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Policy paper with guidelines for successful value networks for mixed farming and agroforestry systems

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

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Executive summary

Background

This report aims to provide a policy paper with guidelines to enable successful value networks for mixed farming and agroforestry systems building on the research and analysis completed in the AGROMIX project. In this context, mixed farming refers to the integration of livestock and crop production and agroforestry refers to the integration of woody vegetation with farming systems. This integration can occur at farm and landscape levels.

Mixed farming and agroforestry, alongside the procuring of farm inputs, are activities that typically occur at the start of a food value chain. This chain can then extend through activities such as distribution and processing through to consumption and disposal. Ideally, stakeholders add value to the product in the different stages of the value chain to increase the end-product value. However in practice, this means that the proportion of the value added retained by the farmer is often only 6-11% of the value paid by the final consumer. Hence an objective of this report is to develop and use a framework to develop guidelines on how value can be created and increased, particularly for farmers, within mixed farming and agroforestry systems.

Method – case study farm reports

Within the AGROMIX project, case study reports have been developed for **four European mixed farming systems** and **nine European agroforestry systems** (Dumper-Pollard et al., 2022). These reports were examined to identify the attributes of the case studies in terms of biophysical constraints, the capacity of the individuals, the costs of production, product differentiation, and farmer satisfaction and wider societal benefits. This analysis highlighted there can be agroecological constraints that determine where mixed farming is appropriate, and the importance of the enhancement of the capacity of farmers through knowledge exchange in enabling mixed farming and agroforestry.

Porter (1998) argues that the long-term above-average performance of business depends on sustainable competitive advantage, which is primarily achieved through: i) low costs or, ii) product differentiation. The analysis of the case studies suggests that there was no example where the mixed farming or agroforestry was associated with both lower variable and fixed costs of production. Hence, the expansion of mixed farming and agroforestry will not occur if price is the primary driver of who engages in the value chain. By contrast, each of the case studies highlighted the **value of product differentiation** within the mixed farming and agroforestry systems, such as through the use of local markets and the engagement of farm shops and/or restaurants. In each of the selected agroforestry case studies and half of the mixed farming case studies, **organic certification** was also important for differentiating the product and securing a higher price for farm products. In addition,

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separate to the market, the farmers involved in the case studies appreciated the environmental and animal welfare benefits of the mixed farming and agroforestry systems.

Three guidelines to support mixed farming and agroforestry

Section 3 of the report considers interventions to support mixed farming and agroforestry value networks, using the behaviour change wheel framework (Michie et al., 2011) which assumes that motivation, capability, and opportunity are three core components that determine behaviour. Using this framework, three guidelines to support agroforestry and mixed farming are considered in terms of i) linking agroforestry and mixed farming with the motivations of governments and farmers, ii) capacity building at farm-scale, and iii) creating opportunities within the supply chain and with consumers.

1. Linking mixed farming and agroforestry with stakeholder motivations

The highest level motivations of government and society are often framed in terms of seventeen Sustainable Development Goals (SDGs). It is clear from research and analysis, that the expansion of mixed farming and agroforestry can maintain levels of food security (SDG 2), sustain economic growth (SDG 8), address climate change (SDG 13) and enhance life on land (SDG 15). Within Europe, these goals are also invoked within the Farm to Fork strategy for a fair, healthy and environmentally-friendly food system, and the 2023–2027 Common Agricultural Policy (CAP). Hence in many aspects there are **clear synergies between mixed farming and agroforestry and such goals**, which creates the basis of societal support for mixed farming and agroforestry. However, in practice there are usually **some trade-offs**. For example, negative effects of including livestock on arable farms can include increased greenhouse gas emissions at the farm-level, and the greater integration of non-food producing trees on farms can reduce the level of food production. **Research and guidance on the nature of these synergies and trade-offs** is important to inform decision making.

The motivations of farmers determine how land is managed at a farm-level. Eight of the thirteen case studies reported that the farmers **found enjoyment or increased well-being** associated with mixed farming and agroforestry systems. Farmers are not just managers, but they also gain purpose and satisfaction from the process of farming and it is important to consider such satisfaction when considering opportunities to improve agri-food systems. Measures which can be taken to increase the motivation of farmers to maintain or adopt mixed farming and agroforestry include **changes in government regulations.** For example, in the EU there are cross-compliance regulations measures to protect hedgerows and landscape features. A second approach is to use grants and subsidies to **moderate the effect of the high investment costs or high variable costs** associated with mixed farming and agroforestry. Hence in Pillar 2 of the Common Agricultural Policy between 2014-2020, the "establishment and maintenance of agroforestry systems" was funded under Article 23 of Regulation 1305/2013.

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2. Building capacity at farm-scale

Instruments that build capacity at a farm level can be useful in encouraging the expansion of mixed farming and agroforestry. For example, Vergamini et al. (2023) reported that farmers with a **background in agricultural education** are more inclined towards adopting agroforestry or mixed farming systems, highlighting the role of formal education in enhancing management capacity. In mixed systems, arable farmers will need to manage livestock, livestock farmers will need to manage crops and with agroforestry, farmers will need to manage trees. Moreover within changing markets, actors in the value chain need to improve their capability to remain competitive. Other methods to increase capacity include **training, demonstration projects, knowledge exchange via farmer networks, workshops,** and **open-days**, research and innovation to develop techniques or tools, and information sheets.

3. Creating opportunities within the value network

The third major approach to promoting mixed farming and agroforestry is by **enabling knowledge exchange between farmers and the rest of the value network** to identify opportunities for synergies and opportunities to take command of resources. Within this context, co-operatives can be an effective way of reducing costs and enabling the creation of added-value secondary products. However, the most common intervention to increase the final price and the proportion of the final price received by farmers for products from mixed farming and agroforestry in the case studies was through **market development with consumers**, such as through the use of short supply chains including farm shops and the use of certification and branding. Each of the 13 case studies highlighted the **advantages of localism in the value chain**. It is noted, perhaps non-intuitively, that local supply chains may involve greater travelling by consumers and result in higher food miles and higher carbon footprints than long supply chains (Malak-Rawlikowska et al., 2019).

Within the case studies, **certification in terms of organic status** was a common feature on each of the agroforestry farms and in two of the four mixed farms. **Animal welfare certification** was also reported on two agroforestry and one mixed farm case study. Although net zero certification was not mentioned in the case studies, it is anticipated that as retailers and processors seek to achieve net zero greenhouse gas emissions in their supply chains by 2050, net zero certification will increasingly be required as a licence to trade in some supply chains. It is anticipated that this will create substantial interest in the increased use of trees on farms such as through agroforestry. By contrast, a drive for net zero on individual farms is anticipated to constrain the expanded use of livestock on arable farms. A final method to increase a premium for agroforestry products is through **direct branding** that promotes the socio-environmental and climate benefits of the products to consumers.

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1 Context and objectives

The AGROMIX research project provides practical agroecological solutions for land use in Europe, focusing on two main agricultural systems: mixed farming - i.e. crops and livestock - and agroforestry - 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 mixed farming and agroforestry 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 mixed farming and agroforestry-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 Common Agricultural Policy 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.

This report is produced with work-package 5 of the AGROMIX project which includes a socio-economic analysis of mixed farming and agroforestry at farm, landscape-and value chain levels. Deliverable 5.1 assessed the farm-level financial socio-economic performance of selected mixed farming and agroforestry systems (Vergamini et al., 2020). Deliverable 5.2 provided a report and factsheets on the characteristics of successful value-chain networks (Dumper-Pollard et al., 2022). Deliverable 5.3 examined the acceptance, institutional barriers and conditions to the adoption of successful and improved value chain networks (Vergamini et al., 2023). Deliverable 5.4 reported on the integrated economic, and life cycle assessment of the impact of specific policy instruments to support mixed farming and agroforestry systems and value networks (Thiesmeier et al., 2023).

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This report (Deliverable 5.5) aims to provide a policy paper with guidelines for successful value networks for mixed farming and agroforestry systems building on the research and analysis completed in the AGROMIX project.

2 Mixed farming and agroforestry value networks

2.1 Mixed farming and agroforestry

In the AGROMIX project, mixed farming refers to 'the practice of deliberately integrating crop and livestock production to benefit from the resulting ecological and economic interactions' (Püttsepp et al., 2022, Smith et al., 2023) (Figure 1). Agroforestry has been defined 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" (Burgess and Rosati, 2018).

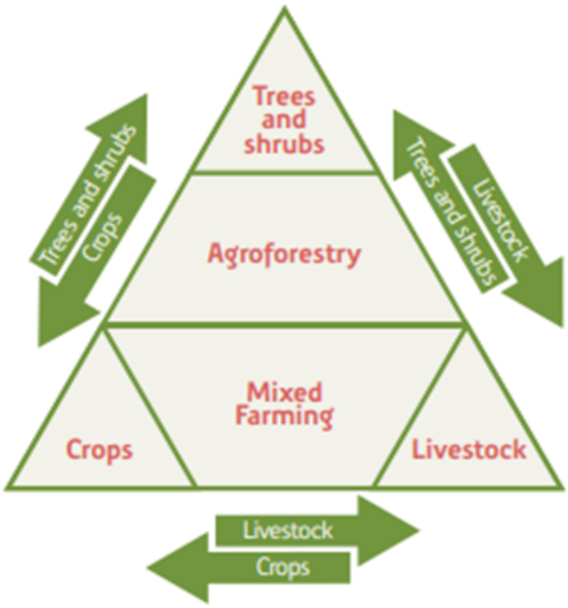

Figure 1. Schematic illustration of integrated land-use systems in relation to monocrops, livestock and trees and shrubs (Burgess 2019)

Mixed farming and agroforestry are land uses that integrate more than one component and hence are likely to produce more than one product, such as animal and crop products, or fibre and timber alongside animal and crop products. The diversity of components can create a greater range of habitats on individual farms and thereby enhance biodiversity at a farm-scale (Torralba et al., 2016). In turn, the diversity of systems, and in particular the integration of perennial woody components, can provide regulating ecosystem services such as moderating runoff, controlling soil erosion, and reducing the loss of nutrients to the wider environment (Wheater et al., 2012; Giannitsopoulos et al., 2020). Modelling studies suggest that mixed farming has the potential to reduce negative environmental impacts compared to specialised farming (Marton et al., 2016). However, the uneven distribution of manure in crop-livestock systems can result in overloading in some areas and deficiency in others (Sekaran et al., 2021).

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The integration of woody components will also increase the level of biomass carbon, the level of carbon sequestration, and often soil organic carbon at a farm-level (Tsonkova et al., 2012; Giannitsopoulos et al., 2020; Ivezic et al., 2022). Diversified systems can also lead to improved weed, pest, and disease control than monoculture systems (Malezieux et al., 2009; Kremen and Miles, 2012). The diversity of systems can also provide enhance cultural values by offering nature-based opportunities for recreation, tourism and aesthetic appreciation (Fagerholm et al., 2019).

The integration of crops into livestock systems, the integration of animals into crop systems, and the integration of trees with farming can be defined as an agroecological approach (Burgess et al., 2023). Depending on the audience, agroecological approaches can be defined in terms of science, as a social movement (HLPE, 2019; Gliessman, 2018, IPES Food, 2022), and as a set of practices (Wezel et al. 2014). If the focus is on the principles of agroecological systems, then the social aspects of agroforestry and mixed farming is also important.

Sometimes the differentiation between mixed and specialised farming is one of scale (Moraine et al., 2014; Vergamini et al., 2020). For example, a cereal farm supplying a livestock farm with animal feed, and receiving animal manure could be viewed as a "mixed farm system" but at a greater scale (Figure 2). One question is whether the balance of administrative costs in exchanging products between farms is more efficient than carrying out those operations within a farm. A second question relates to the greenhouse gas emissions associated with undertaking mixed farming at these two scales and whether there are efficiencies at either of these two scales that makes either of them preferable as a general approach.

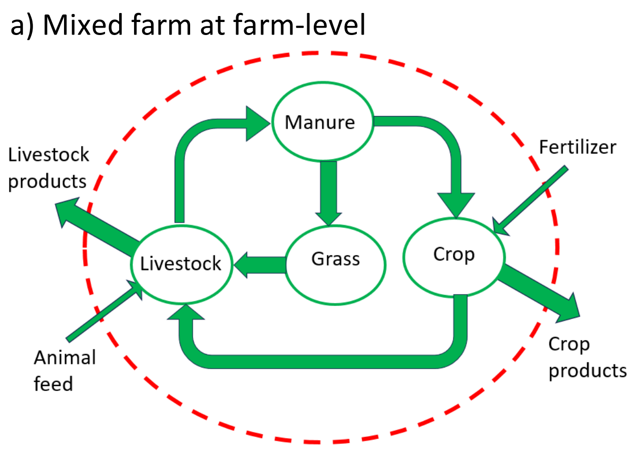

Figure 2. The interactions between crop and livestock production can occur at a farm-level or between farms. The dotted red line represents the boundary of a farm.

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2.2 Characterising value networks

The objective of this report is to examine approaches to support successful value networks associated with mixed farming and agroforestry. The purpose of this section is to explain the term "value network", to highlight the typical proportion of the final product value that is received by the farmer, and to describe some approaches for characterising value networks.

2.2.1 Value chains and networks

When Porter (1985) used the term "value chain" in his book "Competitive Advantage", the focus was on how value was created in an organisation. In that analysis, he split the activities of an organisation into: i) primary activities such as inbound logistics, operations, outbound logistics, marketing and sales, and service, and ii) support activities (Figure 3). However, within the AGROMIX project (Vergamini et al., 2020) and within this report the focus is on the changes in value across the supply chain of a product, which is traditionally described as a series of linear links. Kogut (1985) quoted by Gereffi et al. (2005) defines value chains as 'the process by which technology is combined with material and labour inputs, and then processed inputs are assembled, marketed, and distributed". Henrsiksen et al. (2010) places the emphasis on the actors connected along a chain producing and bringing goods and services to consumers through a complex and sequenced set of activities. The World Business Council for Sustainable Development (WBCSD, 2011) define value chains as the "full life cycle of a product or process, including material sourcing, production, consumption and disposal/recycling processes". Sometimes the term supply chain is used instead of value chain (Vermeulen et al., 2008). In addition, with an increasing focus on the circular economy, Peppard and Rylander (2006) recommend the use of the term "value networks" which allows for a system of connected nodes that can work together to produce and distribute goods and services. Within this report the terms "value chain" and "value network" are used as synonyms.

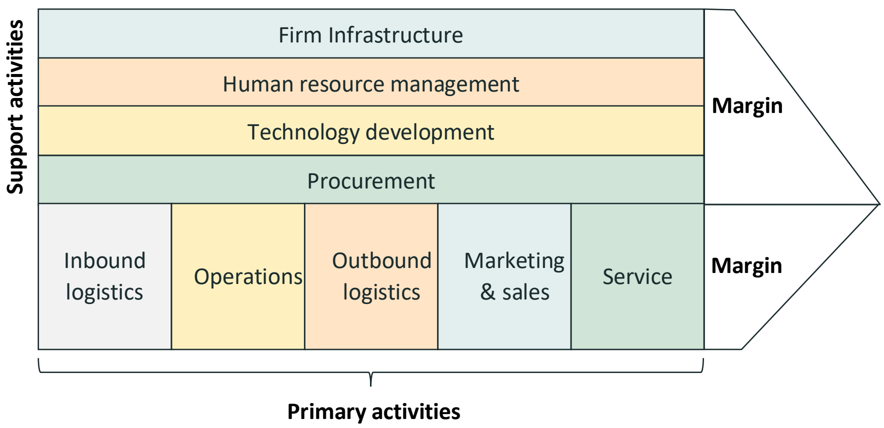

Figure 3. Porter (1985) used the term value chain to focus on the activities within an organisation that created value. This included primary activities such as inbound logistics, operations, outbound logistics, marketing and sales, and service and support activities

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2.2.2 Proportional distribution of final value

An analysis of value chains or value networks can cover their structure, their change, the distribution of where value is added and how standards affect participation (Bolwig et al., 2010). Ideally in the different stages of value chain, different stakeholders add value to the product to increase the end-product value (Reddy Amarender, 2013). However in practice, farmers may typically only acquire a small proportion of the final value of the food sold to the consumer. For example, in the UK, the agricultural sector receives about 8.7% (range: 6.4-11.4%) of the value paid by the final consumer (Figure 4).

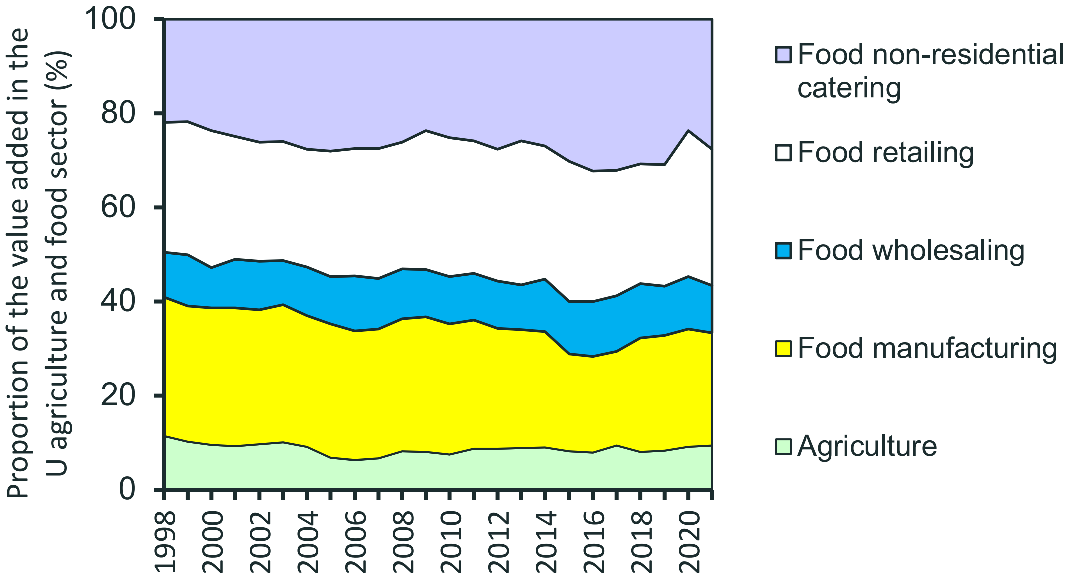

Figure 4. Annual estimates (1998 to 2021) of the proportion of the value added by different sectors of the agriculture and food sector in the United Kingdom (Defra, 2024).

Penrose (1959), quoted by Gereffi et al. (2005), argued that the capability of a firm to capture value "depends in part on the generation and retention of competencies (that is, resources) that are difficult for competitors to replicate". In a recent systematic review, Low et al. (2023) argue that there is a shortage of frameworks for understanding how value is created within mixed farming and agroforestry systems.

2.2.3 Governance and information flow in value chains

Irrespective of the term "value chain" or "value networks", Gereffi et al. (2005) provides a useful categorisation of how governance and information flow can vary between different types of value chain ranging from a primarily market-driven situation to systems where the same organisation both produces and sells the product (Figure 5). Gereffi et al. (2005) defines a modular chain as one where producers have high capabilities and make products to customer specifications based on substantial quantities of "non-price information" flowing across the "inter-firm boundary". The third category is a relational value chain where spatial, family, or ethic linkages can enable information flow. The

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fourth category is a captive network typified by a dominant firm which specifies the criteria for products from its suppliers. In general, the complexity of transactions is lowest in the market system, but as the transactions become more complicated, there is tendency for the market to assume a more modular or relational structure. Amongst the farmers practising mixed farming and agroforestry, interviewed for Deliverable 5.3, many operated within a "market-driven" value network where they sell a product at a price driven by the market on a specific date at a specific location (Vergamini et al., 2023). Gereffi et al. (2005) also argue that if suppliers are able to establish a reputation and responsibility for product enhancement, then a value chain may move from a market systems to a modular or relational value chain.

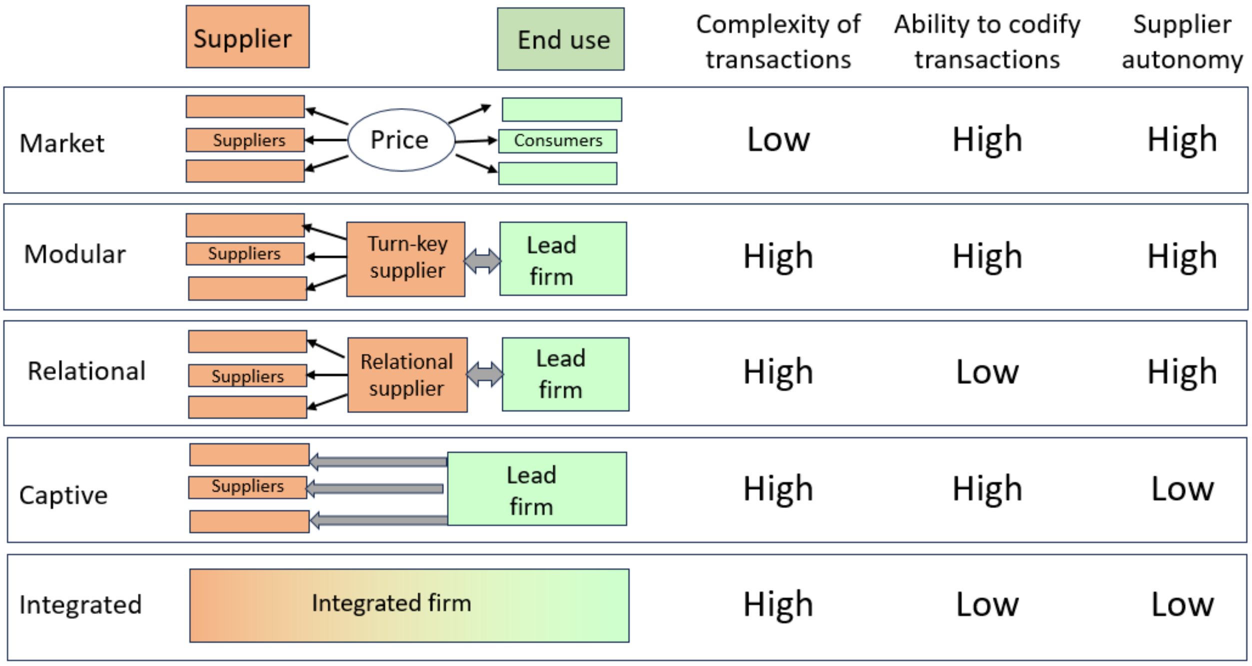

Figure 5. Five contrasting types of governance in value chains ranging to a market where costs of switching between partners is low to a hierarchy system where production and end use is embedded in a single company (after Gereffi et al. 2005). The five value chain types tend to be associated with different levels of the complexity of transactions, the ability to codify transactions, and supplier autonomy. The small line arrows show where exchange is based on price while the larger block arrows represent thicker flows of information and control.

2.2.4 Strategies for growing a business

A typical feature of integrating livestock on arable farms, crops on livestock farms, and trees on farms is that it means that the farm business is producing new products, and hence the farmer needs to be informed about the requirements of a new market. Ansoff (1957) refers to this process as product development, and he highlights that this process is not easy. In fact, he outlines four strategies to increase the size of a business which are: i) focusing on existing products to existing markets, ii) creating new products for existing markets, iii) enabling new markets for existing products, or iv) creating new products for new markets. Meldrum and McDonald (1995) argue that the least risky strategy is generally i), followed by iii), ii), and then iv).

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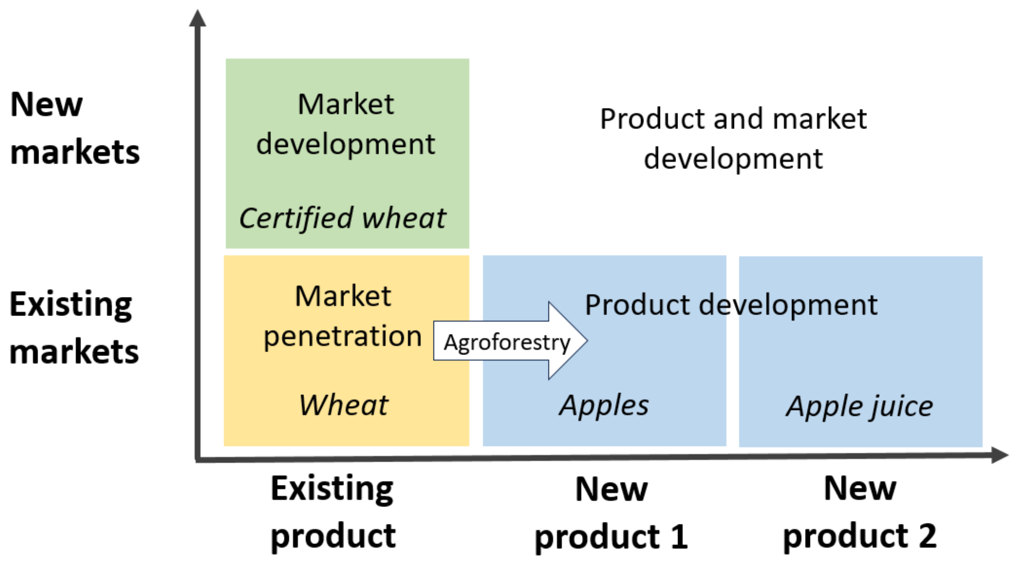

Figure 6. A company can grow by either focusing on increasing penetration of the existing market, developing new products for existing markets, or creating new markets (after Ansoff, 1957). The arrow illustrates the integration of agroforestry on a wheat farm through the addition of apple trees

Irrespective of whether a farm is creating a new market or developing new products, Porter (1998) argues that "the fundamental basis of above-average performance in the long run is sustainable competitive advantage". He argues that the two primary types of competitive advantage are either **i) low cost** or **ii) product differentiation.**

2.3 Attributes of mixed farming and agroforestry case studies

In order to identify the attributes of successful mixed farming and agroforestry value chains, we reviewed the 13 European case studies for success criteria and challenges as described in the EIP-Style Factsheets (Dumper-Pollard et al., 2022). The success criteria within the case studies were first reviewed in terms of biophysical constraints. Then building on the case studies, the success criteria were analysed in terms of i) increasing capacity of the individuals in the value chain, ii) reducing the costs of production, iii) product differentiation, and iv) contributing to farmer satisfaction and wider societal benefits.

2.3.1 Biophysical capacity for mixed farming or agroforestry

The suitability of mixed farming can depend on the geography. For example, mixed farming is likely to be most advantageous on farms including contrasting soil types with different levels of agricultural potential (Bell et al., 2014). Some parts of the farm may be especially suitable for crop production whilst other parts can only support grass production. However, the capacity to practice crop production on a livestock farm may be constrained by weather or soil conditions. Eliasson et al. (2010) reports that about 57% of the agricultural area across Europe can be classified as Less Favoured Areas (LFA) where crop production is marginal. Hence these areas are dominated by

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extensive cattle and sheep farms, often with limited opportunity for integrating crops. By contrast, such areas can be suitable for greater integration of tree cover.

2.3.2 Need for high human capacity

An analysis of the case studies for mixed farming (Table 1) and agroforestry (Table 2) highlight that for both types of system, success was associated with increasing human capacity within the system by research, education or knowledge exchange. This involved for instance, participation in European or regional research projects on agroforestry, experts visiting the farms, "customer education", guided tours school classes, or farm festivals. In Deliverable 5.3, Vergamini et al. (2023) also highlighted that opportunities to improve farmer capability could support the adoption of mixed farming or agroforestry systems.

Table 1. Identified positive or negative attributes of successful mixed farming as identified from four AGROMIX case studies

Country	Greece	Italy	Germany	UK
Case study number	2	6	7	12
Increased capacity				
Research/education	✓	✓	-	✓
Knowledge exchange	-	✓	-	✓
Reduced costs per unit product				
Reduced variable cost	X	-	✓	X
Reduced fixed costs	X	X	X	-
Production resilience	✓	✓	✓	✓
Financial resilience	✓	-	X	✓
Product differentiation valued by market				
Differentiation by localism	✓	✓	✓	✓
Farm shop/cafe/restaurant	-	✓	-	✓
Enabling marketing opportunities	✓	-	-	-
Certification organic	✓	✓	-	-
Certification animal welfare	-	✓	-	-
Certification carbon/biodiversity	-	-	-	-
Societal value and farmer well-being				
Enjoyment/improved well-being for farmer	✓	X	-	✓
Community engagement	✓	✓	✓	✓
Perceived environmental benefits by farmer	✓	✓	✓	✓
Perceived animal welfare benefits by farmer	✓	✓	-	-
Government finance for agri-environment	-	-	✓	-
Other support	-	-	-	-

Legend: tick means a positive factor mentioned; cross means a negative factor mentioned; "-" means that factor is not mentioned or not relevant.

2.3.3 Challenges in enabling reduced costs per unit product

Porter (1998) argues that one of the two potential sources of competitive advantage for a business is the capacity to supply a product to the market at a lower cost. However across the four mixed farming and nine agroforestry case studies, only one system reported reduced variable costs, and

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even in that case fixed costs were reported to have increased. In fact, higher variable or fixed costs were reported in all 13 case studies (Table 1 and Table 2). Responses revolved around high labour requirements, intensive farm workload, inputs, and sometimes farm staff receiving low wages. Hence, whilst Peyraud et al. (2014) report that mixed farming systems can create additional income and employment, this can also be interpreted as higher costs. The one case where variable costs were reduced was on a mixed farm (Table 1). Low et al. (2023) report that mixed farming can sometimes reduce variable costs in producing, for example grain and meat, by replacing expensive inputs such as fertilizer with a waste product such as manure. However, reductions in variable costs were not reported on the case study farms; the typical result was that variable costs increased.

Table 2. Identified positive or negative attributes of successful agroforestry case studies as identified from nine AGROMIX case studies

	Silvopastoral system							Silvoarable	
Country	GR	GR	BG	IT	GER	POL	UK	UK	AU
Case study number	1	3	4	5	8	9	11	10	13
Increased capacity									
Research/education	✓	-	✓	✓	✓	✓	✓	✓	✓
Knowledge exchange	✓	-	✓	✓	✓	✓	✓	✓	-
Reduced costs per unit product									
Reduced variable cost	-	X	X	-	X	-	X	-	X
Reduced fixed costs	X	X	X	X	-	-	-	X	X
Production resilience	✓	✓	✓	✓	✓	✓	✓	✓	✓
Financial resilience	✓	✓	-	-	✓	-	✓	✓	X
Product differentiation valued by market									
Differentiation by localism	✓	✓	✓	✓	✓	✓	✓	✓	✓
Farm shop/cafe/restaurant	-	✓	-	✓	✓	-	✓	✓	✓
Enabling marketing opportunities	✓	-	✓	-	✓	-	✓	✓	✓
Certification organic	✓	✓	✓	✓	✓	✓	✓	✓	✓
Certification animal welfare	-	✓	-	✓	-	-	-	-	-
Certification carbon/biodiversity	-	-	-	-	-	-	-	-	-
Societal value and farmer well-being									
Enjoyment/improved well-being for farmer	X	✓	✓	✓	X	✓	X	✓	✓
Community engagement	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perceived environmental benefits by farmer	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perceived animal welfare benefits by farmer	-	✓	-	✓	-	-	✓	-	-
Government finance for agrienvironment	-	-	-	✓	-	✓	✓	-	X
Other support	-	-	-	✓	-	-	-	-	-

Legend: GR: Greece; BG: Belgium; IT: Italy; GER: Germany; POL: Poland; UK: United Kingdom; AU: Austria

It has been proposed that when considering the outputs of two products, agroforestry can lead to higher yields per hectare due to greater efficiency of light, water or nutrient use (Cannell et al., 1996). For example, modelling of agroforestry has resulted in land equivalent ratios of agroforestry of 1.0-1.4, which means that it can take up to 40% more land to create the same quantity of timber and grain growing the trees and crop separately rather than together (Graves et al., 2007). However, the choice of the default monoculture systems in such analyses is important. For instance, in a

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silvoarable system in England, it has been reported that if the default tree system is widely spaced, the land equivalent ratio can be 1.22-1.45 (Graves et al., 2007) but less than 1.12 if the tree system is densely spaced (Graves et al., 2010). This effect may be one reason why reduced costs from yield benefits were not indicated by the case studies.

The results from the case studies, suggest that combining livestock with crop production or combining trees with farming can increase fixed costs, as also observed by Low et al. (2023). Introducing crops or animals on a farm will require up-front investment in new facilities, and these high investments costs can be unattractive to farmers (Do et al., 2020). In addition to higher capital costs, the human and administrative costs of mixed farming and agroforestry systems can be high. García de Jalón et al. (2018) also identified increased labour costs, management costs, and increased administration costs as the dominant negative aspects of agroforestry identified by stakeholders across Europe.

By contrast, Garrett et al. (2017) has argued that mixed farming and agroforestry could result, on average, in more stable income flows during the year and over time compared to continuous crop or livestock production. There is also an argument that mixed farming systems are less sensitive to changes in costs, because of less reliance on non-farm inputs (Low et al., 2023). This observation is supported by the analysis of the case studies, which indicated that the four mixed farms (Table 1) and the nine agroforestry farms (Table 2) reported higher levels of production resilience. Increased financial resilience was reported in two of the four mixed farms and five of the nine agroforestry case studies.

2.3.4 Opportunities for market development through product differentiation

With regard to product differentiation valued by the market, all case studies had links with local communities and networks, whilst in 8 out of 13 there was a farm shop, café or restaurant on-site where products were directly sold. The case studies also highlighted that the mixed farming or agroforestry was associated with certification, with 11 of the 13 case studies receiving organic certification, and three case studies highlighting some form of animal welfare certification (Table 1). None of the case studies mentioned carbon or biodiversity certification.

2.3.5 Wider societal and environmental benefits

The last attribute highlighted in the case study reports was the recorded effect on farmer satisfaction and wider societal value. The effect on farmer satisfaction was positive in eight of the case studies and negative in four. Each of the case studies also reported positive community engagement and perceived environmental benefits by the farmer. In five cases, the farmer reported positive animal welfare benefits, with no negative effects reported. The positive role of government finance for the environment was mentioned in four cases, and a negative effect in one case. In terms of other support, one case study discussed policy tools and CAP measures to restructure a mill and develop a farm shop (Table 1).

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3 Interventions to support mixed farming and agroforestry value networks

In this section, possible interventions to support value networks for mixed farming and agroforestry are examined using the Behaviour Change Wheel framework.

3.1 The behaviour change wheel framework

The Behaviour Change Wheel framework is based on that the idea that motivation, capability, and opportunity are three core components that can determine action (Figure 7). Vergamini et al. (2023) in Deliverable 5.3 recognised that adoption and maintenance of mixed farming or agroforestry is a multi-dimensional process including motivation (e.g. profitability and relationship to value systems), opportunity (e.g. communication between parties), and capability (e.g. education). Moreover, the model outlines different interventions depending on whether the objective is to increase capability, opportunity, or motivation, which can be related to different policy categories (Michie et al., 2011; Michie et al., 2014) (Figure 7).

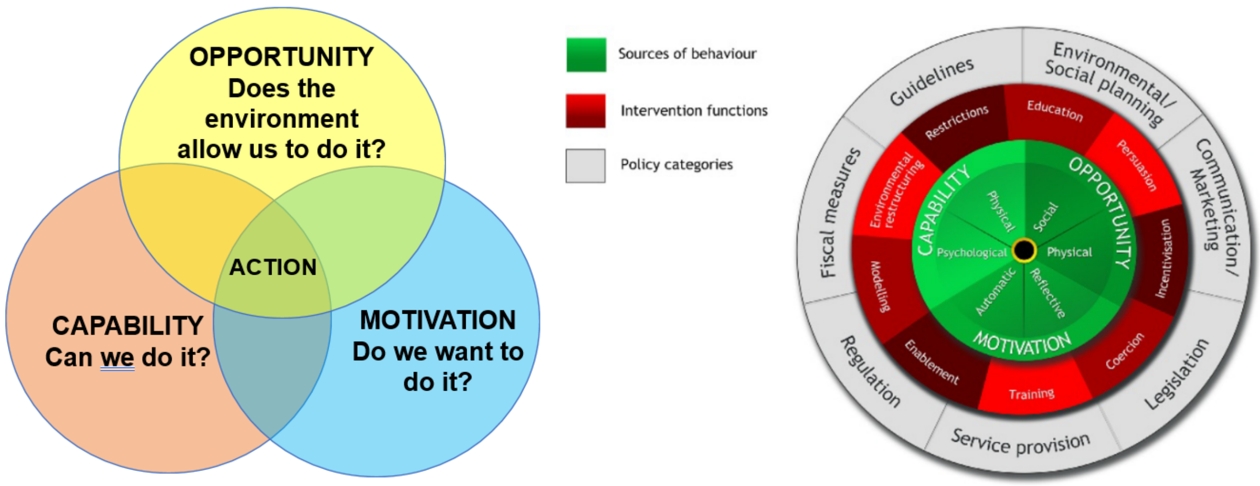

Figure 7. The Behaviour Change Wheel assumes that behaviour change occurs when a) motivation, capability, and opportunity aligns. Moreover the ability to affect motivation, capability and opportunity can require different interventions (Michie et al., 2011)

Using the Behaviour Change Wheel as a basis, the interventions to support agroforestry and mixed farming are considered firstly in terms of clarifying motivations for: i) governments and ii) farmers, iii) capacity building at farm scale, and iv) creating opportunities within the supply chain and for market development with consumer (Figure 8). The potential instruments that can help clarify motivations, enhance capability, and create opportunities are described in Table 3.

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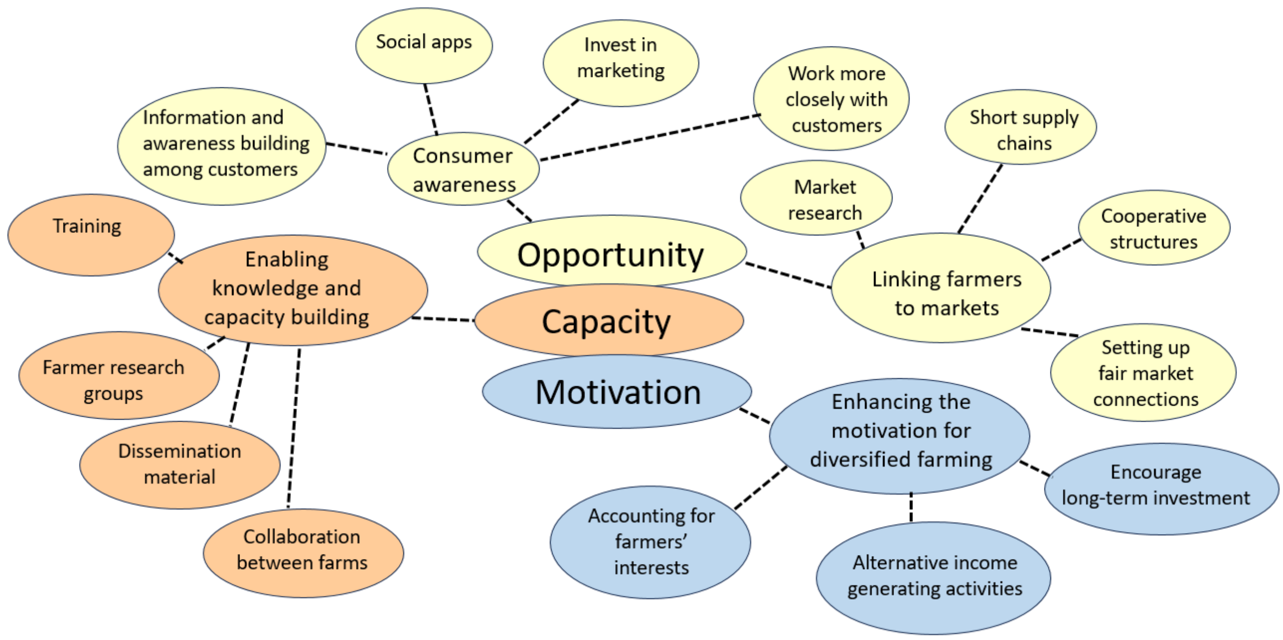

Figure 8. Schematic illustration of the role of opportunity, capacity and motivation in agroforestry and mixed farming value networks

Table 3. Interventions that can support the required behaviour change (ModelThinkers, 2024)

Intervention	Definition	Link to capability, motivation or opportunity
Education	Informing and explaining to increase knowledge and understanding	Motivation and capability
Persuasion	Influencing to develop positive or negative feelings that stimulate action	Motivation
Incentivisation	Establishing rewards and incentives	Motivation
Coercion	Establishing punishments and costs	Motivation
Training	Developing knowledge and skills	Motivation and capability
Enablement	Increase means or reduce barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring). E.g. surgery to reduce obesity or prostheses to promote physical activity	Motivation and capability
Modelling	Providing a role model or example	Opportunity
Environmental restructuring	Changing the social or physical environment	Motivation, capability and opportunity
Restriction	Using rules or laws to change behaviours	Opportunity

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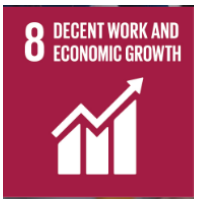
3.2 Government motivations for mixed farming and agroforestry

John Dewey identified that “We only think when we are confronted with a problem”. At a governmental level, the motivations for promoting mixed farming and agroforestry are based on the premise that they can provide a method of addressing some of the major economic, social, and environmental challenges faced by society.

One of the most successful attempts at framing motivations for governments is the UN Sustainable Development Goals which identifies 17 goals for government if we are to achieve sustainable development at national and global levels (United Nations, 2015). Mixed farming and agroforestry can support a large number of the Sustainable Development Goals, but they are particularly pertinent in terms of SDG 2 on ending hunger and improving food security, SDG 8 on sustained economic growth, SDG 13 on addressing climate change, and SDG 15 on promoting sustainable use of terrestrial ecosystems (Table 4).

Table 4. Mixed farming and agroforestry can contribute to the achievement of Sustainable Development Goals (after United Nations, 2015)

	SDG 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture e.g. target 2.4: “By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality”
	SDG 8 – Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all e.g. target 8.2: “Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors”
	SDG 13 – Take urgent action to combat climate change and its impacts e.g. target 13.1: “Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries”
	SDG 15 – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss e.g. target 15.3: “By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world”

3.2.1 Food security

As described in Section 2.1, there is evidence that mixed farming and agroforestry can play a role in enhancing food security. Although the effect of mixed farming and agroforestry can be to reduce the yield of the original products, they can at the same time be more resilient agricultural practices

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that "maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality". In addition, they can increase the range of products grown from a specific area of land and have the potential to make more efficient use of light, water, and other environmental resources (Graves et al., 2007; Graves et al., 2010; Peyraud et al., 2014).

3.2.2 Decent work and economic growth

Davis and Rylance (2005) and Hawkes and Ruel (2011) both suggest engaging stakeholders (public, private companies, consumers and NGO) and that using a value chain approach means paying explicit attention to job demand and supply, which may involve considering temporary or permanent job creation and considering job quality.

3.2.3 Climate action

Climate change action can be related to both mitigation and adaption. There is substantial research that the adoption of agroforestry can increase carbon storage as biomass and soil carbon at a farm-level (Burgess et al., 2023; See Appendix 6.2). However whereas the introduction of crops on livestock farms can provide benefits in terms of climate change mitigation, introducing livestock on arable farms can increase greenhouse gas emissions at the farm-level.

The adoption of trees on livestock farms can also help with climate adaptation. For example the dehesa or montados systems in Spain and Portugal with long crop rotations, low stocking rates and closed nutrient cycling, contribute to the sustainability of these systems and can also provide shade to livestock whilst minimising the risk of fire damage (Damianidis et al., 2021; Rodríguez-Rojo et al., 2022). Such adaptability to climate change can improve the biophysical resilience of the farming system (Viñals et al., 2023). In Deliverable 5.3 of the AGROMIX project, Vergamini et al. (2023) underlined that participants' decision to undertake agroforestry is strongly influenced by the attempt to reduce exposure to changes in climate and new pest diseases or by reducing the influence of external regulations on the farming system.

3.2.4 Life on land

Within the European Union, the Common Agricultural Policy (CAP) applies the objectives of the SDG within the context of European land use. The three objectives of the CAP include viable food production, sustainable management of natural resources and climate action, and balanced territorial development. The high ecological and social value of agroforestry is recognised by the EU in Council Regulation (EC) No 1698/2005, and this is the basis for support for agroforestry within the Common Agricultural Policy (Augère-Granier, 2020). For example, Rodríguez-Rojo et al. (2022) explains that the diversity in dehesas is dependent on complex understorey vegetation and heterogeneous habitats. A review of the responses to EU agri-environmental schemes in South West Germany indicated that such schemes tended to reduce fertilizer application, but the effect on greenhouse emissions was mixed (Stetter et al., 2022).

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Recent developments in the European Union to support the EU's goals for sustainability include the Farm to Fork (F2F) strategy for a fair, healthy and environmentally-friendly food system (European Commission 2020). The 2023–2027 Common Agricultural Policy also offers greater opportunities for context-specific approaches (Guyomard et al. 2023) and empowering non-state actors (Moschitz et al. 2021).

3.3 Farmer motivation for mixed farming and agroforestry

In the analysis of the 13 mixed and agroforestry farms studied for the EIP-Style factsheets (Dumper-Pollard et al. 2022), eight of the case studies reported that the farmers found enjoyment or increased well-being associated with mixed farming and agroforestry systems. Farmers are not just managers, but they also gain purpose and satisfaction from the process of farming. They typically have a personal interest in ensuring that state of farm is improved from one generation to the next including improvements in soil health and farm-level biodiversity. Methods to reduce agrochemical use can both be beneficial financially and in terms of reducing toxicity risks to the farmers and farm workers. For such reasons, Low et al. (2023) argues that mixed farming may allow "more fulfilling and permanent employment". Morris and Potter (1995) argue that farmers who have a particular commitment to environmental concerns can be early adopters of sustainable farming practices (Table 5), and the promotion of mixed farming and agroforestry should be concentrated on awareness raising. For example, Vergamini et al. (2023) reports that motivational factors for adopting sustainable farming practices include the significance of improving resilience against climatic and market changes for agroforestry farmers. By contrast, 'passive adopters'' and the ''conditional non-adopters'' may be engaged more on the basis of regulation and financial incentives. Vergamini et al. (2023) reports that this may include "a particular emphasis on reducing dependence on external inputs and navigating regulatory changes".

Table 5. Farmers' attitudes towards adopting sustainable farming systems can be disentangled into the following four categories (after Morris and Potter, 1995)

Types of adopters	Characteristics	Timeline for change
Active adopters	They are driven by a commitment driven by environmental concerns and personal values.	Short term
Passive adopters	They are motivated by profitability and financial gains from farming activities, including system changes.	Short – medium term
Conditional non-adopters	They are open to adoption if it becomes more profitable	
Resistant non-adopters	They are unlikely to change due to various barriers, including scepticism towards new systems and resistance to change	Long term

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3.3.1 Regulations to motivate farmers

Government regulations can increase the motivation to establish or maintain mixed farming and agroforestry systems. For example, in the EU cross-compliance regulations can protect hedgerows and landscape features. In many regions, there are restrictions on the annual application of nitrogen. In France, Peyraud et al. (2014) reported that reintroducing for example a herd of 200 ewes to a livestock farm could provide 710 kg of N, 770 kg of P and 1050 kg of K, which would be sufficient to fertilize about 15 ha per year, thus reducing reliance on fertilizers as external inputs. Governments can also play an important role in regulating competition which can help to limit uncompetitive behaviour and concentration in value chains, and in setting food safety policy (Vermeulen et al., 2008). In some situations, mixed farming may be constrained by downstream purchasers who, for example, identify health issues in purchasing vegetables from land receiving animal manure.

When introducing regulation, it can also be useful to consider the administrative costs. As indicated earlier, García de Jalón et al. (2018) identified increased administration costs as a dominant negative aspects of agroforestry identified by stakeholders across Europe. Some of this administration is related to government regulation. For example in some countries, single farm payments may only be made on parts of an agroforestry field and the farmer has to individually identify the areas of trees and the areas of cultivation.

3.3.2 Grants and subsidies to promote mixed farming and agroforestry

As indicated in Table 1 and Table 2, high costs associated with mixed farming and agroforestry suggests that the expansion of mixed farming and agroforestry will not be supported by a market primarily driven by low cost of production. Nevertheless, there is an argument that because mixed farming and agroforestry can provide “public services”, a case can be made for public funding to support these systems. This is one of the reasons why agroforestry establishment is supported in the Common Agricultural Policy through Pillar 1 and Pillar 2 payments. Although some farmers are concerned by how the integration of trees on agricultural land affects the eligibility of Pillar 1 payments, the actual level of eligibility depends on interpretation of the EU regulations at a national level (Lawson 2020a).

In the implementation of Pillar 2 of the CAP between 2014-2020, the “establishment and maintenance of agroforestry systems” was funded under Article 23 of Regulation 1305/2013 (Lawson 2020b), and it is covered by Sub-measure 8.2 in Rural Development Plans. The measure was implemented in 35 regions within eight countries (France, Greece Spain, Italy, Portugal, Belgium, Hungary and the UK). Other measures that support agroforestry more indirectly are measures 4.4 (support for non-productive investments linked to the achievement of agri-environment-climate objectives), 10 (payment for agri-environment-climate commitments), and 4.3 (support for investments in infrastructure related to development, modernisation or adaptation of agriculture and forestry).

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In contrast to agroforestry, mixed farming receives minimal policy support and it is rarely mentioned within the Common Agricultural policy (Buratti-Donham et al., 2023).

Vergamini et al. (2023) reported that if the adoption costs for mixed farming and agroforestry were provided by government, then 69% of farmers on mixed farms and 76% of farmers with agroforestry intended to maintain their system (Table 6). By contrast, without policy support to compensate for the costs, only 27% of farmers for both systems indicated that they were extremely likely or likely to continue their systems in 2030. The results clearly indicate that land management choices are sensitive to, and influenced by, the availability of grants and subsidies.

*Table 6. Stated adoption in 2030 either **assuming new schemes** or **no policy support** to reimburse the compensation cost for **adoption** of agroforestry and mixed farming systems (source: Vergamini et al., (2023); numbers rounded)*

	System	Proportion of responses (%)					
		Current adoption	Extremely likely	Likely	Neutral	Unlikely	Extremely unlikely
New policy support	Agroforestry	Yes	54	22	9	4	11
		No	6	27	21	22	24
	Mixed Farming	Yes	34	35	20	4	6
		No	5	18	18	24	34
No policy support	Agroforestry	Yes	18	9	22	5	44
		No	4	11	35	24	25
	Mixed Farming	Yes	9	18	34	17	22
		No	3	7	24	28	38

3.4 Building capacity at farm level

3.4.1.1 Education and technical capability

Mixed farming or agroforestry are considered more complicated systems than monocultures. Arable farmers will need to be able to manage livestock, livestock farmers will need to manage crops, and in agroforestry systems farmers will need to manage trees. Hence the establishment and maintenance of mixed farming can require higher levels of technical and management capacity than the management of specialised systems. Moreover, Gereffi et al. (2020) argue that it is vital for suppliers to continue to improve their capability if they are to avoid being involved in a captive value chain (Figure 5). Increasing the capability of staff can be viewed as one component of the supporting activities that can determine the margins obtained by a firm (Figure 9). Kroesen et al. (2015) argues that the capacity of farmers relates both to their technical capacity and their beliefs, and cultural values and attitudes. Moschitz et al. (2021) also argue that European targets for organic agriculture are also dependent on support for the agricultural knowledge and innovation system (AKIS) and improved capability of actors across the value chain.

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Vergamini et al. (2023) analysed the factors leading to the adoption of mixed farming and agroforestry systems and the role of policy in creating such changes in Germany, Serbia, Greece, United Kingdom and Italy. They reported that farmers with a background in agricultural education are more inclined towards adopting agroforestry or mixed farming systems, highlighting the role of formal education in shaping perceptions and openness to sustainable practices.

One method for building technical and management capacity is to provide training and access to networks and resources (Eade, 2007; Emery et al., 2007). Other means of building capacity can include demonstration projects to showcase successful practices, knowledge exchange via farmer networks, workshops, and open-days and research and innovation to develop techniques or tools. Farmer research can be a particularly effective means of disseminating information. For example, during farm open-days, farmers have the potential to showcase their farm systems, how they are designed, what is produced, and present their results. They can also identify, develop, and field-test innovations that could improve the benefits and viability of agroforestry or mixed farming.

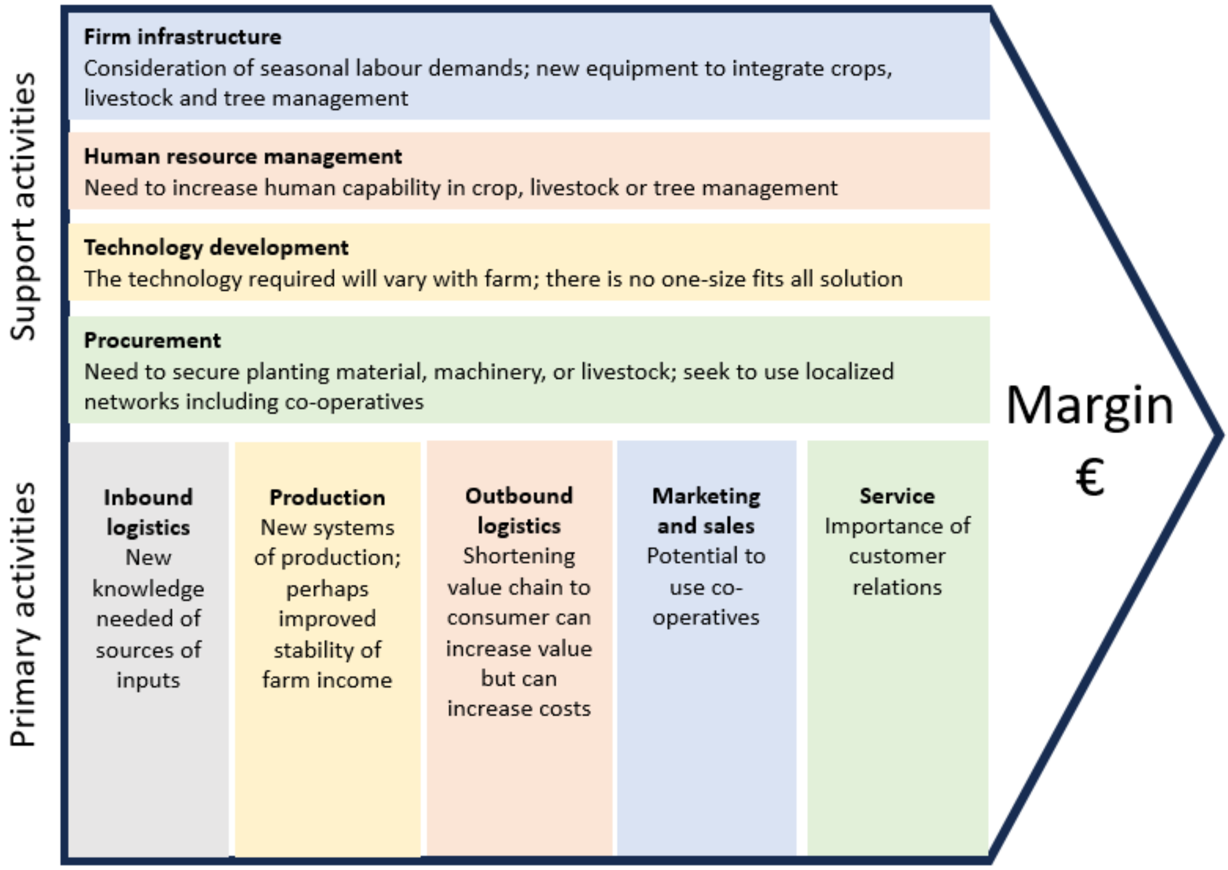

Figure 9. Porter's analysis of the value chain within a business illustrating how primary and support activities may need to change to ensure margins are maintained or increased following the implementation of mixed farming or agroforestry

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Developing the technical skills required to plan the scheduling of the major activities with mixed farming and agroforestry systems is also important. For example, when integrating livestock on an arable farm, the peak periods of livestock management should not coincide with the peak periods of crop management and harvest.

Independent information is often a major constraint in the development of agroecological systems. Hence there can be advantages in NGOs and other organisations producing high quality syntheses of evidence that can be applied on a range of farms. For example, in the AGFORWARD project, 46 "Innovations leaflets" (brief one page documents) and 10 "Best practices leaflets" were produced for stakeholder groups across 13 European countries (AGFORWARD, 2018).

3.5 Creating opportunities in the value network

Ndlela and Worth (2023) argue that building farmer capacity should go beyond training to encourage learning among all stakeholders in terms of skills and in terms of creating "opportunities to take command of and access to resources" along the value chain.

3.5.1 Understanding the market opportunities

Forging vertical linkages that improve communication and dissemination along value chains can be an effective means of improving the functioning of the value chain and/or the terms of participation of selected beneficiaries (Henriksen et al., 2010). Farmers should ideally be familiar with the potential suppliers of inputs and purchasers of outputs prior to embarking of new agroforestry or mixed farming systems. This relates to inbound logistics in Figure 9. In this situation, advisory practitioners can be particularly useful in supporting farmers' or land-owners' decision making. Gereffi et al. (2005) also reports that because standards and protocols can change, there can be distinct advantages to those organisations that actively participate in the rule-setting process.

Low et al. (2023) report that organisation and collaboration between farms can offer substantial benefits such as the reduction of operating costs and enabling the scaling up of the benefits of mixed farming and agroforestry system. Collaboration can also enable farms with different specialisations to engage with one another and make use of comparative advantages, such as in knowledge and capital. Such synergies may be one way of overcoming the increased labour demands that are often associated with mixed farming and agroforestry systems (Low et al., 2023).

3.5.2 Use of co-operatives

Low et al. (2023) report that co-operative structures and the collective processing of primary outputs into added-value secondary products allows farmers to take greater ownership of their value chain and capture more value. In Deliverable 5.3 of the AGROMIX project, Vergamini et al. (2023) provides some evidence that farmers with agroforestry systems tended to derive a higher proportion of the value of the sale of arable and livestock products through co-operatives than non-

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agroforestry farms (Table 7). The proportion of the value of wood and arable crops used within the farm also tended to be greater on agroforestry rather than non-agroforestry farms.

Table 7. Proportion of economic value derived from selected sales channels of wood, arable and livestock products from farms without agroforestry (-AF) and with agroforestry (+AF) (source: Vergamini et al. (2023)

Selected sales channels	Proportion of economic value obtained from selected sales (%)					
	Wood		Arable		Livestock	
	-AF	+AF	-AF	+AF	-AF	+AF
Cooperative	9.2	10.4	11.1	14.6	9.9	27.1
Geographical indications	4.2	6.7	0.8	7.3	10.8	6.1
Reused on the farm	9.5	20.1	17.9	26.6	6.1	2.8
Self-consumption	4.4	0	3.0	0	10.6	1.6

In the same study, a review of the share of the economic value derived from wood, arable and livestock products from mixed farms also showed a greater use of co-operatives than non-mixed farms, and the use of geographical indications for the sale of livestock products (Vergamini et al., 2023) (Table 8). There is also evidence that mixed farms made greater use of wood and arable products within the farm itself.

Table 8. Share of economic value derived from selected sales channels of wood, arable and livestock products from farms without mixed farming (-Mixed) and with mixed farming (+Mixed) (Vergamini et al., 2023)

Selected sales channel	Proportion of economic value obtained from selected sales (%)					
	Wood		Arable		Livestock	
	-Mixed	+Mixed	-Mixed	+Mixed	-Mixed	+Mixed
Cooperative	6.7	12.6	8.3	15.5	5.0	21.5
Producer organisation	4.1	5.5	2.5	15.8	1.9	6.8
Geographical indications	0.9	4.2	7.8	7.6	6.8	13.9
Individual sales to local markets	0.8	2.5	1.4	3.3	1.0	5.6
Reused on the farm	6.3	16.9	14.5	24.8	6.6	4.4

3.6 Opportunities for market development with consumers

In contrast to the limited opportunities to be competitive on price alone, mixed farming and agroforestry can offer opportunities in terms of securing a premium through product differentiation. Meldrum and McDonald (1995), using the Ansoff matrix (Figure 6), argue that such differentiation is usually less risky than producing a totally new product. The opportunities for such market development with the consumer include the use of short supply chains including farm shops and the use of certification and branding.

3.6.1 Short supply chains

Each of the 13 case studies in Table 1 and Table 2 highlighted the advantages of localism in the value chain for their mixed farming and agroforestry system. In many cases the network of customers was

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built up over many years (Dumper-Pollard et al., 2022). Short food supply chains can result in both a higher price for the final product and also farmers receiving a higher proportion of the final sale price achieved in long value chains (Malak-Rawlikowska et al., 2019). In addition, small-scale direct marketing of agroforestry and mixed farming products can potentially overcome marketing and labelling costs by appealing to consumers' beliefs and emphasizing for instance the nutritional and physical composition of products, taste, origin, animal welfare and environmental stewardship (Rohrig et al., 2020). Williams et al. (2024) also relates the use of farmers' markets to the development of regional value chains.

It is also possible that local value chains provide greater autonomy to the farmer (Malak-Rawlikowska et al., 2019; Aouinaït et al., 2022). However a review of short food supply chains by Malak-Rawlikowska et al. (2019) also showed that localised production and consumption (which included pick-your-own) can be associated with high food miles and also higher carbon footprints. The same review also indicated that the labour requirements of short supply chain per unit product also tend to be higher, partly related to the greater time spent in transporting products and the preparation of smaller quantities for market.

3.6.2 Improved product quality

Dumper-Pollard et al. (2022) reported that a typical characteristic of most stakeholders' farms in the AGROMIX project was the high quality of products. It has been reported that agroforestry can enable the cultivation of a wider range of edible plants including indigenous fruits, nuts, and vegetables that are often richer in protein, fibre and micronutrients than staple crops (Jamnadass et al., 2013). The USDA National Agroforestry Centre provided case studies of agroforestry producers who have focused on "unique and high-quality products" such as speciality maple syrup, pecans and elderberries as part of their marketing strategies (Lim et al., 2021).

3.6.3 Product certification and labelling

One way to promote differentiation in the market is through certification. Chever et al. (2022) argued that certification schemes can provide assurance that certain product characteristics or certain production systems have been achieved. The certification schemes can either operate between businesses (B2B) or between businesses and consumers (B2C). The tendency is for business to consumer schemes to use logos, whereas this is less common in business to business schemes.

There are a wide range of types of certification schemes ranging from good agricultural practice or animal welfare issues to a specific attribute such as geographic origin, organic status, net zero status, fair-trade and absence of genetically modified organisms (Table 9). However there are few certification schemes that specifically focus on mixed farming or agroforestry.

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Table 9. Example types of certification schemes adapted from Chever et al. (2022)

	Scheme	Description
1	Good agricultural practices	Schemes focusing on environmentally friendly methods of production
2	Animal welfare and health	Focus on animal welfare and health
3	Origin/quality of the final products	Schemes guaranteeing a specific origin and/or attributes on the final product
4	Organic+	Based on organic standards, with some additional rules
5	Climate	Specific focus on climate-related issues
6	Multi-purpose	Focus on a combination of issues, for instance good agricultural practices and quality management
7	Traceability/safety	Schemes committing to provide high transparency on the origin and quality management of products all along the supply chain
8	Non-genetically modified	Main guarantee is the absence of genetically modified organisms
9	Fairtrade	Focus on social and ethical trade commitments

Within the 13 case study mixed and agroforestry farms, organic status was a common feature on each of the agroforestry farms and in two of the four mixed farms (Table 1 and Table 2). In two of the agroforestry and one of the mixed farm case studies, certification related to animal welfare was also reported.

Across the 13 case study sites, there was no certification of climate change or net zero greenhouse gas emission reductions. However such schemes are rapidly being developed such as the Bas-Carbone label and the Woodland Carbon Code (Woodland Carbon Code, 2024). Moreover major retailers have indicated that they are targeting net zero greenhouse gas emissions in their supply chains by 2050 (Morrisons, 2023; Sainsbury's, 2023; Tescos, 2021; Waitrose, 2023).

Gereffi et al. (2020) argue that the ability to codify product differences can determine the type of governance within a value chain. For example, if greenhouse gas emissions cannot be codified, then a move from market to modular or even vertical integration may become more common (Figure 5). It is anticipated that the effect of certification for greenhouse gas emissions is likely to be positive for agroforestry systems, as increasing tree cover on farms is one of the few ways of increasing carbon sequestration. There can also be greenhouse benefits to integrating crops on livestock farms, but adding livestock on arable farms can increase greenhouse gas emissions at a farm level (Burgess et al., 2023).

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3.6.4 Consumer-driven marketing and awareness creation

One method of increasing consumption of agroforestry and mixed farming products would be to promote the socio-environmental and climate benefits of products to consumers. This could be done by governments, organisations within the value chain, or individual farmers. One example of where direct marketing of agroforestry occurs as part of the product design (Figure 10) is in the production of cheeses by Silvo in Brittany in France (Ellen McArthur Foundation, 2012). In Deliverable 5.2, Dumper-Pollard et al. (2022) also highlights that one farm manager believes that social apps will be important in helping customers to understand the story regarding production techniques used on the farm and the methods used for processing traditional products.

Figure 10. Silvo is a cheese brand in France that directly markets the advantages of agroforestry (Ellen McArthur Foundation, 2021)

However, transferring the message of agroforestry and mixed farming systems to customers is not straightforward. For instance the AGROMIX Deliverable 5.2 report highlighted that there seems to be little awareness of “meat/milk/cheese from free grazing” and biodynamic products (Dumper-Pollard et al., 2022). Hence in many cases agroforestry and mixed farms may benefit from being engaged in existing schemes such as animal welfare and organic certification. For example, in the UK the integration of trees in free-range poultry systems is required for the RSPCA Assured scheme which focused on animal welfare (RSPCA Assured 2024).

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4 Conclusions

Across many food value networks, farmers may only acquire 6-11% of the final value of the food purchased by the consumer. For many farmers, the production of food is financially precarious and there is limited capacity to invest in new farming practices even if they can improve animal welfare, enhance biodiversity and reduce greenhouse emissions. The focus is often financial survival.

In a recent paper, Williams et al. (2024) argue that one option is for key actors to facilitate a transition from the current dominant form of the agro-industrial control of food production to value chains that support the multi-functional benefits that can be produced by farms or value chains that emphasis food as a community good (Table 10).

Table 10. Characteristics of three types of agri-food value chains: agro-industrial control, multi-functional value chains, and civic food networks (after Williams et al., 2024)

	Type of value chain		
	Agro-industrial control	Multi-functional value chains	Civic food networks
Guiding logic	Food as a commodity	Food value includes socio-ecological qualities	Food as a community good
Description	Farmers are high dependent on and influenced by value chain and state actors	Organisation innovations in the formal value chain place value of farmer autonomy, ecological, and/or regional food qualities	Farmers and consumers organise to create relations outside of main markets
Defining features	State regulation, subsidies, advisory services, R&D, contract farming, private quality standards	Collaborative relationships, innovation, sustainability labels/brands, state funding and support, peer influence and capacity building	Actors unite, CSOs lobby the state, knowledge sharing, personal relationships, direct trade, changing attitudes and value
Relative farmer autonomy	Low	Medium	High

The creation of multi-functional value chains is particularly important in the context of global and national targets to restrict global temperature and to achieve net zero greenhouse gas emissions. As retailers and processors seeks to achieve the net zero emissions targets for their supply chains, increasing pressure will be placed on farmers and landowners. Whilst this creates challenges for the integration of livestock on arable farms, it also creates opportunities for agroforestry and the integration of crops on livestock farms.

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Based on the results in this report, we propose three main guidelines for establishing successful mixed farming and agroforestry value networks:

1. **Linking mixed farming and agroforestry with stakeholder motivations**
   Existing research and practice highlights that there are clear synergies between societal goals, such as the Sustainable Development Goals, and the impact of agroforestry and mixed farming. Clear identification and articulation of these links provides the motivation for government and others to support mixed farming and agroforestry. In some areas, where the links are unclear there is a need for research, development, and dissemination. Clear and consistent messaging of the long-term societal goals by national governments in terms of food security, net zero emissions and biodiversity are also useful in guiding the decisions of farmers and others in the value chain.

   At a farm-level, there are benefits of encouraging farmers to reflect on the motivations and objectives of their business and how this relates to their well-being. In some cases, enhancing the security of tenancies will help farmers to take a longer-term viewpoint. The analysis within this report highlights that mixed farming and agroforestry systems typically have higher variable and fixed costs. Hence such systems will be undermined if the only focus of the market is on achieving the lowest cost. Government regulation is one means of preventing unscrupulous means of producing low cost products. Governments can also motivate farmers by providing public payments in the form of grants and subsidies for public services such as enhancement of biodiversity and cultural benefits. In terms of regulation and the allocation of grants, it is important that the level of administration required is appropriate.

2. **Building capacity at farm-scale**
   The creation of a dynamic and healthy agricultural sector depends on encouraging and enhancing the capabilities of those who work in the sector. The use of demonstrations, living labs, and extension activities to facilitate learning is important.

3. **Creating opportunities within the value network**
   One way of identifying and maximising the opportunities for synergies and innovation in value chains is to support initiatives that bring members of the supply chain together. This can include the involvement of co-operatives. The primary opportunities for farmers to derive greater value for agroforestry and mixed farming products includes the use of short value chains and certification when the financial benefits outweigh the administration and registration cost. For selected products there may also be opportunities to incorporate the features of agroforestry or mixed farming in the packaging and labelling of the product. As processors and retailers seek to achieve net zero supply chains, there will be a need for more information flow within value networks. The drive to move towards net zero will also increase the use of trees on farms and of crops on livestock farms, but it may limit the integration of ruminants on arable farms.

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6 Appendix

6.1 Description of mixed farming and agroforestry case studies

Table 11. Characteristics of the four mixed crop and livestock case studies (Dumper-Pollard et al., 2022)

Case study	Farm size (ha)	Main crops	Main livestock	Products
2. Farsala region - Greece	40	Cereals, legumes, vegetables and livestock fodder crop mixtures	Sheep	Sheep graze on crop stubble. Fodder grown to supplement livestock diets.
6. Veneto region - Italy	12	Barley, wheat, triticale, corn, horticulture	Cattle, pigs	Farm cereals (triticale, burley, corn) and unsold vegetables are used for feeding pigs. Manure from the livestock is used to fertilise the soil to improve vegetable production. Weed control is facilitated by a rotation and use of biological/mechanical methods.
7. South of Leipzig - Germany	911	Cereals, oilseed rape and legumes	Cattle	Feed is 85% grown on-farm, only mineral feed and coarse colza meal are bought from outside. Dung from livestock is used as organic fertiliser on the arable land
12. East Sussex - UK	220	Cereals, vegetables	Cattle (dairy and beef), pigs, sheep, chickens (eggs and meat), ducks, turkeys, geese	Feed grown for animals, animal dung as fertiliser for fields and vegetable garden.

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Table 12. Characteristics of the nine agroforestry case studies (Dumper-Pollard et al., 2022)

Case study	Farm size (ha)	Main crops	Main livestock	Agroforestry type	Products
1. Evrotas valley - Greece	2	Citrus fruit, figs, mulberries, olives, beans, herbs	N/A	Multi-layered agroforestry system	Companion planting, poly-cropping, support species planting.
3. Pelion region - Greece	0.5	Fruit and nuts (many different varieties), olives, wine	Ducks, chickens, guinea fowl, turkeys, geese	Polyculture Silvopastoral System	Orchard grazing
4. Brugge region - Belgium	4	Fruit and nut orchards, vegetable garden and edible flower strips	Goats, pigs, sheep	Silvopastoral	Orchard grazing
5. Tenuta di Paganico region - Italy	1500	Grapes, olives, wheat, barley, oats, corn	Cattle, pigs	Silvopastoral	Grow hay and straw for animal feed, woodland grazing.
8. Rhineland-Palatinate - Germany	112	Fruit (apples, pears, cherries, quinces, currant, plums) sold fresh or juiced	Cattle, chickens	Silvopastoral	The chickens are allowed in an area of around 5 ha, and the cows are allowed to graze in around 9 ha orchards.
9. Małopolskie region - Poland	30.5	Wood (for own use) and apples	Cattle	Silvopastoral	Orchard grazing
10. Suffolk-Norfolk border region - UK	22.5	Cereals, legumes, fruit, hedge laying staves, vegetables, hemp, haberdashery, woodchip	N/A	Silvoarable	Crops grown on a rotation in tree alleys. Woodchip from trees used as fertiliser. Organic crop rotation
11. Northeast Cotswolds - UK	1000	Cereals, vegetables, floristry products	Cattle, sheep, laying hens, turkeys	Silvopastoral	Hens graze 40m wide paddocks in between lines of alder and apple trees and use trees for shade while fertilising soil. Hens provide weed control.
13. Weinviertel region - Austria	100	Wood, fruit and nuts, cereals	N/A	Silvoarable	Crop alleys and poly-cropping for a high-value silvoarable system

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6.2 Summary of evidence of impact of mixed farming and agroforestry

This section is reproduced from Burgess et al. (2023). Evaluating Agroecological Farming Practices. Report from the "Evaluating the productivity, environmental sustainability and wider impacts of agroecological compared to conventional farming systems" project for DEFRA. 20 February 2023. Cranfield University and UK Centre for Ecology and Hydrology. **https://randd.defra.gov.uk/ProjectDetails?ProjectId=20584**

Integrating livestock into crop systems

The re-integration of crop and livestock production has been suggested as a method to solve challenges of the global food system (Garrett et al. 2017). This integration can occur at field, farm, and regional levels, but the focus of this analysis is at a farm-level. It can be useful to consider the integration of livestock into crop systems (Table 13) separately from the integration of crops into livestock systems (Table 14) as the impacts can be different. Bell and Moore (2012) report that closer integration typically requires more attention to management and reduced integrated typically requires an increase in external inputs.

Table 13. Impacts of integrating pasture and livestock into crop systems

Statement	Confidence	Effect
Soil carbon: Integration of pasture into arable crop rotation results tends to increase soil carbon, but results are often temporary or minimal	Established but incomplete	Similar or benefit
Biodiversity: Pasture integrated into crop land increases abundance of bees	Well established	Benefit
Yields: crop yields in integrated crop livestock systems can be similar to those in crop systems without livestock	Unresolved	
Greenhouse gas emissions: integration of cattle on crop farms increase greenhouse gas emissions per hectare	Well established	Disadvantage
Revenue and costs: Fertiliser costs can be reduced Weed control costs in arable crops can be reduced Mixed systems reduce the inter-annual variation in gross margins Potential to produce marketable product from a cover crop	Established but incomplete	Benefit
Costs to manage livestock increase	Well established	Disadvantage
Other: Zoonotic diseases prevent integration of livestock with leafy vegetables	Well established	Disadvantage
References reviewed for integrating pasture into arable crop systems: Bell and Moore (2012); Carvalho et al. (2010); Cooledge et al. (2022); Hilimire (2011), Liebig et al. (2021); Maughan et al. (2009), Morandin et al. (2007); Peterson et al. (2020); Peyraud et al. (2014); Salton et al. (2014); Sanderson et al. (2013); Sekaran et al. (2021); Tamburini et al. (2022); Tracy and Zhang (2008); Willoughby et al. (2022); Zani et al. (2021)		

Soil carbon: the effect of integration of grazed forage crops into an arable farm is generally to increase soil organic carbon (Salton et al. 2014), but results are often temporary or minimal (Cooledge et al. 2022; Zani et al. 2021).

Biodiversity: integration of pasture and livestock into a crop system increases the agricultural diversity of crops, but also the abundance of arthropods (Tamburini et al. 2022) including bees (Morandin et al. 2007). Animal wastes can also increase the microbial diversity of the soil (Peyraud et al. 2014).

Crop yields: in a meta-analysis, Peterson et al. (2020) reported similar crop yields from integrated crop livestock systems compared to crop systems without livestock; whereas the use of grazed winter cover crop increased mean maize yields compared to continued maize production in the USA (Maughan et al. 2009; Tracy and Zhang 2008). Willoughby et al. (2022) report that an organic system without livestock produced more protein per unit area but less fat per unit area than an organic system with livestock.

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Greenhouse gas emissions: integrating cattle into crop systems increases GHG emissions per hectare due to the release of methane by cattle (Liebig et al. 2021).
Costs: the integration of livestock into crop systems increases animal husbandry costs, can potentially provide additional revenue, can decrease fertilizer costs and weed control costs (Hilimire, 2011, Peyraud et al. 2014; Sanderson et al. 2013). In the stocking density is reduced, then loss of nitrogen to the environment can be reduced (Sanderson et al. 2013). Mixed systems can also reduce the inter-annual variation in gross margins (Bell and Moore, 2012; Sekaran et al. 2021)
Other issues: one consideration when integrating livestock into crop systems is the availability of animal husbandry skills (Hilimire, 2011). In addition, different livestock breeds may be more suited for an integrated system, than specialised production (Hilimire, 2011). Zoonotic disease impacts of allowing livestock access to leafy vegetables can also create regulatory and food safety concerns.

Integrating crops into livestock systems

There is relatively little information regarding the benefits or disadvantages of integrating crops into livestock systems. In some cases, the integration of crops into livestock systems should provide the opposite effect of "pasture-fed livestock systems".

Table 14. Impacts of integrating crops on pasture and livestock farms

Statement	Confidence	Effect
Soil carbon: integrated crop livestock systems tend to reduce or have similar soil organic carbon contents as permanent pasture	Established but incomplete	Disadvantage
Biodiversity: increasing heterogeneity could increase biodiversity	Inconclusive	Unclear
Yields: Winter grazing of annual crops can increase livestock feed relative to pasture	Established but incomplete	Benefit
Livestock production increases from integrating a crop with mineral fertiliser on degraded grassland	Established but incomplete	
Mixed systems reduce the inter-annual variation in gross margins	Established but incomplete	Benefit
References reviewed for integrating crops on livestock farms: Bell and Moore (2012); Bell et al. (2015); Bonaudo et al. (2014); de Sant-Anna et al. (2017); Dove et al. (2015); Garrett et al. (2017); Powlson et al. (2011); Salton et al. (2014).		

Soil carbon: integration of annual crops into a permanent pasture system tends to decrease (Salton et al. 2014; Powlson et al. 2011) or statistically similar levels of soil carbon (de Sant-Anna et al. 2017).
Biodiversity: White et al. (2019) using models argued that increasing the heterogeneity of productive land could lead to biodiversity gains, but we did not find field-based evidence.
Yields: Research in Australia suggests that introducing a winter feed crop such as wheat or oilseed rape into a pasture-only system resulted in greater sheep grazing days (Dove et al. 2015) and farm revenue (Bell et al. 2015). Integration of a crop with mineral fertilizer has been beneficial for livestock production on degraded grassland in regions of low natural soil fertility e.g. Brazil (Bonaudo et al. 2014; Garrett et al. 2017). Mixed systems can also reduce the inter-annual variation in gross margins (Bell and Moore, 2012).
Evidence gaps: most of the papers reviewed are outside of Europe and there seems to be a lack of replicated comparisons of integrated and specialised systems in UK and the rest of Europe.

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Silvoarable agroforestry

Silvoarable agroforestry, also known as tree intercropping and alley cropping, refers to the integration of trees with arable crops.

Soil carbon: there is evidence that tree intercropping systems increases soil carbon levels relative to conventional arable cropping, primarily in the uncultivated areas next to the trees (Established but incomplete) (Table 15).

Table 15. Impacts of tree intercropping (TI) relative to arable cropping (AC)

Statement	Confidence	Effect
Soil carbon: TI increases soil carbon relative to arable cropping (AC)	Established but incomplete	Benefit
Biodiversity: TI increases biodiversity relative to AC	Well established	Benefit
Yield: High tree density TI decreases arable yields compared to AC	Well established	Disadvantage
Low tree density TI may result in similar crop yields compared to AC	Established but incomplete	Similar
Other environmental: TI increases above-ground carbon relative to AC	Well established	Benefit
TI reduces soil erosion losses relative to AC	Well established	Benefit
TI and AC results in similar GHG emissions	Unresolved	
TI reduces soil nitrate losses relative to AC	Well established	Benefit
Economic: TI increases labour and management costs relative to AC, assuming continued arable production	Established	Disadvantage
TI can increase or decrease farm profitability relative to AC	Established but incomplete	Similar
TI can result in greater societal values than AC	Established but incomplete	Benefit
References for tree intercropping: Aertsens et al. (2013); Asbjornsen et al. (2013); Garcia de Jalón et al. (2018a); Garcia de Jalón et al. (2018b); Kanzler et al. (2018); Kim et al. (2016); Lin et al. (2017); Thevathasan et al. (2016); Torralba et al. (2016); Tuomisto et al. (2013)		

Biodiversity: a review of European tree intercropping studies has indicated a positive effect on biodiversity relative to arable cropping (Well established).

Yield: there is a wide range of tree-intercropping systems: those with closely-spaced trees will eventually reduce understory crop yields as the tree canopy develops (Well established); however some widely-spaced arrangements where, for example, the arable crop benefits from reduced wind speeds (e.g. Kanzler et al. 2018) may sustain yields (Established but incomplete).

Other environmental: there is strong evidence that tree intercropping increases carbon storage in above- and below-ground woody tissues (Well established). There is mixed evidence as to whether tree-intercropping, relative to arable cropping, reduces net greenhouse gas emissions, as CO_2 emissions generally decrease, but N_2O emissions can increase (Kim et al. 2016). There is modelled and field evidence of reduced soil erosion losses (Well established) relative to arable cropping.

Economic: tree-intercropping typically results in greater labour and management costs than conventional arable cropping, assuming continued arable production (Well established). The relative financial profitability of the system depends partly on the financial return from the tree component ranging from negative (Garcia de Jalón et al. 2018b) to positive effects (Graves et al. 2007). The inclusion of market values for the environmental benefits of such systems typically means that the societal benefit of such systems can exceed that of arable cropping (Established but incomplete).

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Silvopasture

Soil carbon: The overall effect of integrating trees on grassland in a silvopastoral system on below-ground carbon ranges from similar (Upson et al. 2016) to positive effects (Seddaiu et al. 2018) (Established but incomplete) (Table 16).
Biodiversity: a European meta-analysis (Torralba et al. 2016) indicates a positive effect of integrating trees on grassland on biodiversity (Established)
Yield: the effect of trees on pasture production depends to a large extent on the number of trees per hectare. High tree densities can supress grass yields, but low densities can enhance production, and can often provide additional fodder. The impact can also be affected by whether the grass is fertilised or not; with the effect of the trees likely to be more positive where the grass is not fertilised (Moreno Marcos et al. 2007).
Other environmental: integrating trees on grassland increases above-ground carbon storage and reduces soil erosion (Torralba et al. 2016) (Well established).
Animal welfare: stakeholders perceive that silvopasture systems improve animal welfare (Garcia de Jalón et al. 2018a).
Economic: the inclusion of trees tends to increase management and labour costs (Well established). The net effect of such systems on farm profitability is unresolved.
Evidence gap: no studies of the effects of silvopasture on greenhouse gas emissions were reviewed for this report.

Table 16. Statements related to silvopasture (SP) relative to grassland

Statement	Confidence	Effect
Soil carbon: SP relative to grassland results in similar or increased below-ground carbon	Established but incomplete	Benefit
Biodiversity: SP relative to grassland increases biodiversity	Well established	Benefit
Yield: the effect of SP on grassland yields depends on the tree density	Established but incomplete	Variable
Welfare: SP relative to grassland increases livestock welfare	Established but incomplete	Benefit
Other environmental: SP relative to grassland increases above-ground carbon SP relative to grassland reduces soil erosion	Well established Well established	Benefit Benefit
Economic: SP relative to grassland increases farm labour SP relative to grassland increases farm profitability	Well established Unresolved	Disadvantage
References: Aertsens et al. (2013); Costa et al. (2018); Garcia de Jalón et al. (2018a); Seddaiu et al. (2018); Moreno Marcos et al. (2007); Torralba et al. (2016), Upson et al. (2016)		

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