping, such as strip farming; mixed livestock, such as mixing granivores and ruminants; or diversified tree stands).

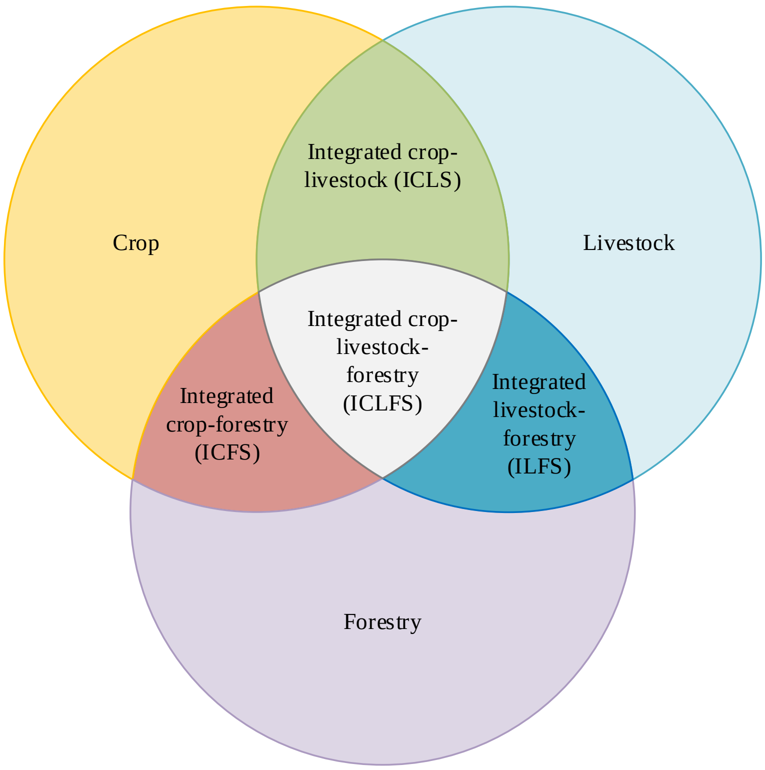


Figure 1. Diagram depicting the different combinations of MiFAS.

2.2. Value chains and ecosystem service valuation

According to Porter (1998), the value chain is the chain of activities performed by an actor, each of which adds value to a product. These value-added activities represent a myriad of different process that allow the value chain actor to create more value. In a MiFAS for instance, a farmer may lower her operating costs by reducing the use of inputs such as agrochemicals and replacing them with lower cost inputs or alternative processes (e.g. no-till, manure-spreading), allowing her to improve the profit margins, *ceteris paribus*; or a farmer could improve the attributable qualities of her outputs by utilising more environmentally friendly practices that could raise the prices of her outputs and differentiate them from competing products. However, value is created along the so-called “long value chain” (the value chains of multiple actors), and products and value are sold on from actor to actor until the point of consumption (Nagurney, 2006). As products are sold, economic value is internalised by the selling actor (e.g., as profit), in simple terms reflecting market, and supply and demand forces.

Furthermore, in all value chains, some values are not always internalised, and are known as externalities. These can be negative (e.g., as pollution) or positive (e.g., carbon capture); as externalities, the cost of producing negative externalities or the benefits of producing positive externalities are not transmitted or valued economically along the value chain. As such, some processes and activities create value that is not in the form of a tangible output for revenue, particularly if they are ecologically or environmentally driven processes (Power, 2010). Being agroecological farming systems, MiFAS are designed to create value for the food production chain, which can be more or less internalised, i.e., either valued by the end consumers, other value chain actors, or public institutions. Such values can be environmental, ecological, or societal. For our research, similarly to Gaitán-Cremaschi et al. (2015), we place the MiFAS in the long value chain where it creates and transmits tangible value while acknowledging that through ecosystem services produced it also creates additional externalities (Figure 2).

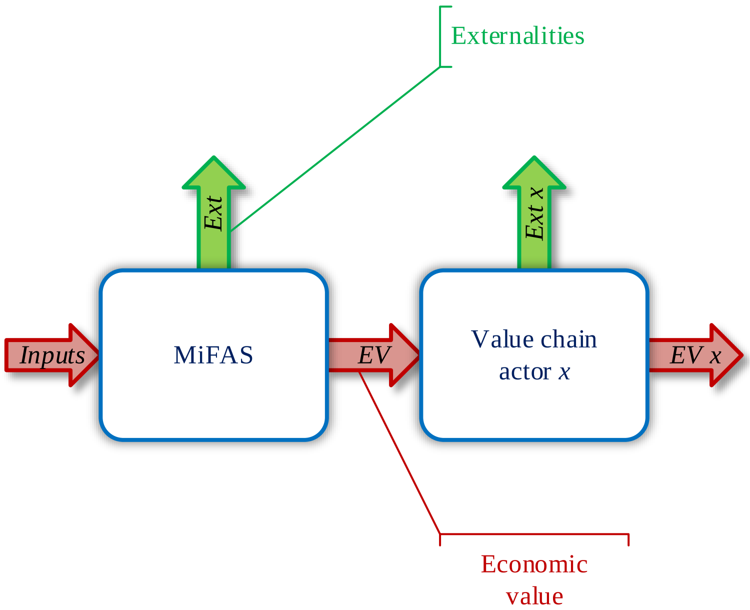


Figure 2. Schematic representation of a MiFAS in the value chain, representing flows of economic value (in red) and externalities (in green).

3. Methods

3.1. Transposing principles into the literature search

In order to select articles that addressed the potential impacts of MiFAS on value chains, we followed the PRISMA protocol (http://www.prisma-statement.org/) for performing systematic literature reviews (Moher et al., 2015). We formed a search string using the *Scopus* citation database (https://www.scopus.com) to search for relevant literature pertaining to the subject of this review; that is, literature studying the value chain impacts of mixed farming and agroforestry systems. Logically, the search string was split into two sections joined by the AND operator so as that articles returned in the search must meet two sets of inclusion criteria.

Keywords and terms in the first set are included to return papers on value or supply chains, farming system design, or which are explicitly review or framework papers. Acknowledging that value chain literature on MiFAS is sparse and our desire to keep a system-wide view (i.e., the whole MiFAS) rather than on singular processes we selected broad-reaching keywords for this half of the search. We also specifically chose papers that include the root "compar*" (i.e., to return "comparison", or "comparing") for their breadth of scope.

The first set:

TITLE-ABS-KEY ("supply chain" OR "value chain OR "farm* system design" OR "production chain" OR "upstream" OR "downstream") OR TITLE ("review" OR "framework" OR "compar*") OR KEY ("chain")

The second set is comprised of different synonyms and arrangements of MiFAS. These keywords were chosen based on our understanding of the various integrated farming systems encompassing a multiple of farming enterprises; namely arable, livestock, and forestry. We identified these, other synonyms and specific variations of MiFAS from our early scoping of the literature.

The second set:

TITLE-ABS-KEY ("integrated agriculture" OR "integrated farm*" OR "mixed-farm*" OR "crop-livestock" OR "livestock-crop" OR "dual-purpose" OR "agroforestry" OR "crop-forestry" OR "forestry-crop" OR "livestock-forestry" OR "forestry-livestock" OR "silvopasture" OR "crop-livestock-forestry" OR ("crop" W/2 "forestry" AND "livestock") OR ("crop" W/2 "livestock" AND "forestry") OR ("livestock" W/2 "forestry" AND "crop") OR ("integrat*" W/2 "crop" OR "forestry" OR "livestock"))

Additionally, we specifically chose not to include keywords or terms relating to ecosystem services as much research has already been done about this topic in the service of agroecological farming systems. The valuation of ecosystem services (for instance *true cost*/*price*) also has its own strand of literature. However, as we have acknowledged earlier (see Section 2), the nature of MiFAS as an agroecological farming system design concerns processes that create societal and environmental value (or negate negative externalities). While not featuring in the search string, we nonetheless allowed in our methods and later thematic analysis (see Section 3.2) for the valuation of ecosystem services to emerge in our discussion of the literature, given its importance in the broader discussion of MiFAS value chains. We focused on peer-reviewed papers, namely articles and reviews published in journals indexed in *Scopus* – therefore excluding grey literature – and written in the English language. *Scopus* was used as it is the largest and most expansive database for scientific articles (including *ISI Web of Science*) and includes articles from a large variety of academic fields and journals.

Our search yielded 1,333 results (Figure 3). First, we performed a screening in order to eliminate duplicate entries and papers indexed on *Scopus* but for which no links to the articles could be found (e.g. .pdf files, journal hyperlinks, etc.), leading to the exclusion of 28 papers. Following this, all papers were subjected to further screening by one of the authors to scrutinise their content and their relevancy. The three inclusion criteria were: 1) the paper is set in the developed economies of Europe (EU28), Northern America, Australasia, and Eastern Asia (excluding China); 2) the paper has a focus on agricultural and/or food production, or on agricultural supply and/or value chains; and 3) the paper can specify a mixed farming or agroforestry system. These three inclusion criteria were imposed in order for the retained papers to be topically and contextually relevant to the review. While developing economies present highly relevant and interesting studies on MiFAS (namely Brazil, China, and India), their supply and value chain contexts and the trends facing their agricultural systems offer paradigms too different from those found in the included regions. 161 papers were retained, which we subdivided into three categories: highly relevant (12), moderately relevant (44), and slightly relevant (105) (Figure 3). A paper's relevancy is determined by the context and scope of discussion concerning value and supply chain impacts. More relevant papers explicitly discuss the value or supply chain impacts of MiFAS and analyse or compare the merits of different MiFAS configurations; whereas slightly relevant papers make an important point on value chain impacts but are otherwise implied, contextually narrow, or lack external validity. Papers in each category feed into the thematic analysis (Figure 3), where highly and moderately relevant papers were therefore expected to impel the thematic analysis (see Section 3.2) and discussion, while slightly relevant papers were expected to provide additional supporting evidence.

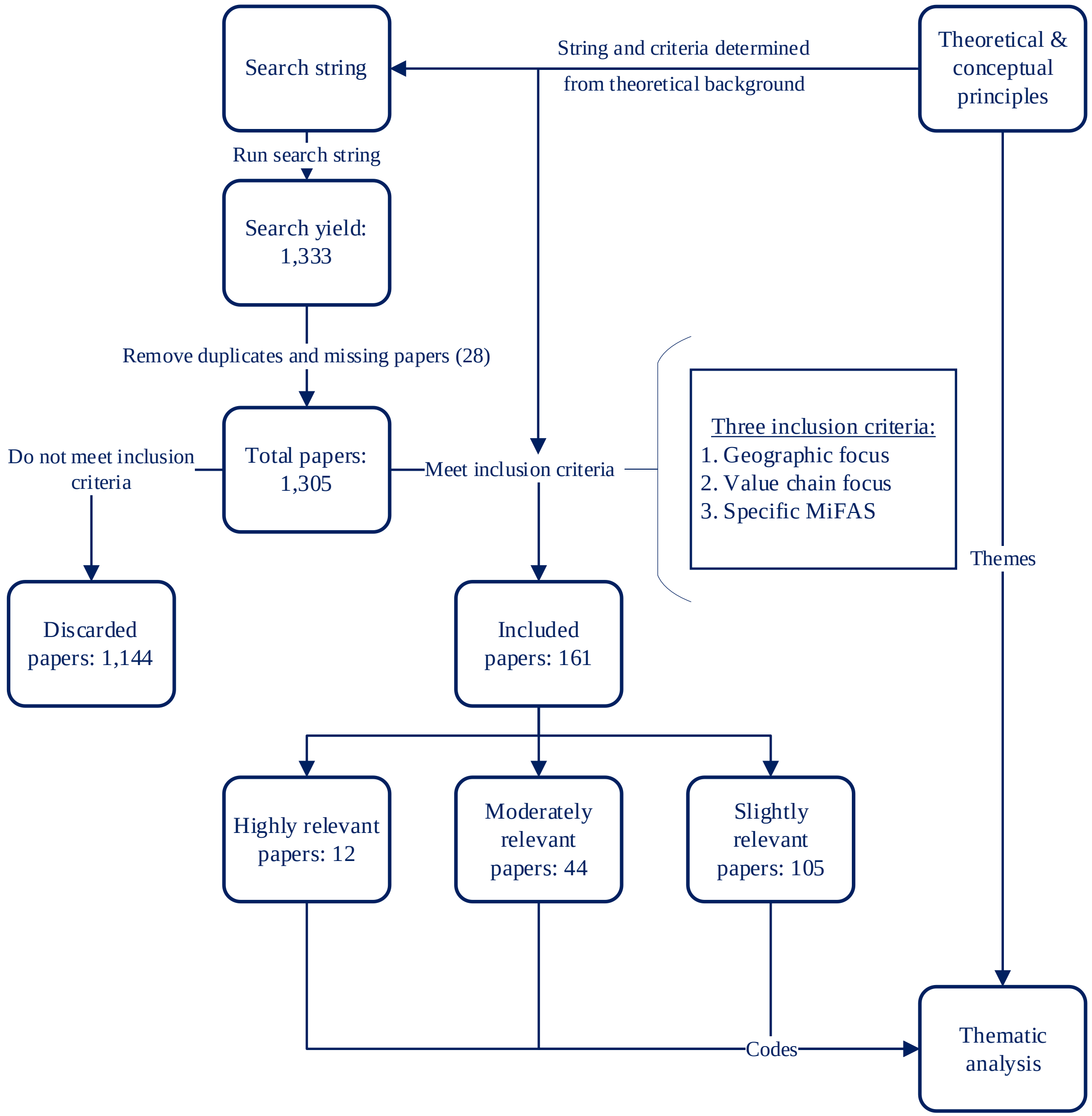


Figure 3. Schematic overview of the method used to perform the literature review, following the PRISMA guidelines

3.2. Methodology for analysing the literature

Thematic analysis is a method for identifying, analysing, and reporting patterns within qualitative data (Snyder, 2019; Ward et al., 2009). Specific approaches and methods for performing a systematic thematic analysis are established in Braun and Clarke (2006) and Thomas and Harden (2008), wherein qualitative codes (describing basic features of data) are generated from text, and are then clustered into themes – the units for analysis. According to Braun and Clarke (2006), themes can be identified in two primary ways: through induction (bottom-up) or deduction (top-town). Our review used the deductive approach for the themes, mainly as we are concerned with exploring pre-determined themes. In order to determine the themes, we used the conceptual principles from Section 2, from which we have identified four main themes centred around the creation and transmission of value in MiFAS chains.

The first principal theme was *Farm-level value creation*, centred upon value being created specifically within the farm-level boundary and considering the processes for value creation strictly performed within the MiFAS. Chiefly, these would be the values that are produced as a consequence of the integration of the various farming and agroforestry enterprises. The second theme was *Impacts of the farming environment on value creation*. This theme addressed the influencing factors that could influence value creation in the MiFAS, where the farming system must respond to the pressures outside of its control or boundary and which can affect how value is subsequently created by the MiFAS. Thirdly was *Ecosystem services valuation:* this theme addressed the value that is not always immediately internalised through the sale of products from a MiFAS, where the value created and transmitted is often non-tangible, but which could be appraised either economically or socially and/or ecologically. Fourthly and lastly, the theme *Integration in the long value chain* concerned the integration of the MiFAS in the long value chain, where the value created by the farm-level is directly linked with the interactions that the farming system has with both upstream (e.g., for farming inputs) and downstream actors (e.g., buyers of farming outputs).

With the themes generally having been established, qualitative codes could then be produced from the literature. In Braun & Clarke (2006), it is suggested that initial codes are produced from data extracts (e.g. from the literature itself) that are of interest to the analyst, and refer to the most basic elements of the raw data such that they can be analysed in a meaningful way. In the initial process, this required that as many codes were created for the themes as possible, while also being able to grasp the nuances of the surrounding data (such as the context). Codes for data extracts at their earliest inception could also fall under multiple themes. In our work, we undertook this initial process to generate 65 separate codes from the 12 most relevant articles. In a second step we re-focused the codes at the thematic level, requiring that codes were repurposed to better align with the identified themes and to clear inconsistencies, as proposed by Braun & Clarke (2006). For instance, longer codes were split into separate and distinct codes falling under different themes; overly detailed codes were simplified to better reflect patterns in the data rather than the raw data itself; and normative codes were turned into positive codes. This second step allowed us to reduce the number of codes to 46 simpler, distinct and nuanced codes. Furthermore, this step simplified the task of processing the remaining articles identified in the search, such that the codes could be reused where applicable and new codes created where necessary (such as new data hitherto uncoded); thus, most codes would reappear across papers, and the nuances of the arguments and discussions found in the literature would be discussed in greater detail in the subsequent thematic analysis.

Later, we used the codes, now grouped under the four themes, to extract meta-narratives per theme. As MiFAS literature is diverse and specific research on value chains is limited, we produced meta-narratives in order to qualitatively review thematically relevant literature and the topic's development across research traditions (Snyder, 2019). Meta-narratives are used to tell a compelling and coherent story from the literature while providing concrete evidence and examples from the data to "capture the essence of the point you [*sic*] are demonstrating, without unnecessary complexity" (Braun & Clarke, 2006). Meta-narratives are comparable with meta-analyses, where the latter is typically applied to summarise quantitative empirical literature (DerSimonian & Laird, 1986; Wong et al., 2013). Once the codes had been extracted from the literature and placed under their appropriate themes, the meta-narratives could be produced. Furthermore, we also identified in three of four themes (*Farm-level value creation*, *Impacts of the farming environment on value creation*, and *Ecosystem services valuation*) that sub-themes were required in order to give structure to the codes we had identified and to allow us to discuss complex sub-issues within themes. Once we had cemented the purpose and content that each theme will discuss, we proceeded with the producing the thematic analysis (i.e., the meta-narratives). Therefore, the extraction of meta-narratives brings together the storylines (i.e., codes) within each theme. We therefore place this part of the analysis in the discussion section of the paper.

3.3. Building a conceptual framework

While analysing the literature, we observed that a common understanding of how MiFAS value chain actors interact with each other is lacking. Therefore, we propose a conceptual framework of MiFAS configurations, i.e., value chain designs, which is informed by what we observed in the papers being included in our thematic analysis. We were suitably placed to identify how different configurations of MiFAS create value and believe that an overview of these can help to identify and refer to value chain configurations in future research, the factors that influence it from within, in addition to how that value is a result of external factors and its integration in the long value chain.

4. Results

Using the procedure described in Figure 3, we identified 159 papers that relevant for the review. We classified these into 12 which are highly relevant, 37 which are moderately relevant, and 109 which are slightly relevant. In this working paper, from our reading of 20 research articles, we identified 46 codes. In Figure 4, we categorize these codes into sub- and main themes that we derived from our theoretical background section 2. In theme 1, *Farm-level value creation*, we identified the two sub-themes *1a. Configuration design* and *1b. Coordination management* which include 15 and 8 papers, respectively. In theme 2, *Impacts of the farming environment on value creation* we identified three sub-themes *2a. Biophysical*, *2b. Political & institutional*, and *2c. Economic*, including 3, 4, and 5 papers, respectively. In theme 2, *Ecosystem services valuation*, we identified two sub-themes: *3a. Economic valuation* and *3b. Ecological valuation*, with 5 and 8 papers, respectively. Lastly, theme 4, *Supply & value chain integration* is standalone, with 3 papers included. We thus observe that most papers are dealing with issues in theme 1 followed by themes 2, 3, and 4. Tables 1a and 1b list the codes by theme and sub-theme and summarise the frequency by which they appear amongst the 20 research articles read.

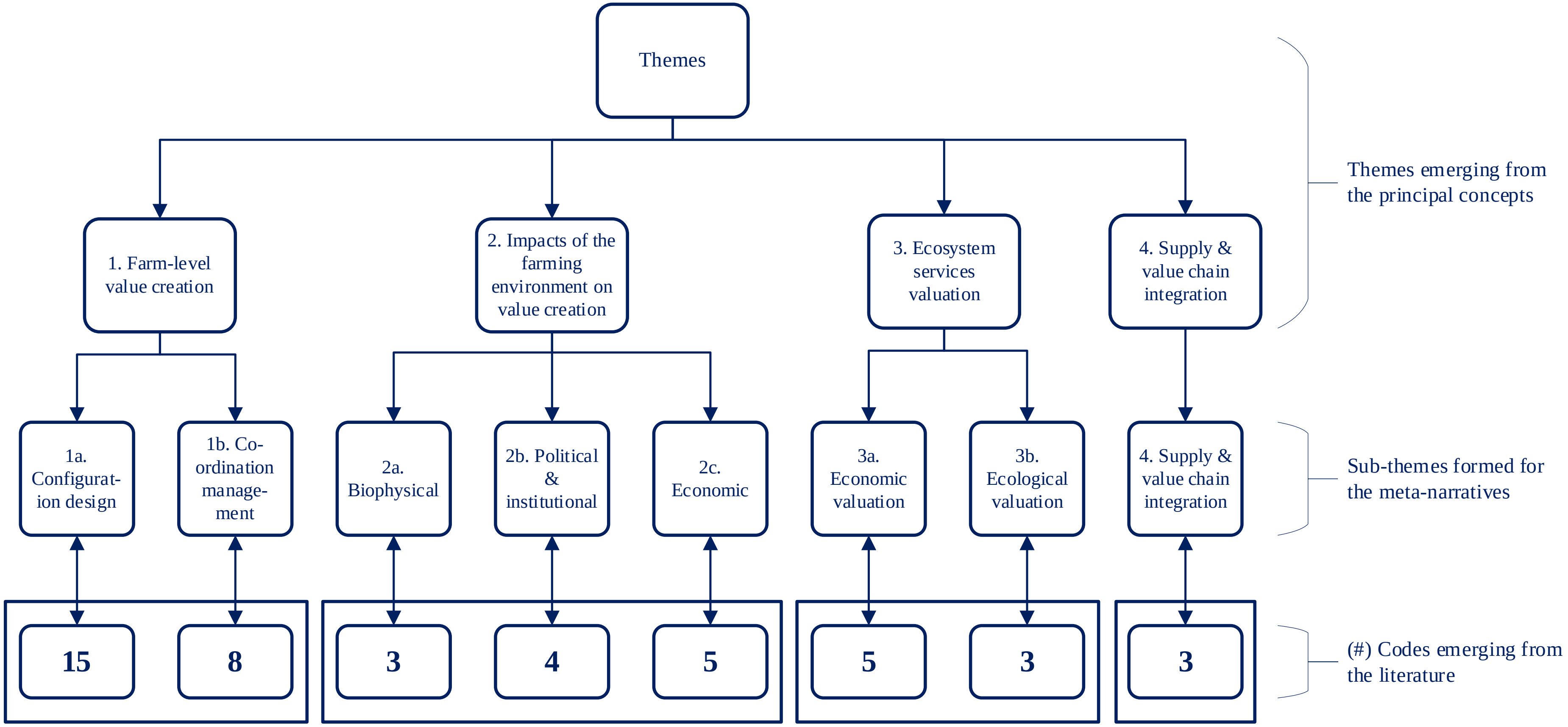


Figure 4. Schematic overview of the thematic structure for producing the meta-narratives

Table 1a. List of codes sorted by themes and sub-themes, including frequency of appearance in 20 research articles

Theme	Code List	Code	Frequency
Farm-level Value Creation (1)	1	*Diversification provides flexibility and adaptive capacity against adversity*	1
	2	*Diversification stabilises income*	2
Configurations Design (1a)	3	*Diversification without integration (fewer synergies) limits benefits*	1
	4	*Diversified holdings are harder to upscale*	2
	5	*Ecosystem services decrease variable input use and costs*	11
	6	*Ecosystem services increase yields*	8
	7	*Ecosystem services permit synergistic and continuous production cycles*	3
	8	*Fixed costs are more significant in IS with greater integration*	1
	9	*Functional integrity of ecosystem services increases with diversity and synergy over time and space*	2
	10	*IS performs better under adverse conditions than specialised systems*	2
	11	*Labour costs are more significant in IS with greater integration*	3
	12	*Land competitively used negatively affects yields*	1
	13	*Land is used more efficiently through layering of enterprises*	3
	14	*Short-term opportunity cost of knowledge impedes IS*	4
	15	*Temporal adjustments of IS designs gradually reduces exposure and vulnerability to adversity*	2
Co-ordination Management (1b)	16	*Coordination between farmers creates internal supply chains and standardisation*	3
	17	*Coordination between farmers is prohibitively difficult*	3
	18	*Coordination between farmers/enterprises creates internal markets that improve value creation and retention*	4
	19	*Coordination between farmers/enterprises improves risk sharing, flexibility, and resilience to adversity*	7
	20	*Coordination between farmers/enterprises produces more ecosystem services*	3
	21	*Coordination between managers reduces costs of labour and knowledge*	2
	22	*Extensive management is required for spatial integration*	2
	23	*Management costs/requirements (management and planning) increase in IS*	3

Table 1b. List of codes sorted by themes and sub-themes, including frequency of appearance in 20 research articles

Theme	Code List	Code	Frequency
Impacts of the Farming Environment on Value Creation (2)	24	*Agroclimatic conditions constrain ecosystem services and integration*	2
	25	*IS can take better advantage of marginal agricultural land*	8
Biophysical (2a)	26	*IS is more resilient to climate and weather risks*	5
Political & Institutional (2b)	27	*Policy disincentivises certain IS designs (e.g. food safety)*	6
	28	*Policy does not sufficiently subsidise IS ecosystem services (e.g. for the cost of provision of public goods)*	6
	29	*Policy reinforces specialisation of management skills*	3
	30	*Policy reinforces specialisation of supply chains*	2
Economic (2c)	31	*Higher costs of labour negatively affect labour intensive activities such as those involved in IS*	5
	32	*IS is more resilient to price volatility for inputs and outputs*	2
	33	*Low socio-economic capital (e.g. rural abandonment) in regions inhibit IS*	3
	34	*Social vulnerability proxies a farming system's ability to cope socio-economically to adverse conditions*	1
	35	*Specialised (technological and homogenised) systems are more affordable and straightforward than IS (leading to specialisation in territories?)*	4
Ecosystem Services Valuation (3)	36	*End-consumer awareness of IS value-added is lacking*	1
Economic Valuation (3a)	37	*Labelling IS outputs increases perceived value*	2
	38	*Labelling/certification costs impede IS*	2
	39	*Labelling/certification for IS outputs is lacking*	3
	40	*Social value-added motivates IS*	4
Ecological Valuation (4b)	41	*Conservationism motivates IS*	3
	42	*Ecosystem services (including those intermediately consumed) are economically undervalued (positive externalities are not internalised)*	3
	43	*IS produces fewer negative environmental externalities (to be addressed by the public domain)*	3
Supply & Value Chain Integration (4)	44	*Direct marketing, voluntary price signalling, and Coasean agreements extend value captured within IS boundaries*	3
	45	*Existing supply and logistics chains determine IS design*	2
	46	*Weak supply and production chain integration and influence reduces IS competitiveness*	4

5. Discussion

5.1. Meta-narratives

5.1.1. Farm-level value creation

Sub-theme 1a. Configurations design

Sub-theme *1a. Configurations design* emerged as a distinct sub-theme as its primary focus was on the processes performed strictly through the integration and interconnectedness of farming enterprises within the so-called "farming boundary"; i.e., farming activities. This entails value being produced through the integration of production of the various farming and agroforestry enterprises over time and space dimensions.

It was found that integration tends to improve yields and land-use efficiency and can reduce variable costs. Namely, most of these benefits are tied directly to the provision of ecosystem services, which decrease the need for synthetic inputs such as fertilisers and pesticides (being replaced instead by biological processes) and therefore can reduce variable costs (11)*; and can improve yields (8) particularly by allowing for synergistic and continuous production cycles (3) that allow land to be used more optimally and mobilise greater biological activity (3). Furthermore, the functions of ecosystem services are reinforced by time and a greater diversity of biological processes in the farming system (2). Therefore, as ecosystem services are continually provisioned within the farming system, the greater the production and efficiency benefits.

* Numbers between parentheses represent the number of papers making the preceding point and are in reference to the codes found in tables 1a and 1b

However, increases in yields and efficiency can be withheld by constraints. Firstly, land may be used more effectively, but only up to the point where it is not being used competitively amongst farming activities (1); and, for ecosystem services to materialise into production benefits, diversification should lead to synergies, as a lack thereof increases the likelihood of resource competition (1). Secondly, while variable costs can be reduced, integrated systems also seem to face significant challenges with respect to fixed costs, such as of capital investments (1), and of labour (3). Diversified holdings tend to require a higher minimum required threshold for farming infrastructure and machinery and of labour (likely exceeding what can be available on a family farm, for instance); as such integrated systems may also be harder to upscale due to these cost constraints (2). Limited knowledge can also be a drawback for farms seeking to become more integrated and presents a significant opportunity cost (4).

While the effects of integration on costs seem contentious, integrated systems present a greater degree of adaptability against adverse conditions (1) and can perform better than specialised systems under adversity (2), such as by providing income stability as diversification can spread revenue streams (2). Furthermore, the longer a farm remains integrated and diversified, the more such a farm can manage its resilience to adverse conditions (2); ecosystem functions also seem to play a reinforcing role in increase resilience capacities.

In essence, sources of value creation within a MiFAS stems from its ability to reduce variable costs as well as maintain if not raise yields, primarily by improving the efficiency that resources such as nutrients and land are utilised; the process itself being directly governed by the provision of ecosystem services. Value creation in a MiFAS, however, is stymied by constraints not necessarily linked with the provision of ecosystem services themselves (which are typically biological in nature), but rather take on a socio-economic streak. The high cost to work an integrated system in terms of economic and human capital may affect the viability of MiFAS. Specific advantages of MiFAS versus specialised or less integrated/diversified farming systems may manifest in their purported ability to be more resilient under adverse conditions and over longer periods of time, as strengths are reinforced and challenges overcome. Rather than assessing the added value of MiFAS in the short term, the benefits of MiFAS may need a more nuanced, longer-term perspective and assessment.

Sub-theme 1b. Coordination management

Distinctly from configurations design, this sub-theme emerged to address the importance of a third dimension of integration: management. Particularly, the management of integrative processes was identified as a key driver for their intensity and scale; where the management capabilities, capacities, and desires of farmers may affect the degree to which the farming system is integrative. Additionally, this allowed us to additionally interpret a MiFAS farming boundary as one that can also enclose multiple interconnected farm businesses, including functionally specialised farms.

It was found that increased coordination between farmers is highly desirable, as it implicitly allows for greater integration between the enterprises themselves. In so doing, coordination between farm managers enables the provision of more ecosystem services (3), which as mentioned earlier has a positive knock-on effect on production synergy, while additionally enabling internal markets and supply chains to form allowing farms to improve value creation and retention (4) potentially increasing the farming system's ability to negotiate with downstream actors. Internal markets themselves can also be partly facilitated through the standardisation of production (3). With closer integration, value may also be added into the

MiFAS boundary by reducing costs of labour and opportunity costs of knowledge through the pooling of resources (2), while simultaneously permitting greater risk sharing and flexibility against adversity (7).

However, increased coordination and integration between farms has been found to be prohibitively difficult (3), as synergising processes and operations over time and space requires extensive management from involved parties (2); differences in management styles, planning, and risk attitudes only become more exacerbated as the prerequisites (such as trust) and costs for closer integration increase (3).

By expanding the definition for what a MiFAS boundary may encompass, i.e., multiple farm businesses, we could identify that coordination between farms has the potential to multiply the productivity benefits of integration at the farm-level, such as by increasing the provision of ecosystem services and reducing operating costs. Furthermore, it may also enable farms with different specialisations to engage with one another and make use of comparative advantages, such as in knowledge and capital. Internal markets and supply chains facilitate trade and exchange of by-products and resources such as land; significantly, this may also enable farms to increase the territory upon which integrative operations take place; for instance, expanding the useable area for farming rotations. However, the high management cost of coordination hinders the adoption of more integrative practices between farming enterprises; interpersonal challenges may not necessarily be overcome by economic arguments alone. It may suffice that integrating practices may be kept to an acceptable maximum while the source of value-added comes from the boundary’s interactions with downstream value chain actors.

5.1.2. Impacts of the farming environment on value creation

Sub-theme 2a. Biophysical

Darnhofer, Fairweather, et al., (2010) indicated that the behaviour of farming systems is nested within three main domains: the ecological (for our sake named biophysical); policies and social norms (political and institutional); and economic. We purposed these domains as broadly concerned with the factors that can influence value creation in a MiFAS, where the farming system has to respond to pressures outside of its control or boundary and which can affect how value is subsequently created by the MiFAS.

Sub-theme *2a. Biophysical* identified three codes. Agroclimatic conditions such as weather and geography may constrain the kinds of ecosystem services produced and forms of integration (2). In the high rainfall zone of southern Australia, Nie et al. (2016) describe that in drought events crop-pasture intercropping (rotating cropping and livestock) may exacerbate grain yield penalties as a result of competition for above- and below-ground resources, while stubble grazing by livestock may reduce soil cover essential for moisture retention and organic matter recycling. It should be noted that in Nie et al. (2016), yields can be improved under normal growing conditions. On the other extreme, Alary et al., (2019) describe that if climatic and growing conditions are ideal for specific agricultural productions, lower-value productions are pushed towards more marginal and less productive lands enforcing agricultural specialisation in regions; in this case in southern France, areas suitable for high-value permacultures (such as vineyards and orchards) tend to exclude livestock. As such, growing conditions may cause the dislocation and disassociation of farming enterprises and limit integration.

On the upside, integrated systems may nonetheless take better advantage of marginal agricultural lands (8), where the provision of ecosystem services may enhance the suitability and profitability of farming enterprises. In New Zealand, the integration of trees (including for timber) in pasturelands on North Island alleviates issues of soil erosion arising from difficult topography, high rainfall and highly erodible soils, enabling farmers to maintain productive systems in lands sometimes even too steep for livestock systems alone (Cubbage et al., 2012). The adoption of silvopasture and silvoarable systems in areas exhibiting high temperature and humidity conditions such as in the southern United States can both improve the productivity and wellbeing of livestock and reduce the severity of crop-losses due to drought and flooding, respectively (Cubbage et al., 2012). By extension, as climate and weather risks become more frequent and severe due to the onset of climate change, integrated farming systems have also been shown to be more resilient (7).

We have found that the biophysical environment plays a particularly important role in determining the kinds and amount of ecosystem services produced by a MiFAS. While it is found that some integrations are not necessarily optimal under specific environmental conditions, or when such a situation arises where the value of ecosystem services are not greater (in terms perhaps of economic returns) than employing specialised systems, MiFAS may nonetheless be better suited to utilise marginal lands where high-value production is limited. In cases where the provision of ecosystem services through integration improves the productivity and resilience of farming systems over specialised systems, a MiFAS may be able to create more value-added, particularly over longer periods of time where changes to weather patterns are concerned. This could open the possibility for repurposing land that has otherwise been abandoned due to environmental and geophysical challenges with relatively higher value-added productions.

Sub-theme 2b. Political & institutional

Under sub-theme *2b. Political & institutional*, we identified that significant barriers exist for the adoption or practice of MiFAS. We find that policy has a tendency towards disincentivising MiFAS designs (6). In California, for example, regulation on the passing of one year between the application of raw manure and the planting of leafy greens effectively forces farmers to separate crops from livestock – while meeting the regulation (Leafy Green Marketing Agreement) is voluntary, downstream buyers may identify produce coming from ICLS as hazardous (Hilimire, 2011). Barriers can emerge from a lack of subsidies, support or awareness of the ecological and societal value that integrated systems may have (6); in the EU, for example, there is a distinct lack of subsidies or support schemes integrated in the Common Agricultural Policy for integrated systems, affecting economic profitability, causing land-use polarisation, and harming the integrity of existing integrated systems (Flinzberger et al., 2020; Havet et al., 2014). All the while, agricultural policies in Western countries (such as in Europe) have historically focused on increasing productivity, increasing health safety and standardising agricultural production. In recent years awareness for the impacts that agriculture has on the environment has led to a gradual shift in policy objectives. This has largely pushed for more regulation on limiting the negative impacts of agriculture in the reins of the free-market (Duru & Therond, 2015). As a result of weak policy, few farmers are incentivised to either transition to or maintain MiFAS and has the knock-on effect of reinforcing the specialisation of farming systems, leading to an institutional lock-in effect of both management skill specialisation (3) and supply chain specialisation (2).

Sub-theme 2c. Economic

In this sub-theme, the most significant issue identified centred around the high cost of labour, which more significantly affects farming systems that perform labour intensive activities such as those involved in integrated farming (5); labour requirements to perform integrated farming tend to increase or become more intense, offsetting cost reductions. Exacerbating this issue is the lack of social capital in farming regions (e.g., in the form of rural abandonment), leading to labour shortages that could more severely affect integrated systems (3). For instance, an evaluation of crop-livestock systems in the United States suggested that labour requirements increased by 59% and 232% when alfalfa and livestock are introduced to farming systems, respectively, while at the same time an aging and diminishing rural population makes labour intensive work less sustainable (Hendrickson, 2020), forcing systems to specialise (requiring less labour and capital). In other regions, such as in the Mediterranean, high costs and low profitability of extensive livestock systems have further led to rural abandonment and intensification, at the expense of extensive crop-livestock and agroforestry systems that require both ecological diversity and knowledge capital (Aguilera et al., 2020). However, in being more diversified, integrated systems can nonetheless be more resilient against market and price risks such as price volatility for inputs and outputs; the former due to being less dependent on external inputs, and the latter due to diversification (2).

It emerged that specialised farming systems tended to be both more affordable and straightforward than integrated systems, being less dependent on increasingly limited socio-economic capital of agricultural regions (4). While market and price risks may be reduced in MiFAS, a significant limiting factor surrounding the viability of MiFAS seemed to concern how well they can be integrated in farming regions where broader socio-economic trends are pushing towards specialisation. Interestingly, the literature has suggested that social vulnerability, for instance in rural job security, could proxy a farming system's ability to cope socio-economically to adverse conditions (1); while labour demands may increase in integrated systems, such farming systems that require more fulfilling and permanent employment could alleviate trends in depopulating rural areas.

5.1.3. Ecosystem services valuation

Sub-theme 3a. Economic valuation

Sub-theme *3a. Economic valuation* emerged as the first of two sub-themes on ecosystem services valuation. We recognised that value is not always immediately internalised through the sale of MiFAS products, where value created and transmitted is sometimes non-tangible but which could be appraised in the value chain. In this regard, the literature has highlighted labelling as a positive recourse towards capturing more value within the MiFAS boundary, as labelling outputs that are produced using ecosystem services increases consumers' perceived value (2). For instance, labelling and certification schemes permit quality assurance to consumers (Röhrig et al., 2020). Additionally, labelling outputs from regions traditionally employing integrated farming, such as with geographic indicators, may also support their conservation by increasing value-added and alleviating issues of land abandonment and intensification (Flinzberger et al., 2020). Labels may also support the establishment of internal markets that can strengthen the cohesion and social interactions of integrated farmers (1) (Moraine et al., 2014).

Barriers against labelling exists, however. Firstly, labelling and certification standards are simply lacking (1). This can be due in part to the costs of producing, implementing, and marketing a label being too expensive (2), while all the while market infrastructure and consumer awareness of the value-added of MiFAS products are negligible (2). Implicit in the labelling process requires a substantial degree of coordination and compliance between MiFAS, in order to both market outputs and reduce costs. Cooperative structures and collectively processing primary outputs into added-value secondary products allow farmers to take greater ownership of their value chain and capture more value. It was suggested in Röhrig et al., (2020) that small scale, direct marketing of MiFAS products could both overcome marketing and labelling costs by appealing to consumers' beliefs of nutritional and physical characteristics of products, taste, origin, animal welfare and environmental stewardship.

Sub-theme 3b. Ecological valuation

Ecosystem services may alternatively create ecological value that is not appraised in the value chain and instead produce externalities that are nonetheless consumed in some fashion. Valuing the ecological externalities produced from ecosystem services should have for an objective to make producing positive externalities more equitable. Conservationism seems to be motivator for implementing and supporting integrated systems, as such systems are dependent and interlinked with the local ecologies that they are situated in (3), such as the silvopastoral montado system that has played an important historic role in the Portuguese agricultural landscape (Flinzberger et al., 2020). Beneficiaries of the impacts of the ecosystem services produced by MiFAS (such as in reducing negative externalities and creating positive externalities) tend to be both the farmer and the public domain. The farmer may benefit from ecosystem services by increasing their resilience and reducing risks (such as against weather shocks or fire incidence). The public domain broadly benefits from better agricultural practices that may limit environmental and ecological degradation, for example (3) (Alary et al., 2019;

Campos et al., 2020). However, the need to form mechanisms to support the provision of these ecosystem services must come through better evaluating the true cost of producing them. Subsidies or environmental credit schemes may help to promote integrated farming systems, as would appraising the intermediate processes that produce inputs to be consumed during the production process of primary outputs; for instance, inputs that would otherwise be considered without value such as by-products or waste (e.g., rotten fruit or overgrowth that can be eaten by livestock) (3) (Campos et al., 2020).

5.1.4. Supply & value chain integration

This standalone theme concerns the integration of MiFAS in the long value chain, where the value created by the farm-level is directly liked with the interactions the farming system has with both upstream actors (e.g., for farming inputs) and downstream actors (e.g., buyers of farming outputs). It was found that weak supply and production chain integration and influence reduces that amount of value captured by MiFAS (4). For example, farms participating in long supply chains in globalised markets need to concentrate and specialise production in order to be competitive (Moraine et al., 2014); farms that are diversified and reduce their use of external inputs also participate less in their procurement from the market (taking less advantage of economy of scale, though in return potentially making up for it in economy of scope) (Havet et al., 2014). Even integration at a territorial level may present additional challenges in the form of additional transportation and logistical costs and need for increased management and organisation (Garrett et al., 2017; Moraine et al., 2014); physical infrastructure and distance may impede the certain territorial MiFAS designs (2). Shortening the supply chain and long value chain in order to reach sellers of inputs and buyer of outputs may help to alleviate some stresses (3). The local procurement of inputs can reduce logistical costs, where closer integration between farmers may lead to Coasean agreements that may extend value captured within MiFAS boundaries (Havet et al., 2014; Röhrig et al., 2020). Likewise, direct marketing, voluntary price signalling, and on-site processing may increase the perceived value of products and place farmers in integrated systems closer to the final consumers of their products, reducing how much value is passed to intermediary supply chain actors and enabling farmers to capture more value-added (Alam et al., 2014; Röhrig et al., 2020).

5.2. Framework for assessing MiFAS value chains

While the literature were being produced, we understood that the was a lack of a framework available for the study of MiFAS designs, particularly with respect to how value is created. All the while, the literature tended to focus on the merits of specific interspecies interactions or processes, and rarely with the viewpoint of value creation within the entire farming system.

In the process of producing the meta-narratives, we became increasingly informed of the means by which value is created within the MiFAS boundary (i.e., *Farm-level value creation*); how different external factors can influence value creation in the MiFAS (i.e., *Impacts of the farming environment on value creation*); how the externalities created by a MiFAS are or could potentially be appraised in the long value chain (i.e., *Ecosystem services valuation*), and; how MiFAS are integrated in wider supply and value chains (i.e., *Supply & value chain integration*).

As a result, we propose the following schematics (Figures 5a-5e.) as baseline MiFAS configurations, upon which we propose the hypothesis that each configuration creates, captures and transmits value differently. Each configuration is designed such that a researcher may more concretely describe the following: the value-added processes performed within the MiFAS boundary; and the placement of and connections between value chain actors both within the boundary and without. The configurations themselves are universal, not focusing on the individual arrangements of species or processes but instead on the characteristics and standards of the systems they represent. Integration between farming enterprises is referred to in these configurations as "interconnectedness", in order to encapsulate all kinds of synergies as well as drawbacks.

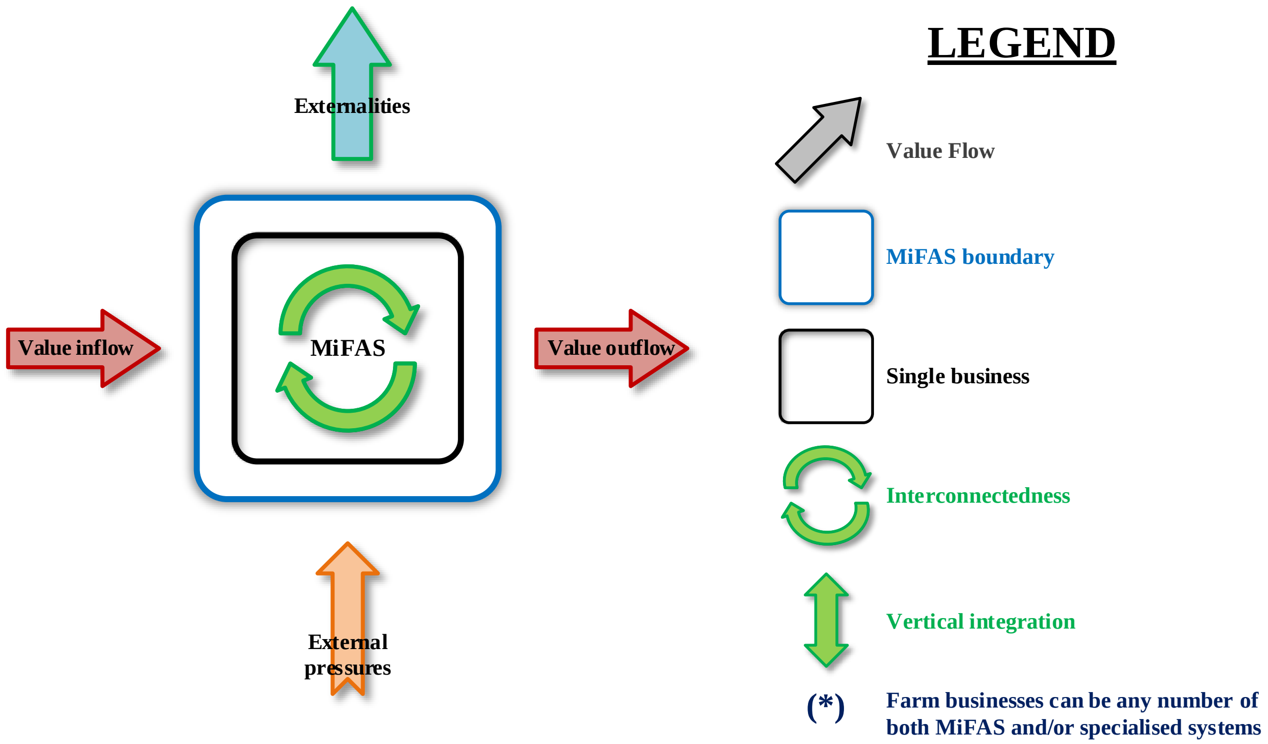
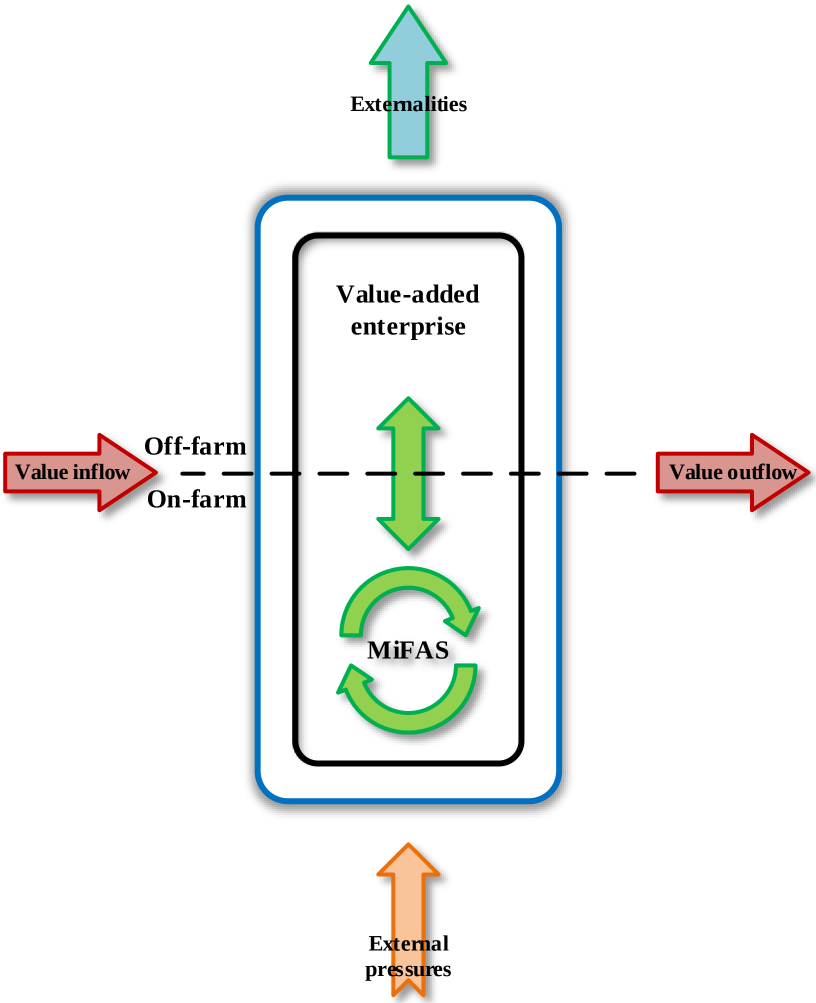
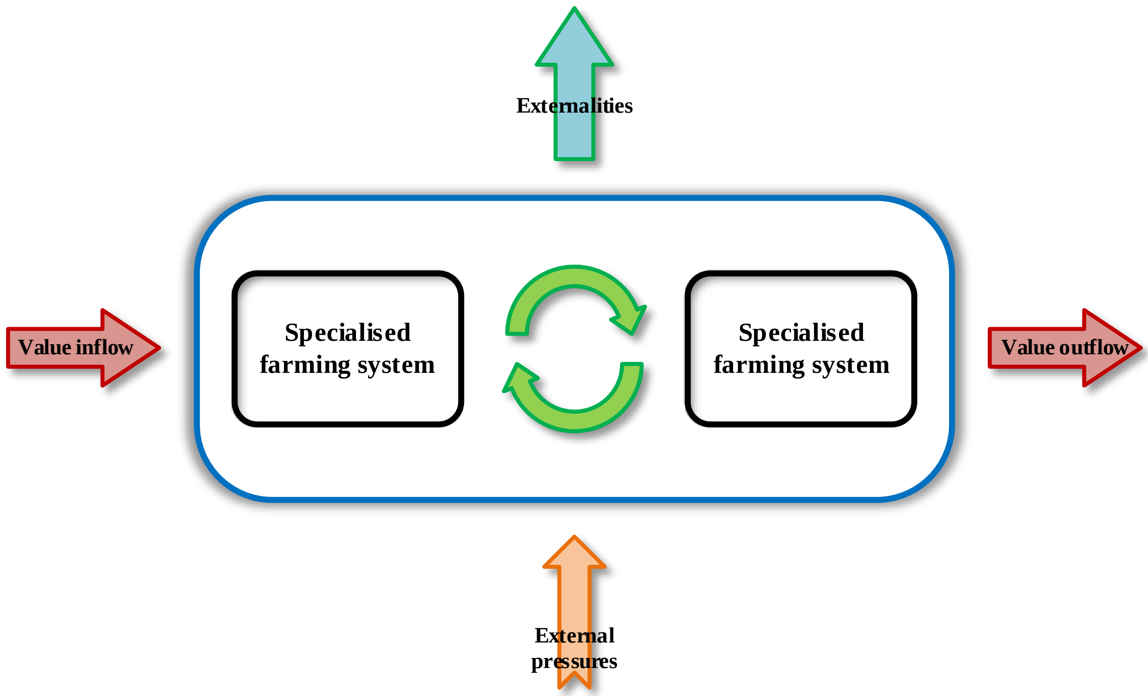


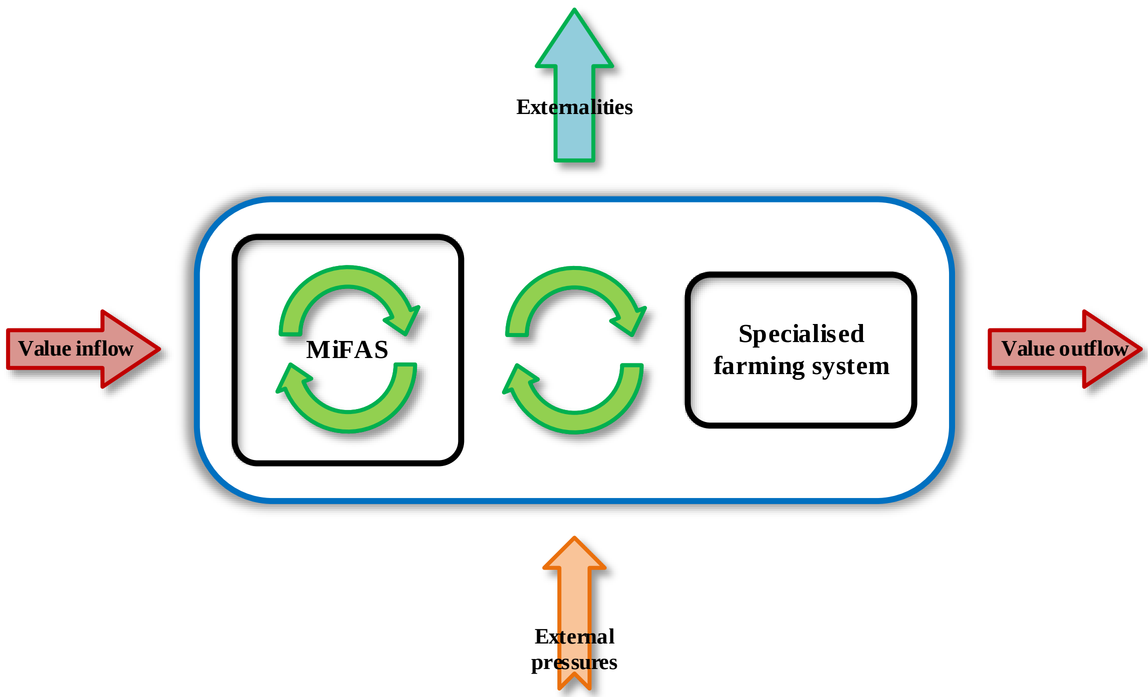
Figure 5a. Single-farm MiFAS



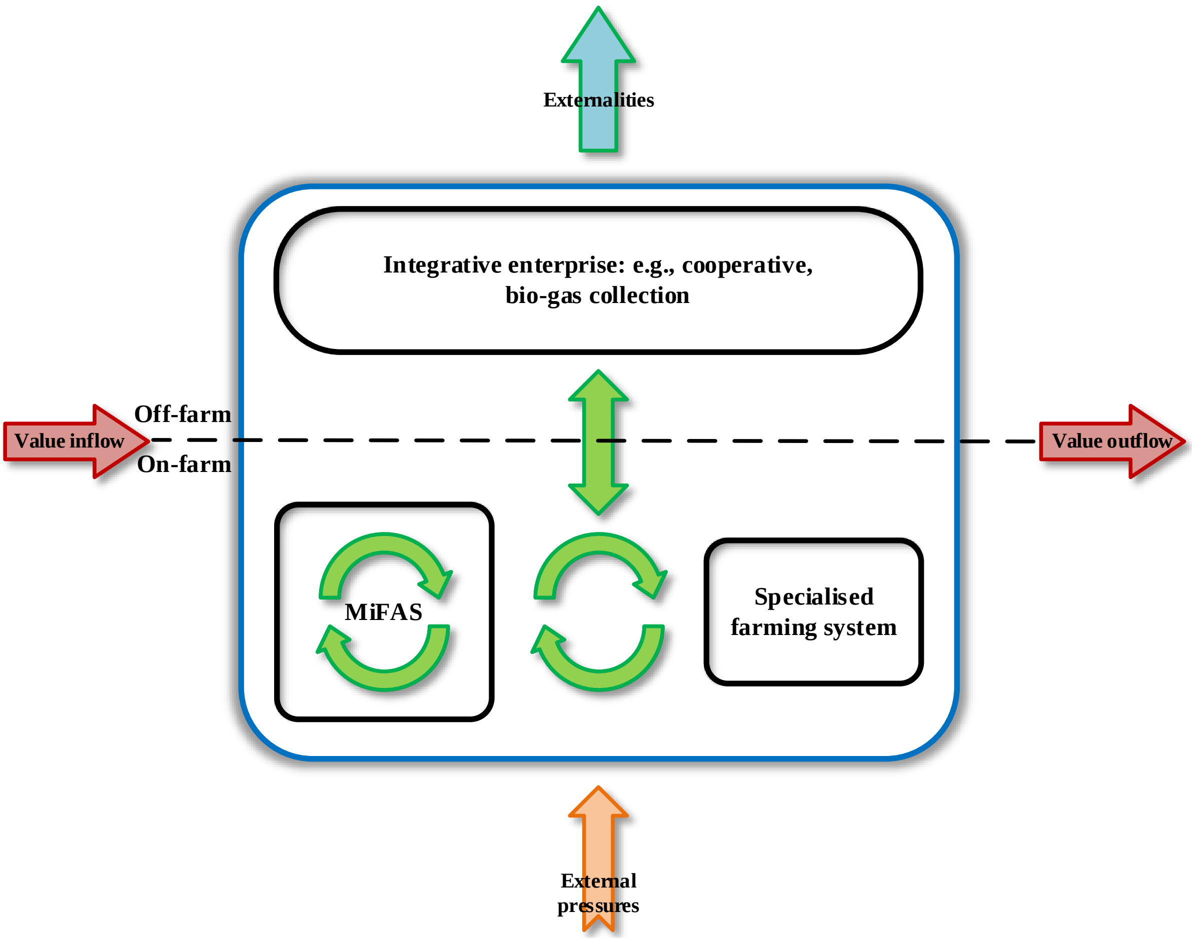
5b. Single-farm integrated MiFAS



5c. Multi-farm landscape MiFAS



5d. Multi-farm hybrid landscape MiFAS (*)



5e. Multi-farm integrated landscape MiFAS (*)

7. References

Aguilera, E., Díaz-Gaona, C., García-Laureano, R., Reyes-Palomo, C., Guzmán, G. I., Ortolani, L., Sánchez-Rodríguez, M., & Rodríguez-Estévez, V. (2020). Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. *Agricultural Systems*, *181*, 102809. https://doi.org/https://doi.org/10.1016/j.agsy.2020.102809

Alam, M., Olivier, A., Paquette, A., Dupras, J., Revéret, J.-P., & Messier, C. (2014). A general framework for the quantification and valuation of ecosystem services of tree-based intercropping systems. *Agroforestry Systems*, *88*(4), 679–691. https://doi.org/10.1007/s10457-014-9681-x

Alary, V., Moulin, C.-H., Lasseur, J., Aboul-Naga, A., & Sraïri, M. T. (2019). The dynamic of crop-livestock systems in the Mediterranean and future prospective at local level: A comparative analysis for South and North Mediterranean systems. *Livestock Science*, *224*, 40–49. https://doi.org/https://doi.org/10.1016/j.livsci.2019.03.017

Bell, L. W., Moore, A. D., & Kirkegaard, J. A. (2014). Evolution in crop–livestock integration systems that improve farm productivity and environmental performance in Australia. *European Journal of Agronomy*, *57*, 10–20. https://doi.org/https://doi.org/10.1016/j.eja.2013.04.007

Borrelli, P., Robinson, D. A., Fleischer, L. R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V., Bagarello, V., Oost, K. Van, Montanarella, L., & Panagos, P. (2017). An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications 2017 8:1*, *8*(1), 1–13. https://doi.org/10.1038/s41467-017-02142-7

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research* *in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706QP063OA

Campos, P., Oviedo, J. L., Álvarez, A., Ovando, P., Mesa, B., & Caparrós, A. (2020). Measuring environmental incomes beyond standard national and ecosystem accounting frameworks: testing and comparing the agroforestry Accounting System in a holm oak dehesa case study in Andalusia-Spain. *Land Use Policy*, *99*, 104984. https://doi.org/https://doi.org/10.1016/j.landusepol.2020.104984

Cubbage, F., Balmelli, G., Bussoni, A., Noellemeyer, E., Pachas, A. N., Fassola, H., Colcombet, L., Rossner, B., Frey, G., Dube, F., de Silva, M. L., Stevenson, H., Hamilton, J., & Hubbard, W. (2012). Comparing silvopastoral systems and prospects in eight regions of the world. *Agroforestry Systems*, *86*(3), 303–314. https://doi.org/10.1007/s10457-012-9482-z

Dalgaard, T., Hutchings, N. J., & Porter, J. R. (2003). Agroecology, scaling and interdisciplinarity. *Agriculture, Ecosystems & Environment*, *100*(1), 39–51. https://doi.org/10.1016/S0167-8809(03)00152-X

Darnhofer, I., Bellon, S., Dedieu, B., & Milestad, R. (2010). Adaptiveness to enhance the sustainability of farming systems. A review. *Agronomy for Sustainable Development*, *30*(3), 545–555. https://doi.org/10.1051/agro/2009053

Darnhofer, I., Fairweather, J., & Moller, H. (2010). Assessing a farm’s sustainability: Insights from resilience thinking. *International Journal of Agricultural Sustainability*, *8*(3), 186–198. https://doi.org/10.3763/IJAS.2010.0480

DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials*, *7*(3), 177–188. https://doi.org/https://doi.org/10.1016/0197-2456(86)90046-2

Duru, M., & Therond, O. (2015). Livestock system sustainability and resilience in intensive production zones: which form of ecological modernization? *Regional Environmental Change*, *15*(8), 1651–1665. https://doi.org/10.1007/s10113-014-0722-9

Duru, M., Therond, O., Martin, G., Martin-Clouaire, R., Magne, M.-A., Justes, E., Journet, E.-P., Aubertot, J.-N., Savary, S., Bergez, J.-E., & Sarthou, J. P. (2015). How to implement biodiversity-based agriculture to enhance ecosystem services: a review. *Agronomy for Sustainable Development*, *35*(4), 1259–1281. https://doi.org/10.1007/s13593-015-0306-1

Evenson, R., & Gollin, D. (2003). Assessing the Impact of the Green Revolution, 1960 to 2000. *Science*, *300*(5620), 758–762. https://doi.org/10.1126/science.1078710

Flinzberger, L., Zinngrebe, Y., & Plieninger, T. (2020). Labelling in Mediterranean agroforestry landscapes: a Delphi study on relevant sustainability indicators. *Sustainability Science*, *15*(5), 1369–1382.

Francis, C., Lieblein, G., Gliessman, S., Breland, T. A., Creamer, N., Harwood, R., Salomonsson, L., Helenius, J., Rickerl, D., Salvador, R., Wiedenhoeft, M., Simmons, S., Allen, P., Altieri, M., Flora, C., & Poincelot, R. (2003). Agroecology: The ecology of food systems. *Journal of Sustainable Agriculture*, *22*(3), 99–118. https://doi.org/10.1300/J064V22N03_10

Gaitán-Cremaschi, D., Kamali, F. P., van Evert, F. K., Meuwissen, M. P. M., & Oude Lansink, A. G. J. M. (2015). Benchmarking the sustainability performance of the Brazilian non-GM and GM soybean meal chains: An indicator-based approach. *Food Policy*, *55*, 22–32. https://doi.org/10.1016/J.FOODPOL.2015.05.006

Garrett, R. D., Niles, M. T., Gil, J. D. B., Gaudin, A., Chaplin-Kramer, R., Assmann, A., Assmann, T. S., Brewer, K., de Faccio Carvalho, P. C., Cortner, O., Dynes, R., Garbach, K., Kebreab, E., Mueller, N., Peterson, C., Reis, J. C., Snow, V., & Valentim, J. (2017). Social and ecological analysis of commercial integrated crop livestock systems: Current knowledge and remaining uncertainty. *Agricultural Systems*, *155*, 136–146. https://doi.org/https://doi.org/10.1016/j.agsy.2017.05.003

Gliessman, S. R. (2007). *Agroecology: The Ecology of Sustainable Food Systems* (E. Engles, R. Krieger, & E. Mendez (eds.); 2nd ed.). CRC Press, Boca Raton, FL.

Havet, A., Coquil, X., Fiorelli, J. L., Gibon, A., Martel, G., Roche, B., Ryschawy, J., Schaller, N., & Dedieu, B. (2014). Review of livestock farmer adaptations to increase forages in crop rotations in western France. *Agriculture, Ecosystems & Environment*, *190*, 120–127. https://doi.org/10.1016/J.AGEE.2014.01.009

Hendrickson, J. R. (2020). Crop-livestock integrated systems for more sustainable agricultural production: A review. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, *15*(12). https://doi.org/10.1079/PAVSNNR202015012

Hendrickson, J. R., Hanson, J. D., Tanaka, D. L., & Sassenrath, G. (2008). Principles of integrated agricultural systems: Introduction to processes and definition. *Renewable Agriculture and Food Systems*, *23*(4), 265–271. https://doi.org/DOI: 10.1017/S1742170507001718

Hilimire, K. (2011). Integrated Crop/Livestock Agriculture in the United States: A Review. *Journal of Sustainable Agriculture*, *35*(4), 376–393. https://doi.org/10.1080/10440046.2011.562042

Horlings, L. G., & Marsden, T. K. (2011). Towards the real green revolution? Exploring the conceptual dimensions of a new ecological modernisation of agriculture that could 'feed the world.' *Global Environmental Change*, *21*(2), 441–452. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2011.01.004

Kirkegaard, J. A., Conyers, M. K., Hunt, J. R., Kirkby, C. A., Watt, M., & Rebetzke, G. J. (2014). Sense and nonsense in conservation agriculture: Principles, pragmatism and productivity in Australian mixed farming systems. *Agriculture, Ecosystems & Environment*, *187*, 133–145. https://doi.org/10.1016/J.AGEE.2013.08.011

Kremen, C., & Miles, A. (2012). Ecosystem Services in Biologically Diversified versus Conventional Farming Systems. *Ecology and Society*, *17*(4). http://www.jstor.org/stable/26269237

Lüscher, A., Mueller-Harvey, I., Soussana, J. F., Rees, R. M., & Peyraud, J. L. (2014). Potential of legume-based grassland–livestock systems in Europe: a review. *Grass and Forage Science*, *69*(2), 206–228. https://doi.org/10.1111/GFS.12124

Martin, G., Moraine, M., Ryschawy, J., Magne, M. A., Asai, M., Sarthou, J. P., Duru, M., & Therond, O. (2016). Crop–livestock integration beyond the farm level: a review. *Agronomy for Sustainable Development*, *36*(3). https://doi.org/10.1007/S13593-016-0390-X

McCorriston, S., & Sheldon, I. M. (2007). Trade liberalization and net distribution in vertically related markets. In J. F. M. Swinnen (Ed.), *Global Supply Chains, Standards and the Poor: How the Globalization of Food Systems and Standards Affects Rural Development and Poverty* (pp. 59–74). CAB International, Wallingford, UK.

Meuwissen, M. P. M., Feindt, P. H., Spiegel, A., Termeer, C. J. A. M., Mathijs, E., Mey, Y. de, Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vigani, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., … Reidsma, P. (2019). A framework to assess the resilience of farming systems. *Agricultural Systems*, *176*, 102656. https://doi.org/https://doi.org/10.1016/j.agsy.2019.102656

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*(1). https://doi.org/10.1186/2046-4053-4-1

Moraine, M., Duru, M., Nicholas, P., Leterme, P., & Therond, O. (2014). Farming system design for innovative crop-livestock integration in Europe. *Animal*, *8*(8), 1204–1217. https://doi.org/10.1017/S1751731114001189

Nagurney, A. (2006). *Supply chain network economics: dynamics of prices, flows and profits*. Edward Elgar Publishing, Inc., Northampton, MA.

Nie, Z., McLean, T., Clough, A., Tocker, J., Christy, B., Harris, R., Riffkin, P., Clark, S., & McCaskill, M. (2016). Benefits, challenges and opportunities of integrated crop-livestock systems and their potential application in the high rainfall zone of southern Australia: A review. *Agriculture, Ecosystems & Environment*, *235*, 17–31. https://doi.org/https://doi.org/10.1016/j.agee.2016.10.002

Olesen, J. E., & Bindi, M. (2002). Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy*, *16*(4), 239–262. https://doi.org/10.1016/S1161-0301(02)00004-7

Paas, W., Coopmans, I., Severini, S., van Ittersum, M. K., Meuwissen, M. P. M., & Reidsma, P. (2021). Participatory assessment of sustainability and resilience of three specialized farming systems. *Ecology and Society*, *26*(2). https://doi.org/10.5751/ES-12200-260202

Peyraud, J.-L., Taboada, M., & Delaby, L. (2014). Integrated crop and livestock systems in Western Europe and South America: A review. *European Journal of Agronomy*, *57*, 31–42. https://doi.org/https://doi.org/10.1016/j.eja.2014.02.005

Pingali, P. L. (2012). Green Revolution: Impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences*, *109*(31), 12302–12308. https://doi.org/10.1073/PNAS.0912953109

Porter, M. E. (1998). *Competitive strategy: techniques for analyzing industries and competitors*. Free Press, New York, NY.

Power, A. G. (2010). Ecosystem services and agriculture: tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*, 2959–

2971. https://doi.org/10.1098/rstb.2010.0143

Röhrig, N., Hassler, M., & Roesler, T. (2020). Capturing the value of ecosystem services from silvopastoral systems: Perceptions from selected Italian farms. *Ecosystem Services*, *44*, 101152. https://doi.org/https://doi.org/10.1016/j.ecoser.2020.101152

Russelle, M. P., Entz, M. H., & Franzluebbers, A. J. (2007). Reconsidering Integrated Crop–Livestock Systems in North America. *Agronomy Journal*, *99*(2), 325–334. https://doi.org/10.2134/AGRONJ2006.0139

Ryschawy, J., Choisis, N., Choisis, J. P., Joannon, A., & Gibon, A. (2012). Mixed crop-livestock systems: an economic and environmental-friendly way of farming? *Animal*, *6*(10), 1722–1730. https://doi.org/10.1017/S1751731112000675

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333–339. https://doi.org/10.1016/J.JBUSRES.2019.07.039

Soussana, J. F., & Lemaire, G. (2014). Coupling carbon and nitrogen cycles for environmentally sustainable intensification of grasslands and crop-livestock systems. *Agriculture, Ecosystems & Environment*, *190*, 9–17. https://doi.org/10.1016/J.AGEE.2013.10.012

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology*, *8*(1), 1–10. https://doi.org/10.1186/1471-2288-8-45

Tothova, M. (2011). Main Challenges of Price Volatility in Agricultural Commodity Markets. In I. Piot-Lepetit & R. M'Barek (Eds.), *Methods to Analyse Agricultural Commodity Price Volatility* (pp. 13–29). Springer, New York, NY.

Ward, V., House, A., & Hamer, S. (2009). Developing a framework for transferring knowledge into action: A thematic analysis of the literature. *Journal of Health Services*

Research and Policy, *14*(3), 156–164. https://doi.org/10.1258/jhsrp.2009.008120

Wilkins, R. J. (2008). Eco-efficient approaches to land management: A case for increased integration of crop and animal production systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491), 517–525. https://doi.org/10.1098/RSTB.2007.2167

Wong, G., Greenhalgh, T., Westhorp, G., Buckingham, J., & Pawson, R. (2013). RAMESES publication standards: Meta-narrative reviews. *BMC Medicine*, *11*(1), 1–15. https://doi.org/10.1186/1741-7015-11-20/FIGURES/1