Climate-smart agriculture: ecosystem services in mixed farming and agroforestry systems

Deliverable D1.2

16/09/2022

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

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Glossary:

AF	Agroforestry
AGF	AGFORWARD, EC funded project
CSA	Climate-smart agriculture
ED	Ecosystem disservice
ES	Ecosystem service
IPCC	Intergovernmental Panel on Climate Change
MEA	Millenium Ecosystem Assessment
MF	Mixed farming
PES	Payment for ecosystem services
SDGs	Sustainable Development Goals
UNEP	United Nations Environment Programme
WP	Work Package

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1 Executive summary

The aim of this report is to evaluate the ecosystem services and disservices present in mixed farming and agroforestry systems and to assess their relative importance in relation to climate smart agriculture, from a farmers' perspective. An online survey was conducted to gather farmer perceptions of agricultural practices in relation to on-farm resilience , ecosystem services and contribution to climate change mitigation Despite the small data set (44 responses), some general conclusions can be drawn. Almost all farms had experienced extreme weather in the last five years and the vast majority of farmers plan to improve ecosystem services on their farm. The top 5 ecosystem services farmers would like to improve are: carbon sequestration; carbon cycling; enhanced soil fertility; education value; and nitrogen fixation. Farmers cited money and time as the top two requirements for improving ecosystem services on farm. The top 5 practices cited by all farm types to reduce the effects of extreme weather were: keeping the soil covered; increasing diversity of crops; rotational grazing; incorporating trees; and growing indigenous species.

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2 Expected impact

This report is in relation to Task 1.2 within the AGROMIX Grant Agreement. It provides an overview of the ecosystem services and disservices from mixed farming and agroforestry systems that characterise climate-smart agricultural systems, as seen by farmers both within AGROMIX's network of experimental farms and outside. The report provides a ranking system of farmers' perceptions of ecosystem services and disservices in relation to specific farming practices.

The report will be used across the AGROMIX consortium; highlighting the practices and services that farmers perceive to be most relevant in achieving climate-smart agriculture. This will inform other Work Packages, in particular Work Package 6 (policy). A key finding of the work was the motivation of farmers to improve on farm climate resilience and what they need to meet these ambitions. This is key if policy makers, landowners and other stakeholders are successful in providing an enabling environment for farmers to make positive change on their land.

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3 Introduction

Agriculture is a leading cause of climate change, land degradation and biodiversity loss (Willet *et al.,* 2019). However, regenerative practices such as mixed farming and agroforestry offer opportunities for agriculture to be part of the solution to these challenges (Anderson *et al., 2019*). Today, agricultural production occupies 50% of the Earth's habitable land (FAO 2019). As such, how we choose to use our land and how we choose to farm, are critical discussion points if we are to meet the United Nations Sustainable Development Goals.

Agroecology, a transdisciplinary science that includes all economic, social, ecological and political aspects of agricultural systems from production to consumption, is gaining prominence as an approach ~~potential transition~~ towards sustainable food systems for people and planet (Gliessman 2015; HLPE 2019; FAO 2018). In Europe, agroecology has recently been included within the European Common Agricultural Policy (CAP) in order to address the environmental and social issues pertaining to our food systems (European Commission, 2021).

The practical application of agroecology at farm level includes practices such as organic production, agroforestry and mixed farming (Kerr et al., 2021). Agroforestry is defined by Burgess *et al.,* (2015) 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". Mixed farming can also be defined as "the practice of deliberately integrating livestock crop and livestock production to benefit from the resulting ecological and economic interactions". As part of a multifunctional landscape, both agroforestry and mixed farming offer many environmental, social and economic benefits whilst also both adapting to, and mitigating, climate change (Hernández-Morcillo *et al.,* 2018; Mosquera-Losada *et al.,* 2018). Both systems are often managed organically, i.e. following defined organic production standards.

Figure 1, below, depicts the conceptual framework of MF and AF systems used in AGROMIX as a combination of arable, livestock and forestry enterprises.

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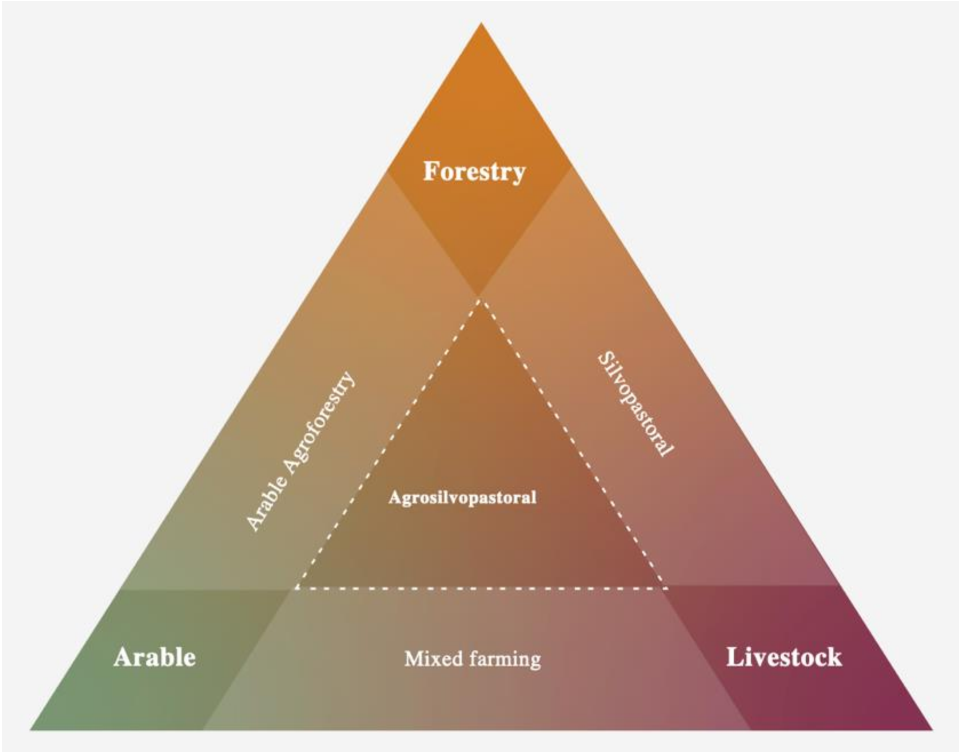

Figure 1: Adapted conceptual framework of mixed farming and agroforestry systems, AGROMIX D1.1 (Püttsepp *et al.,* 2021)

3.1 Climate-smart agriculture

The global food system – defined as the complex web of societal and economic factors influencing the production, distribution and consumption of food – is the biggest driver of global environmental change (GEC) and is responsible for an estimated 60% of global terrestrial biodiversity loss, 24% of greenhouse gas (GHG) emissions, 33% of degraded soils and 20% of overused aquifers (UNEP 2016). As a result, industry, government and civil society, is trained to the question of how we can maintain food production whilst drastically reducing agriculture's contribution to climate change and biodiversity loss. According to the 2018 IPCC report 'Special Report: Global Warming of 1.5C' we must decrease our carbon emissions globally by 50% by 2030 if we are to limit global warming to 1.5C (IPCC 2018). This link between climate, GEC and agriculture has in part, led to the term 'climate-smart agriculture', which offers an approach and set of ideas aimed at reducing agriculture's negative impacts on the climate.

Deliverable 1.1 (D1.1) defines 'climate-smart agriculture' (CSA) as "an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate", which is taken from the FAO definition (FAO 2020). CSA can also be understood as the principles and mechanisms that allow agroecosystems to resist and or recover from

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climate events such as floods, droughts, hurricanes and other extreme weather (Altieri et al., 2015), which is closely linked to theoretical understandings of 'resilience' in agroecosystems.

A key factor as to whether an agricultural system is resilient or not, is its level of functioning biodiversity (Malézieux, 2012; Oliver *et al.,* 2015). In all agroecosystems, a diversity of organisms is needed for the ecosystem to function and provide environmental services (Altieri et al., 2015). Thus, biodiversity is often used as a proxy for resilience in agroecosystems. By building agrobiodiversity, vulnerability is reduced; systems with greater diversity are more likely to contain multiple interactions and support more complex food webs, which in turn, better maintain the integrity of the system (Altieri 1999). Hence, agroecological methods are considered to be climate-smart because (in part) they increase diversity and maximise beneficial interactions from nature and build resilience, as well as reducing reliance on external inputs (which are often fossil fuel based).

3.2 Multifunctionality of cropping systems

In addition to being climate-smart, adaptations in agriculture and food systems have the potential to address other global issues such as inequality, health, poverty, and education (IPES Food 2016). This is not just a priority for the global South; in 2018, 109.2 million people in the EU were at risk of poverty or social exclusion, equivalent to 21.7% of the EU population (Euro Food Bank 2018), and the EU has some of the highest levels of inequality in the world (Our World in Data 2018). There is growing evidence that taking an agroecological approach directly addresses and improves these issues of food security and nutrition, health and poverty, while also having a net benefit ecologically (Anderson *et al,* 2019; Gliessman 2016; FFCC 2021; Kerr *et al.,* 2021).

By asking agricultural production to not just increase yield but to restore degraded lands and soils, to provide habitats for biodiversity, to sequester carbon, to be climate-smart, to provide nutritious food for all, to generate jobs and wealth (and more), we ask agriculture to be multifunctional. That is, to provide services that go beyond that of 'just' crop or animal production and provide both functional and societal objectives (Schulte *et al.,* 2015). Thus, multifunctional agriculture produces both goods, provisioning services, (such as food, fibre, fodder, and medicines), ecological services (like clean water, pollination, and carbon sequestration) as well as social and cultural services (such as recreation for mental and physical health, spiritual experiences and sense of place and tourism), also known as 'ecosystem services' (more in section 1.1.3). This type of agriculture is attractive because it addresses social, economic, and ecological challenges to sustainability.

Cropping systems that are multifunctional are usually characterised by high levels of biodiversity and complexity (Altieri 1999). MF/AF systems then, which represent higher levels of biodiversity and complexity than conventional agriculture can be considered as multifunctional land use systems. Incorporating trees into the farmed landscape and into crop production can enable farmers to diversify their income; produce on-farm bioenergy; improve biodiversity; restore degraded land and reduce herbicides and pesticides (among

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others). Table 1 highlights how MF/AF systems are related to food systems and critically, how these multifunctional systems can address all 17 Sustainable Development Goals.

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Table 1: How MF/AF systems are embedded within each SDG

SDG Goal	Relevance to food systems (Parsons and Hawkes, 2018)	Relevance to MF/AF
1 No poverty	Almost 80% of poor people live in rural areas	○ Agroecological methods have potential to increase productivity and therefore income for farmers (Kerr et al 2021) ○ Diversifying income streams on farm means greater economic resilience since risks are spread over multiple income sources ○ MF/AF may present more skilled labour needs on farms and in value chains ○ Increased livelihood resilience through the provision of ES leading to reduced dependence on unpredictable, distant commodity markets; when harvests are poor, the trees also provide alternative sources of both income and food, for example, fruit, fodder, or fuel ○ Vivid analysis (2021) of five countries – France, Italy, Germany, Bulgaria and Poland – showed that agroforestry creates an average of 56 jobs per €1 million invested compared to 45 jobs for electric vehicles and 31 jobs for road-building. In terms of economic return, every €1 of spending on agroforestry produces on average €3 of gross-valued added (GVA) to the economy compared with €1.8 for electric vehicles and €1.2 for upgrading roads
2 Zero hunger	We produce enough food for everyone, yet about 800 million go hungry	○ Increasing food production whilst enhancing the environment (Burgess et al., 2015)

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		○ Agroecological methods have shown to be more productive and contribute to food security and nutrition (Kerr et al 2021)
3 Good health and well-being	Good health starts with nutrition	○ Improved quality of drinking water and healthier food (Burgess et al., 2015) ○ Sustainable supply of protein (nuts) ○ Well-being effects of trees in the landscape
4 Quality education	Nutritious food is critical to learning	○ Possible increased use of organic production in MF/AF leading to increased nutrition of foods (Huber *et al.,* 2011) ○ AF systems can be very low input / maintenance, giving more time for education (however, the opposite can also be true depending on the set up)
5 Gender equality	Women produce half the world's food, but have much less access to land	○ In the global South, on-farm trees generate considerable fuelwood, saving smallholder family members (particularly women) from walking long distances (sometimes >20 km) in search of firewood, thus enhancing women's well-being and freeing them to educate and tend to children, provide farm labour, or produce other income
6 Clean water and sanitation	Sustainable agriculture holds potential to address water scarcity	○ Improved water quality due to tree uptake of pollutants (Burgess et al., 2015)
7 Affordable and clean energy	Modern food systems are heavily dependent on fossil fuels	○ Woody vegetation in the farmed landscape for bioenergy (Burgess et al., 2015)
8 Decent work and economic growth	Agricultural growth in low-income economies can reduce poverty by half	○ Opportunities for added value (Burgess et al., 2015)

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		○ Increased rural jobs
9 Industry, innovation and infrastructure	Agriculture accounts for a quarter of gross domestic product (GDP) in developing countries	○ Woody cellular material innovation – sustainable materials for circular economy
10 Reduced inequalities	Land reforms can give fairer access to rural land	○ In agroforests, the reduced dependence on external chemical inputs, plus the greater resilience to market fluctuations, can enhance this sense of control, equity, and dignity in work (Chappell et al., 2013; Thorlakson & Neufeldt, 2012). Furthermore, on-farm trees generate considerable fuelwood, reducing the need to cut down natural forests and also saving smallholder family members (particularly women) from walking long distances (sometimes >20 km) in search of firewood, thus enhancing women's well-being and freeing them to educate and tend to children, provide farm labor, or produce other income
11 Sustainable cities and communities	Rural investment can deter unmanageable urbanization	○ Through the promotion of fruit trees in homegardens (Burgess et al., 2015) ○ Trees absorb sound pollutants and particulates from traffic ○ Potential for local provision of edible fruit/nuts
12 Responsible consumption and production	One third of the food we produce is lost or wasted, representing a large excess of CO2 emitted. Dietary trends and choices largely do not sit within sustainable limits in the West.	○ Sustainable production systems (Burgess et al., 2015) - food systems have enormous potential to be made more efficient and re-capture the 'waste' within the system and focus on local markets and processing

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		○ Dietary choices and influences, to eat within local ecosystem capacities could see major reduction in off-shored CO2 emissions from animal agriculture ○ Focus on nutrient recycling ○ Less bulk production, greater opportunity to integrate in short value chains?
13 Climate action	Agriculture is key in responding to climate change	○ Enhanced carbon storage on farm land (Burgess et al., 2015) ○ Climate mitigation and adaption – increased crop resilience to several likely climate change effects, such as drought or higher temperatures, because it enhances water infiltration and storage while reducing evaporation and temperature extremes (Charles, Munishi, & Nzunda, 2013; Garrity et al., 2010).
14 Life below water	Fish gives 3 billion people 20% of their daily animal protein	○ Less pesticide and herbicide usage leading to improved water quality
15 Life on land	Forests contain over 80% of the world's terrestrial biodiversity	○ Enhanced biodiversity (Burgess et al., 2015) ○ Increased landscape connectivity and on-farm habitats ○ Reduce pressure on natural forests for wood collection ○ Restoration of degraded land through MF/AF
16 Peace, justice and strong institutions	Ending hunger can contribute greatly to peace and stability	○ Building resilient communities, connecting consumers to farmers ○ Increasing domestic resource base (food, fodder, fuel)

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		○ Potential to include communities in agroforestry projects
17 Partnerships for the goals	Partnerships help raise the voice of the hungry	○ Increasing on farm diversity may lead to increased partnerships with local communities, increased opportunities for local processing etc

Table 1: How MF and AF systems connect and support food systems and the 2030 Sustainable Development Goal Agenda, adapted from Parsons and Hawkes (2018) and Burgess et al., 2015.

From the table above, we can say that investment in food systems and in MF/AF will drive change across multiple SDGs

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3.3 Ecosystem services as an assessment tool

As stated above, the provision of multiple services, beyond that of food, are also known as ecosystem services (ES). The Millennium Ecosystem Assessment (MEA) was carried out between 2001 and 2005 to "assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being" (MEA, 2005). The MEA defines ecosystem services as 'the benefits humans derive from ecosystems'. These are divided into supporting, provisioning, regulating and cultural services (see Figure 2).

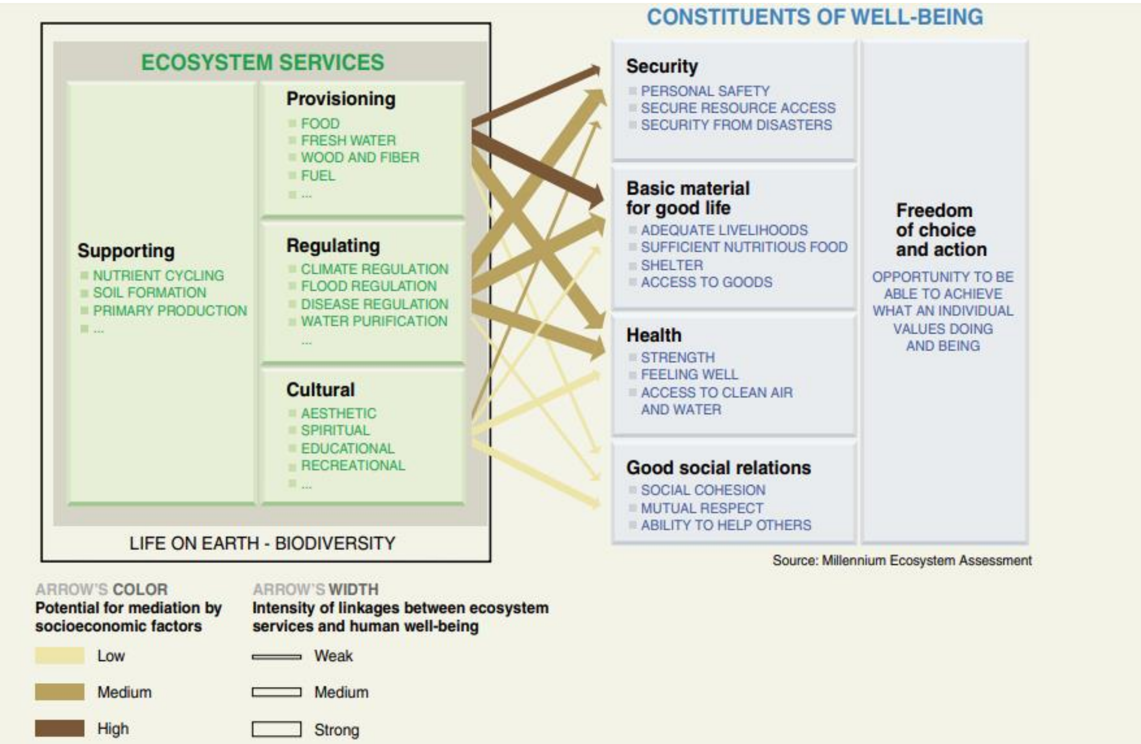

Figure 2: Depiction of ecosystem services which support life on earth, Millenium Ecosystem Assessment 2005

The MEA concept has been popular among civil society, governments and academics as a way to assess, evaluate and communicate the complete dependence humans have on natural processes. It has been influential in environmental policy making and has provided a benchmark for many multilateral agreements and initiatives such as the Ecosystem Services for Poverty Alleviation and The Economics of Ecosystems and Biodiversity.

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Another aspect of ES is the idea of valuing the services nature provides us with. There are many studies looking at the complicated processes of adding a monetary value to these natural processes (Spangenberg and Settele, 2010). Some argue that by adding a monetary value to these processes, we not only translate their importance, but we can incorporate them into our economies and find ways to attribute for the 'negative externalities' so often caused in agricultural production (biodiversity loss, land use changes, decreased water quality etc). The Economics of Ecosystems and Biodiversity report (TEEB 2011) considers valuation a critical tool to conservation and has helped shape the discourse around the subject. The idea of monetizing ES is gaining more ground in both public and corporate spheres, with payments now being made for ES provision, otherwise known as PES – payment for ecosystem services. Regen Network recently facilitated Microsoft's purchase of 'soil carbon credits' which went to an Australian cattle rancher (**https://www.altcoinbuzz.io/cryptocurrency-news/blockchain-technology/microsoft-makes-historic-soil-carbon-credit-purchase-from-regen-network/**).

3.3.1 Ecosystem services in the context of AGROMIX

In the context of AGROMIX, ES are used as one way to assess the impact of different agricultural systems, specifically MF and AF. Generally speaking, the more ES a system provides, the more attractive it is from a sustainability point of view, as there are more ways in which the system can have a beneficial impact (to humans and non-humans).

The ES that were considered for this project were adapted from those listed by the Common International Classification of Ecosystem Services (CICES) (link in annex). This was developed from the work on environmental accounting undertaken by the European Environment Agency (EEA), to standardise the way ES are described and understood, primarily motivated by their link to economic and environmental accounting with regards valuing ES and paying farmers and landowners for ES contributions.

The ES considered within AGROMIX can be seen in Table 2 below.

Table 2: List of ecosystem services and relevant types considered within AGROMIX

Ecosystem service type	Ecosystem service
Provisioning	Cultivated plants for nutrition (i.e crops for consumption)
	Cultivated plants for materials (i.e crops for biomass)
	Cultivated plants for energy (i.e crops for fuel)
	Reared animals for nutrition
	Reared animals for materials or energy

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	Surface or groundwater used for nutrition, materials or energy
Regulating and supporting	Carbon sequestration
	Nitrogen fixation
	Carbon cycling
	Pest and disease control
	Enhanced soil fertility
	Reduced erosion
	Hydrological cycle and water flow regulation
	Improved water quality
	Smell and or noise reduction
	Wind protection
	Fire protection
	Pollination and or seed dispersal
	Regulation of temperature, light, humidity, and transpiration
	Increased animal welfare
Cultural	Aesthetic value
	Recreation
	Educational value
	Spiritual enrichment

3.3.2 Ecosystem services from mixed farming and agroforestry systems

There are a plethora of studies analysing the relationship between ES and AF (Jose 2009; Torralba *et al.* 2016; Kay *et al.* 2019; Kuyah *et al.* 2019). AF systems have been found to improve a variety of regulating ES such as: erosion control; carbon sequestration; pest control; nutrient retention; reduced surface runoff; and improved soil organic carbon (Torralba *et al.,* 2016). However, the majority of studies have focussed on the regulating and provisioning services and have left cultural services out due to "the difficulties to measure them quantitively" (Torralba *et al.,* 2016; 7). This lack of robust measurements for cultural services is true throughout the literature for ES, not just within agroecosystems (Chan *et al.,* 2012) and often results in cultural ES being recognised but not incorporated into decision making tools (de Groot *et al.,* 2002). The link between AF systems, their provisioning and regulating services and thus their relevance and impact on CSA is also well documented (Jose 2009; Vaast *et al.,* 2016).

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There is limited attention given directly to evaluating MF systems through an ES lens in the literature. This could be due to AGROMIX's definition of MF, 'the practice of deliberately integrating crop and livestock to benefit from the crop livestock interactions' (D1.1), whereas terms such as 'mixed cropping' or 'integrated crop and livestock systems' for example, see substantial research for how these systems improve regulating services, but again, not the broad spectrum of provisioning, regulating and cultural services that can be found for AF systems.

The lack of an accepted definition of MF in legislation and/or policy creates challenges when attempting to assess the services provided by a system. However, one can assume that being more mixed (and therefore more diverse) would lead to improved regulating ES (Kremen and Miles 2012). In the US, there are various studies that highlight the ecological benefits of 'integrated crop-livestock systems' (where cattle and annual crops are produced on the same area of land in the same year), which could be used as a proxy for provisioning services (Sanderson *et al.,* 2013). Gabe Brown, an American farmer and author of 'From Dirt to Soil' (2018), dedicates his whole book to narrating, explaining and quantifying the beneficial interactions (both ecological and economic) of 'stacking' crop and livestock enterprises on the same land under the banner of 'regenerative agriculture'.

3.3.3 Ecosystem disservices in the context of AGROMIX

Ecosystems also have functions that are harmful to human well-being. These effects are known as ecosystem disservices (ED) (Shackleton *et al.,* 2016). To date there is not a standardised classification of disservices like that of CICES for ES and limited published research on ED. Campagne *et al.,* (2017) highlighted this marked absence with just 0.6% of reviewed studies focussing on ED. Blanco *et al.,* (2019) highlight how ED have been debated in the ES literature but are 'poorly investigated' which leads to a lack of integration in policy. They also note that perhaps this very 'black and white' approach to ED and ES may also be counterproductive as some ecosystem functions contribute to both ED and ES.

Therefore, the disservices considered were taken from the literature and commonly cited issues among farmer networks, see Table 3 for those incorporated. The impact of various ED associated with different cropping systems can be a key reason as to why a farmer may or may not adopt a system.

Table 3: Ecosystem disservices considered within AGROMIX

Ecosystem disservice
Decreased water quality
Presence of animals as disease vectors
Nutrient loss
Need for more irrigation

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Presence of poisonous plants for livestock
Decreased air quality
Pollination deficit
Damage to infrastructure
Increased maintenance costs

Assessing agroecosystems through the lens of ES and ED has its limitations, as discussed above. However, ES do provide a framework that multiple actors can engage with and are also easily linked to the UN SDGs. As payments for ES become more common and the drive for agriculture to become climate-smart and resilient (or regenerative), it will be critical for farmers and landowners to have quantitative data showing which farming systems would be most appropriate for their specific context and which systems would provide a broad range of ES. Whilst we continue to strive to find a common ground for 'assessing' farming systems based on their resilience, sustainability, suitability and productivity, ES assessments are a step in the right direction.

1.2 Aims and objectives

The aim of this task is to provide the AGROMIX consortium with an overview of the ES and ED from mixed farming and agroforestry systems and how they relate and contribute to CSA.

The objectives for D1.2 are as follows:

- To review AGROMIX's network of experimental sites and farms and evaluate the importance of ES and ED and how they relate and contribute to CSA
- To define and apply a rating system to evaluate on farm practices that generate ES and ED based on the criteria for CSA
- To provide a benchmark for ES and ED from MF and AF systems within the AGROMIX project

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4 Methodology

To meet the aims and objectives of this task, it was decided that a survey would be the most efficient method of data collection. Instead of focussing just on the network of experimental sites and farms within AGROMIX it was decided to broaden the scope of the respondents and also gather data from non-AGROMIX and non-AF/MF sites. This approach seemed better able to meet the objectives of the task as it would provide more evidence between farming systems and ecosystem service provision.

4.1 Survey design

The survey was designed on **www.onlinesurveys.ac.uk** and written in English. The survey consisted of 4 sections with 20 multiple choice questions. The questionnaire aimed to identify and evaluate: the beneficial interactions from nature (ES) on farm; which farming practices were more closely linked to ES and/or ED; and how these interactions influence farmers response to change. As the survey was completed by farmers, the responses are the perceptions of the farmers. As such, the responses to the questions represent the farmers' understanding of the ES and ED on farm and the relation to CSA. This distinction is important to make, given the objectives of the task and the limited response rate. As such, the study can be viewed as an exploration into farmer perception of ES on farm and the impact on on-farm resilience.

The survey was anonymous, but participants could leave their email address to receive the results and information about the AGROMIX project. Survey design and data compliance was assessed and approved through Coventry University's ethical approval system. The full survey can be found in the annex.

4.2 Data collection

Work Packages 2, 3 and 4 were involved in reaching the experimental AGROMIX sites for their input. An online survey was used to gather the data. Some of the sites and farms within AGROMIX are in an early development stage and would thus not have relevant data. To provide more robust data and enable a comparison of ES and ED from MF and AF farms with Non-AF/MF systems, it was also thought appropriate to gather data outside the AGROMIX sites. As such, the survey was also shared online via social media channels and within people's networks. By widening the pool of potential farmers and landowners to complete the survey, it is possible to evaluate which ES and ED are more prevalent in CSA and the possibility of comparing with more conventional cropping systems became possible. The online survey opened in May 2021 and in this deliverable all responses received up to the end of March 2022 are considered.

4.3 Analysis

Data were analysed using R (R Core Team, 2021). The code used to analyse the survey responses can made available upon request.

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The survey recipients could choose from ten farming systems. The ten farming systems were collapsed into three categories: mixed, agroforestry or non mixed/agroforestry according to the definitions in Table 4.

Table 4: Collapsing of farming system categories

Farm system original	Farm system redefined
Arable (no livestock and no woody vegetation)	Non mixed/agroforestry
Horticulture (no livestock and no woody vegetation)	Non mixed/agroforestry
Mixture of temporary crops and livestock (no woody vegetation)	Mixed
Livestock only	Non mixed/agroforestry
Permanent woody crop with temporary crop	Agroforestry
Permanent woody crop with livestock	Agroforestry
Woodland and/or grassland with sparse tree cover and temporary crop	Agroforestry
Woodland and/or grassland with sparse tree cover with livestock	Agroforestry
Cultivated grassland	Non mixed/agroforestry
Natural grassland	Non mixed/agroforestry

If a respondent selected multiple enterprises which combined mixed with non mixed/agroforestry or agroforestry with non mixed/agroforestry this was defined to be either mixed or agroforestry respectively.

We developed a simple rating (‘very important’, ‘important’, ‘neutral/not important’) for farming practices relevant for CSA based on how respondents ranked farming practises on their farm as relevant to delivering ES for CSA (Question 10 of the survey) and their observations of farming practises contributing to their farms’ resilience to extreme weather events (Question 14). This was further amended from literature sources.

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5 Results

5.1 Respondents and farming systems represented in the data

A total of 48 respondents from 14 countries participated in the survey. Table 5 illustrates the number of respondents by country and size of farm (ha). There was a reasonable distribution across farm sizes. Table 6 gives the number of respondents by farming system and size of farm (ha). There were many more respondents from AF systems (29 – 60%) than MF systems (4 – 8 %). For more conventional cropping systems (i.e those without MF or AF), there were 15 -31% respondents (Table 6).

Only seven farms do not report any woody vegetation on their land, whereas half (24) farms of all farm have hedgerows often combined with windbreaks or riparian buffers, and few farms report woody vegetation in windbreaks or riparian buffers without having hedgerows. Furthermore, some farms have small parcels of woodland or scattered trees on permanent grazing land. Eighteen farms are located at least partially in nature conservation areas.

Most farms (24 - 50%) are privately owned, whereas some (10 –21%) are partly privately owned and rented, and with the rest constituting a mixture of rented farms (6 - 13%) or being in different forms of ownerships, such as community or trust owned.

The majority (33 - 69%) of respondents' produce was being sold to the regional or local markets, and only five farms – 10% were selling to the international market only.

Table 5: Number of respondents by country and size of farm (ha)

	< 10 ha	[10.ha, 99.9ha]	[100 ha, 499.9 ha]	[499.9>= 500 ha	Sum
Austria	0	1	0	0	1
Belgium	0	1	0	0	1
Estonia	0	1	1	6	8
France	0	2	0	0	2
Germany	0	1	2	0	3
Greece	2	0	0	0	2
Hungary	3	0	0	0	3
Ireland	0	2	0	0	2
Netherlands	0	1	0	1	2
Poland	2	5	0	1	8
Portugal	2	2	1	0	5

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Spain	0	3	2	0	5
Sweden	1	0	0	0	1
UK	1	3	1	0	5
Sum	11	22	7	8	48

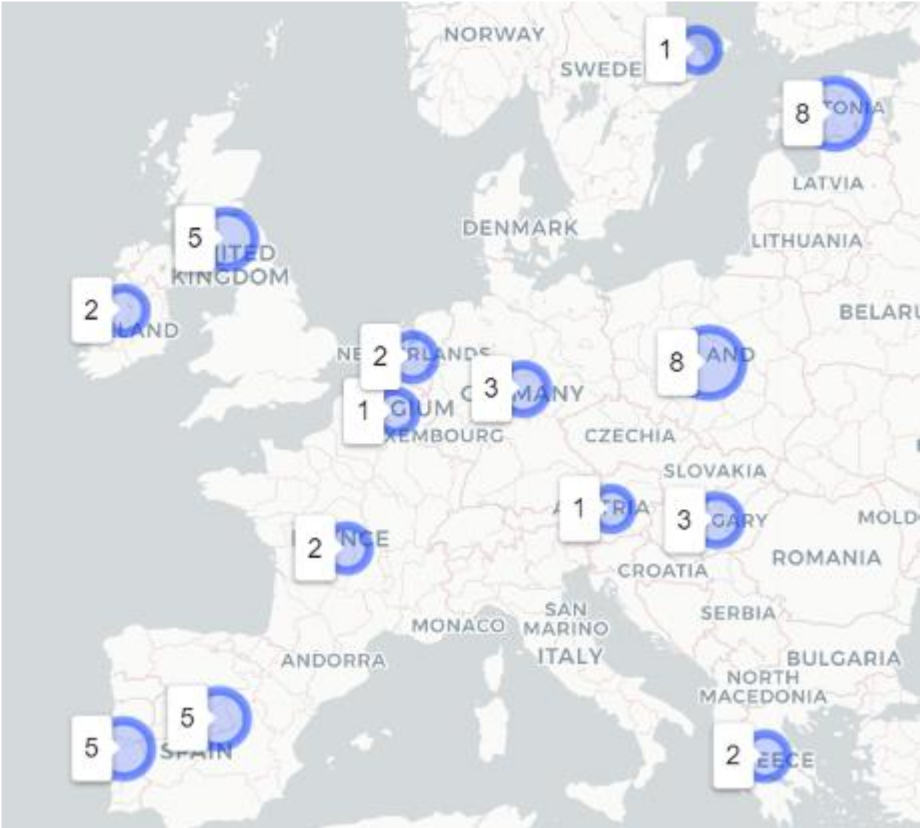

Figure 3: Geographical distribution of responses in map format.

Table 6: Number of respondents by farming system and size of farm (ha)

	< 10 ha	[10 ha, 99.9 ha]	[100 ha, 499.9 ha]	>= 500 ha	Sum
AF	8	13	5	3	29
MF	0	0	2	2	4
Non-AF/MF	3	9	0	3	15
Sum	11	22	7	8	48

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5.2 Ecosystem services in relation to farming practices in mixed farming, agroforestry and other systems

This was reviewed by using Q9 in the survey 'please score the farming practices according to your own assessment of their contribution to the ecosystem services or disservices on your farm' and ordered by number of respondents who selected 'Important'. The six categories (Very important, Important, Neutral, Not important, Doesn't apply and Ecosystem disservice) were collapsed to four categories (Important, Neutral, Not important and Ecosystem disservice), where Very important or Important was redefined to be Important, and Not important or Doesn't apply was redefined to be Not important. Because we received only four responses from MF farms, it was not possible to include them in this analysis and in the following we focus therefore on the 26 AF and 14 other systems, i.e. farms which are neither AF or MF (= 'Non-AF/MF').

Figure 4 and Figure 5 give the full list of practices related to ES in AF and Non-AF/MF systems and how farmers rated them according to their contribution to the ecosystem services or disservices on their farm.

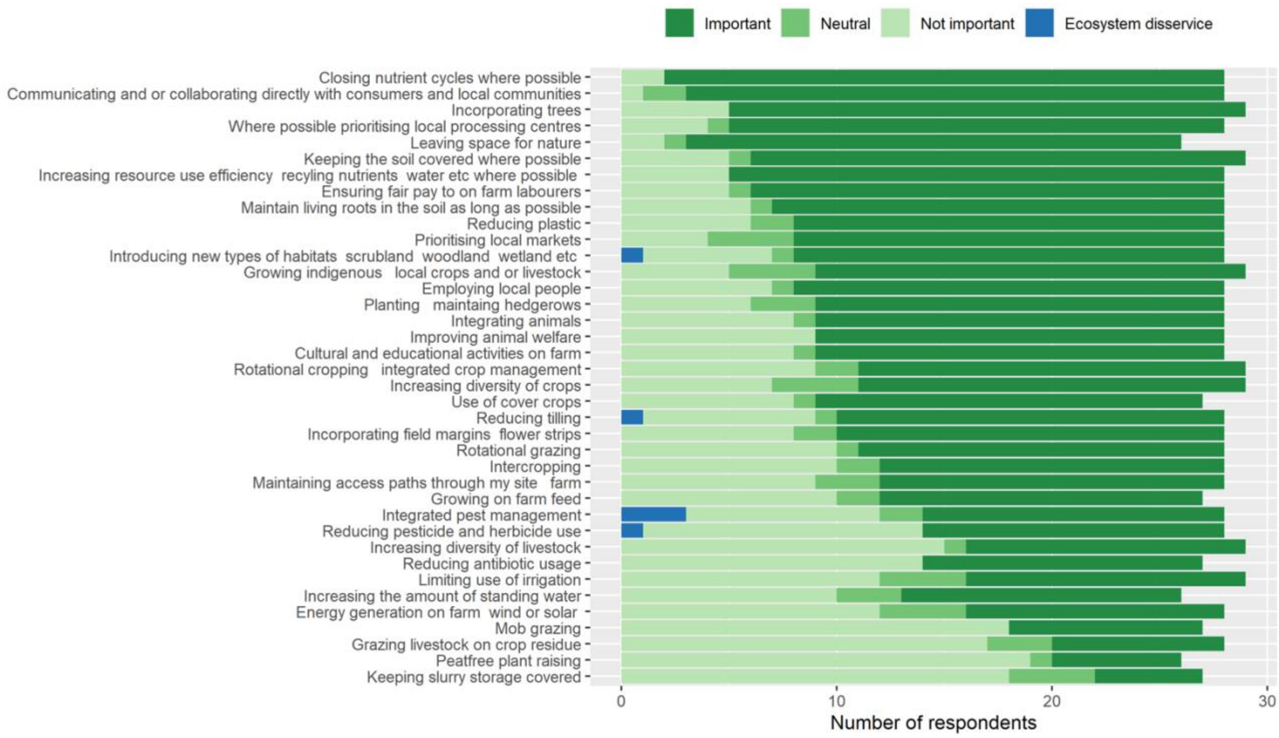

Figure 4: AF system farmers' perception of the linkages between their farming practices and ecosystem services or disservices present on their farms Ecosystem

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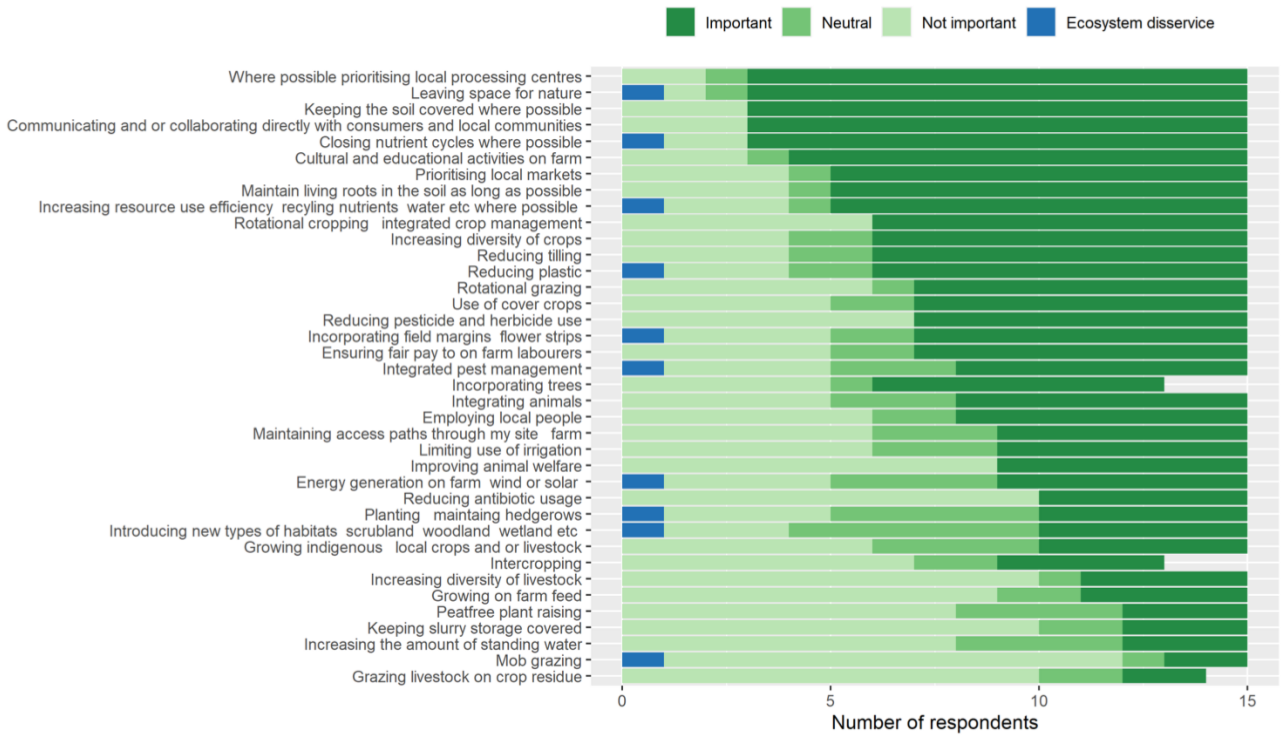

Figure 5: Non-AF/MF system farmers' perception of the linkages between their farming practices and ecosystem services or disservices present on their farms Ecosystem

Table 7: Top rated farming practices in percentage of AF farmers (29 total) and Non-MF/AF farmers (15) who deemed these practices as important for ecosystem services on their farms. The list includes the ten highest valued practices for each group.

Farming practice	AF	Non-AF/MF
Closing nutrient cycles where possible	90	80
Communicating/collaborating directly with consumers/local communities	86	80
Leaving space for nature	79	80
Where possible prioritising local processing centres	79	80
Keeping the soil covered where possible	79	80
Increasing resource use efficiency	79	67
Maintain living roots in the soil as long as possible	72	67
Incorporating trees	83	47
Prioritising local markets	69	67
Ensuring fair pay to on farm labourers	76	53
Cultural and educational activities on farm	66	73

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Incorporating field margins, flower strips	62	53
Growing indigenous local crops and or livestock	69	33

5.3 Perception of ecosystem services contributing to climate-smart agriculture

This result was based on Q 10 in the survey 'rank the top 10 ecosystem services that contribute to climate-smart agriculture on your farm' and ordered by total number of respondents.

The original 10 point ordinal scale Score, where 1 = most important and 10 = least important, was collapsed into a dichotomous variable Importance, where more important was defined to be Score ≤5 and less important was defined to be Score ≥ 6.

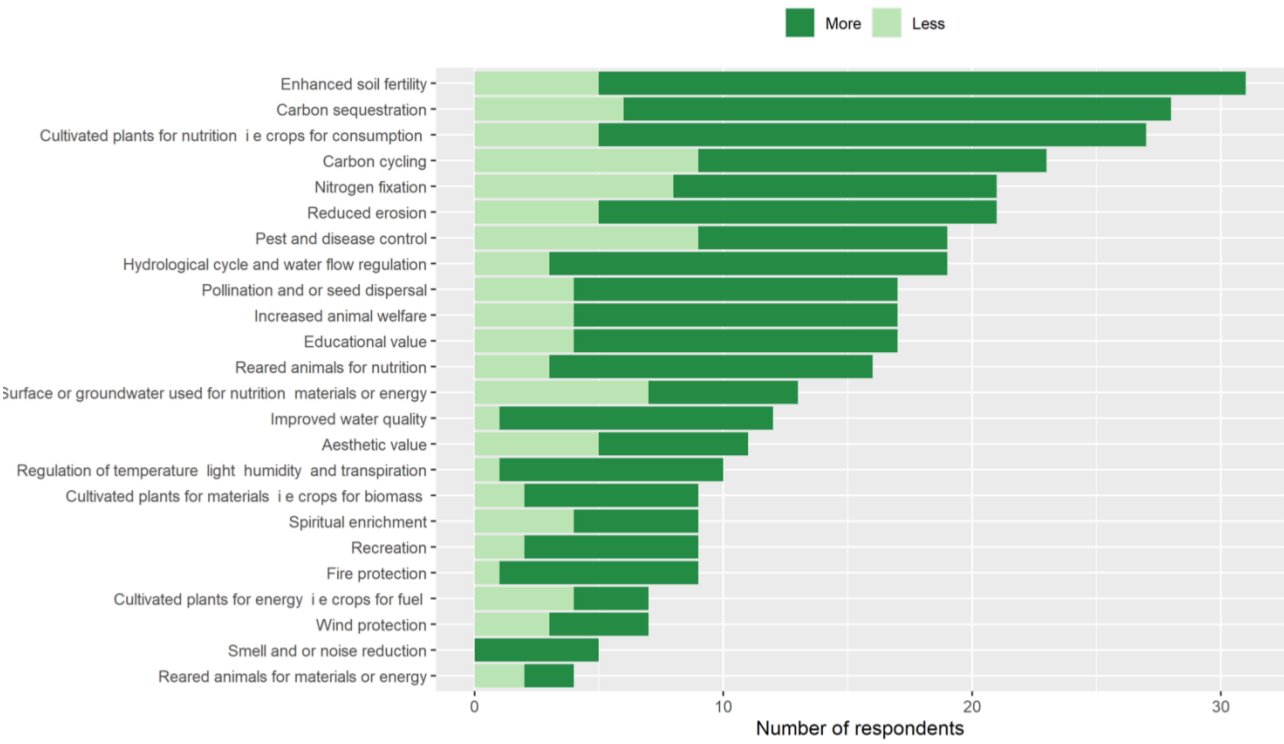

Figure 6: Perception of ES contributing to climate smart agriculture, all respondents

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Table 8: The top 20 ES related to climate-smart agricultural practices deemed important by AF and Non-AF/MF respondents. The total number includes the number of respondents who ranked the practice as less important

Ecosystem service	**AF**	**Non-MF/AF**	**Total**
Enhanced soil fertility	15	10	33
Carbon sequestration	18	5	31
Cultivated plants for nutrition	13	7	29
Carbon cycling	8	8	26
Nitrogen fixation	6	8	24
Reduced erosion	11	5	22
Pest and disease control	4	5	20
Hydrological cycle and water flow regulation	11	4	19
Educational value	10	5	19
Increased animal welfare	8	4	19
Pollination and or seed dispersal	8	7	19
Reared animals for nutrition	9	4	18
Improved water quality	8	4	14
Surface/groundwater used for nutrition, materials, energy	4	2	13
Aesthetic value	5	2	12
Regulation of temperature, light, humidity, transpiration	8	2	11
Fire protection	6	3	10
Recreation	6	2	10
Spiritual enrichment	2	4	10
Cultivated plants for materials	3	2	9

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5.4 Type of farm linked to extreme weather events

Of the 48 respondents, 42 – 88% had experienced an extreme weather event. There was no association between farming system and the perception of level of severity compared to neighbouring farms (Table 9: χ^2 X^2 = 4.9, df = 2, P = 0.085).

Table 9: Number of respondents by farming system and severe weather events

	Less affected	Similarly affected	Sum
AF	10	15	25
MF	0	4	4
Non-AF/MF	8	5	13
Sum	18	24	42

The respondents could list multiple extreme weather events. Drought, flooding due to rain, flooding due to burst river, extreme temperature and fire were cited on 38, 16, 3, 16 and 2 occasions respectively (Table 10).

Table 10: Number of occurrences of the type of extreme event cited

Type	Number of times cited
Drought	38
Flooding (from extreme rainfall)	16
Extreme temperatures	16
Flooding (from rivers of plains)	3
Fires	2

The respondents could list multiple impacts due to extreme weather events. Decreased yield, effect on livestock production, damaged farm equipment, soil erosion, tree felling, waterlogging, shortage of drinking water for livestock and shortage of water for irrigation were cited on 32, 13, 4, 7, 5, 6, 3 and 4 occasions respectively (Table 11).

Table 11: Number of occurrences of the impact due to an extreme event cited

Impact	Number of times cited
Decreased yield	32
Effect on livestock production	13
Soil erosion	7
Tree felling	6
Waterlogging	5

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Damaged farm equipment	4
Shortage of drinking water for livestock	4
Shortage of water for irrigation	3

The respondents could list multiple farming practices which they reported was the reason why their farms were less affected (Table 12).

Table 12: Number of occurrences the reason why a farm was less affected by an extreme weather event

Why less affected	Number of times cited
Reducing tilling	12
Keeping the soil covered where possible	11
Increasing diversity of crops	10
Rotational grazing	8
Incorporating trees	8
Growing indigenous	8
Rotational cropping / integrated crop management	7
Integrating animals	7
Leaving space for nature	7
Reducing pesticide and herbicide use	6
Use of cover crops	6
Maintain living roots in the soil as long as possible	6
Planting or maintaining hedgerows	6
Intercropping	5
Closing nutrient cycles where possible	5
Improving animal welfare	4
Incorporating field margins	4
Introducing new types of habitats	4
Increasing diversity of livestock	3
Mob grazing	3
Increasing resource-use efficiency	3
Growing on farm feed	3
Reducing antibiotic usage	3
Increasing the amount of standing water	2
Integrated pest management	1
Grazing livestock on crop residue	1
Limiting use of irrigation	1

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Energy generation on farm	1
Reducing plastic	1
Keeping slurry storage covered	0
Peatfree plant raising	0

There was no association between farming system and implementation of change due to experiencing an extreme weather event (Table 13: X^2 = 1.4, df = 2, P = 0.49)

Table 13 : Number of respondents by farming system and implement change due to an extreme weather event

	No	Yes	Sum
AF	13	10	23
MF	1	3	4
Non-AF/MF	7	6	13
Sum	21	19	40

5.5 Farmer perception of ecosystem service value

Table 14: Number of respondents by farming system and plans to improve ecosystem services in the next 5 years

	No	Yes	Sum
AF	4	25	29
MF	0	2	2
Non-AF/MF	3	10	13
Sum	7	37	44

There was no association between farming system and plans to improve ecosystem services in the next 5 years (Table 14: X^2 = 0.97, df = 2, P = 0.61)

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The respondents could list multiple ecosystem services which they would like to improve (Table 15).

Table 15: Number of occurrences of ecosystem services respondents would like to improve cited

Ecosystem services would like to improve	Number of times cited
Carbon sequestration	21
Carbon cycling	18
Enhanced soil fertility	15
Educational value	15
Nitrogen fixation	14
Cultivated plants for nutrition	13
Wind protection	12
Reared animals for nutrition	10
Pest and disease control	10
Hydrological cycle and water flow regulation	10
Pollination and or seed dispersal	10
Increased animal welfare	10
Reduced erosion	9
Recreation	9
Cultivated plants for materials	8
Aesthetic value	8
Regulation of temperature, light, humidity, and transpiration	7
Improved water quality	6
Fire protection	5
Spiritual enrichment	5
Cultivated plants for energy	4
Surface or groundwater used for nutrition, materials or energy	4
Smell and or noise reduction	3

Table 16: Number of occurrences various requirements to improve ecosystem services were cited

Requirements to improve ecosystem services	Number of times cited
Money	25
Time	24
Knowledge	18
Space	8

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5.6 Farmer rating of CSA practices delivering ecosystem services on farm

By bringing together respondents' rating of farming practices delivering ES relevant for CSA as well as CSA practices they experienced to have helped on their farms against the impacts of extreme weather events, we have designed an overall rating of CSA practices relevant for CSA (Table 17).

Table 17: Summary and rating of the importance of agricultural practices for delivering CSA relevant ecosystem services and resilience to extreme weather events. Based on farmers perceptions (figures x &X) and literature references.

CSA rating	CSA practices delivering ES	CSA practice for extreme weather	Literature examples
Very important	• Closing nutrient cycles where possible, • Communicating and or collaborating directly with consumers and local communities, • Leaving space for nature, • Keeping the soil covered where possible, • Where possible prioritising local processing centres	• Reducing tilling • Keeping the soil covered where possible, • Increasing diversity of crops, • Rotational grazing, • Incorporating trees, • Growing indigenous/local crops and/or livestock	• Minimal/no till arable land management reduces CO2 and nitrogen emissions from soils (Smith et al. 2008). • Localised food systems and working in collaboration with local communities and consumers has been shown to provide resilience within the system for the farmer and improved food security and nutrition (Rothwell et al., 2016; Kerr *et al.,* 2021) • Integrating animals enables ecosystem functionality; grazed plants photosynethise more and pumps more CO2 into the soil as well as dung improving biodiversity (Brown, G. 2018; Tobin *et al.*, 2020) • Diversity is key for ecosystem health as mineral and nutrient cycles vary • Presence of trees benefits biodiversity, can help mitigate extreme weather

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			events (Hernandez-Morcillo *et al.,* 2018; Wilson & Lovell 2016)
Important	• Hydrological cycle and water flow regulation • Educational value • Increased animal welfare • Pollination and or seed dispersal • Nitrogen fixation • Reared animals for nutrition • Improved water quality • Pest and disease control • Regulation of temperature, light, humidity and transpiration	• Rotational cropping / integrated crop management • Integrating animals • Leaving space for nature • Reducing pesticide and herbicide use • Use of cover crops • Maintain living roots in the soil as long as possible • Planting or maintaining hedgerows • Intercropping • Closing nutrient cycles where possible	• Cover crops inhibit weeds, reduce evaporation rates, increase organic matter, dissipates energy from rain, reduces soil erosion and maintains soil temperatures (Lorin *et al., 2015;* Malezieux *et al.,* 2009) • Incorporating trees can help regulate light, humidity and transpiration given the shelter and shade they provide (Jose 2009) • Evidence to suggest beneficial for livestock having accessible trees and diversity of fodder and browse (Huertas *et al.,* 2021; Sales-Baptista & Ferraz-de-Oliveria 2021)
Neutral/not important	• Fire protection • Recreation • Aesthetic value • Cultivated plants for materials i.e. crops for biomass • Spiritual enrichment • Surface or groundwater used for nutrition, materials or energy • Smell and or noise reduction • Wind protection • Cultivated plants for energy i.e. crops for fuel	• Improving animal welfare • Incorporating field margins • Introducing new types of habitats • Increasing diversity of livestock • Mob grazing • Increasing resource-use efficiency • Growing on farm feed • Reducing antibiotic usage	

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	• Reared animals for materials or energy	• Increasing the amount of standing water • Integrated pest management • Grazing livestock on crop residue • Limiting use of irrigation • Energy generation on farm • Reducing plastic	

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6 Discussion

The survey results provide some insights into farmers perceptions and ratings of ecosystem services and disservices of different farming systems and how they contribute to climate-smart agriculture. Even though the number of responses was not very high, participants represent a good range of European countries and different farming systems with a diverse range of farm sizes, ownership and management. These responses cannot be representative, but they provide nevertheless valuable information about farmers' perspective on how management practices, farming system, design and crop choices impact on ecosystem services and disservices on their own farms. The small number of MF farmer responses means it is not possible to draw conclusions or comparisons with AF or non-MF farms. This low number is seen across the AGROMIX project and wider, in that there is no clear definition or understanding of MF, with a resulting lack of policy, financing and practical farming of this system.

We structure the following discussion of our results into five sub-sections each focused on one question derived from the aims and objectives of task 1.2 of WP1 in the project.

6.1 Does the type of farm have an impact on which ecosystem services and disservices are present and how farmers rate their importance?

We aimed to analyse how farmers valued the importance of ecosystem services and disservices on their farms in relation to their farming system. However, because we had only five respondents from MF systems, we were unable to do a fair comparison for this section and instead choose to focus on AF systems and Non-AF/MF systems only.

Overall, farmers rated a wide range of ecosystem services on their farms as important, and in terms of which ES they rated highest, there was broad agreement between participants (Figure 6). In particular, AF and Non-AF/MF farmer groups both rated the closing of nutrient cycles and leaving space for nature in the top five features contributing to ES. Similar, for both groups communication and collaboration with consumers and local communities came into the top five high rated practices illustrating farmers' awareness of the social dimensions of ES. Unsurprisingly, the majority of AF farmers (22) rated the incorporation of trees within their top five contributing elements, whereas just half of the Non-AF/MF farmers (7) did this and four of them did not think that this practice had contributed to ES on their farms. Few practices were considered ED and just one was selected by more than one respondent (integrated pest management with 3 responses).

While these results provide insights into which ES and ED are present on farms and how farmers value them, they are limited by the fact that the survey did not ask about the extent to which farmers used the practices on their farms. They are also limited in that the presence of the ES or ED is entirely subjective in these results.

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With more time, on farm measurements could be taken which could then be translated into ES or ED. Figure 7 (below) highlights how a study by Boeraeve et al., (2020) compared the contribution of agroecological farming systems with conventional farming systems to the delivery of ES by structuring indicators of ES within a framework that separates ecosystem state, processes, services and benefits. Whilst this study indicated that agroecological farms provide a wider array of regulating services and conventional farms provide a wider array of provisioning services, the study did not account for any cultural services. Establishing a methodology to assess the ecosystem state, processes and functions of all ES and ED could in future facilitate a more robust assessment of which farm types provide which services, however it must be remembered that farming systems are context dependent and 'one-size doesn't fit all'. That is to say, assessing farming systems on their provision of services is a useful tool, but should not be the only tool in the toolbox.

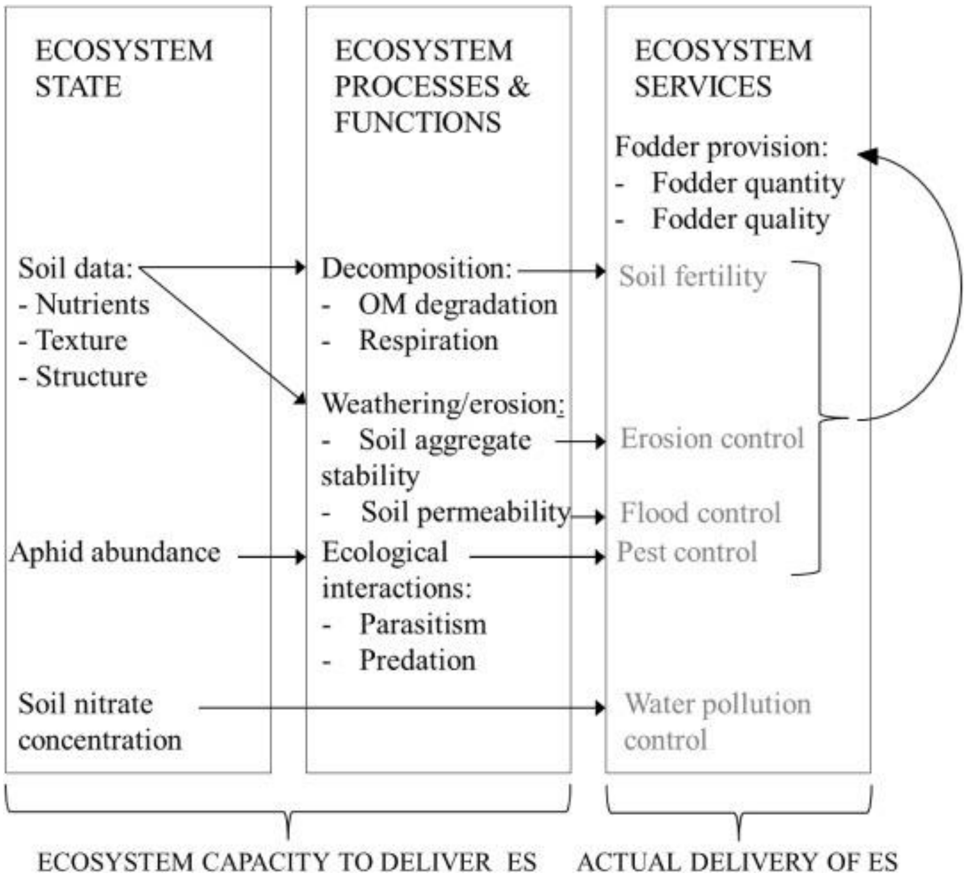

Figure 7: Taken directly from Boeraeve *et al.,* (2020) - Framework depicting indicators (black) used to portray ES delivery (grey). Indicators of ES delivery are either indicator of ecosystem state or of ecological functions and processes, thus representing the ecosystem capacity to delivery ES.

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6.2 Which types of farms are impacted by severe weather events and does being a mixed (and or agroforestry) farm make you more climate resilient?

A vast majority of farmers (88%) had experienced extreme weather events in the last five years, and several AF and non-MF/AF farmers reported to be less affected than neighbouring farms but none of the five MF farms, however, the differences between the groups were not significant. As such it is not possible to draw a conclusion from this data as to whether any of the systems are more climate resilient.

Considering that all groups used practices contributing to ES on their farms (see section above) this provides some evidence that ES supporting practices may contribute to making these farms more resilient to extreme weather events. Of the farms which were less affected by an extreme weather event (18 out of 42), the practices that farmers considered to be important were: reducing tilling (cited 12 times), keeping the soil covered (cited 11 times), increasing diversity of crops (cited 10 times), rotational grazing (cited 8 time), and incorporating trees (cited 8 times). From these results we can suggest that MF and AF systems may be more climate resilient as the practices cited are more commonly found in AF and MF systems, but not exclusively. This fits with the literature whereby more agrobiodiversity adds to climate resilience (Altieri 2015) and effective soil management is key to maintaining healthy ecosystems which support above ground productivity and below ground microbial life and carbon sequestration (Paustian & Lehmann 2016). Hernández-Morcillo *et al.,* (2018) indicate the features that enhance climate resilience in AF systems as: maintaining quality and quantity of products; increasing habitat diversity; increasing structural and functional biodiversity; fostering diversified production opportunities and, reducing impacts of extreme weather events. This can in some circumstances be applied to MF systems.

Given the small sample size of our study it was not possible to analyse information on the presence of ES providing practices on farms and severe weather event outcomes by farm type or type of severe weather event, but this link will be explored further in the AGROMIX project. However, in the next sub-section we look at these practices in more detail for the whole sample.

6.3 Which ecosystem services are seen as most important in terms of climate-smart agriculture?

The top 10 ecosystem services ranked by respondents for their importance to CSA nearly all fall in the categories of supporting (enhanced soil fertility, nitrogen fixation, reduced erosion, increased animal welfare), provisioning (cultivated plants for nutrition, hydrological regulation) and regulating ES (Carbon sequestration, carbon cycling, pest/disease control, pollination). This is hardly surprising as it is these processes which are more aligned in common discourse around climate change and perhaps more theoretically linked. However, one cultural service, educational value, is in a joined 10th position and we believe, that increased animal welfare, although placed here in supporting ES (according to CICES definition), is also embedded in social values and therefore contributes to cultural services. In contrast, rearing animals

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for materials or energy was at the bottom of the list deemed important by just four respondents, i.e., 39 - 88% respondents did not think it contributes to CSA.

These results are encouraging as they are in line with a growing body of evidence that shows the importance of taking an ecosystem approach and managing multiple aspects of the farming system (soil health, reducing nitrogen leaching, increasing above and below ground biomass, biodiversity, carbon sequestration etc) when farming in a more regenerative way. It is also encouraging to see a spread across the ecosystem services, as this suggests that the respondents are taking an ecosystem approach to management when it comes to 'the varying farming principles and mechanisms that allow agroecosystems to resist or recover from climate events such as floods, droughts, extreme rainfall etc' I.e., climate smart agriculture.

6.4 Which on-farm practices made a farm more climate-smart and or resilient to severe weather events?

We compared farmers' perception of which farming practices contribute to climate-smart agriculture on their farm with their answers to the question of which practices were among the reasons that had helped their farm to be more resilient to extreme weather events in the past five years. Enhancing soil fertility topped the list of practices farmers considered most important for climate smart agriculture (28 farmers, Table 08), and this was confirmed when asked which practices had most contributed to being less affected by extreme weather events, when the top reason stated was 'keeping the soil covered where possible' (11 farmers, Table 12). This understanding of the importance of soil management for climate smart agriculture was further underlined by 'reduced erosion' being in the top list of climate smart agriculture practices (Table 08) and 'reducing tilling' as the second most named reason for being less affected by extreme weather events (Table 12).

Most farmers were affected by drought (38), but flooding, both from extreme rainfall and rivers, was also frequently cited (19), with just two farmers experiencing wildfires, illustrating the diverse range of geographical settings of participating farms. Again, the small sample size of our survey did not allow for an in-depth analysis to identify which practices may have been significant in contributing to an outcome from severe weather events which affected farmers more or less than their neighbours with regard to the type of severe weather event and impact effect (e.g. decreased yield, effects on livestock etc).

In terms of defining a rating system to evaluate on farm practices that generate ES and ED based on the criteria for CSA, Table 17 gives a summary, whereby CSA practices delivering ES as well as CSA practices for extreme weather are ranked (Very important, important, neutral/not important). The combination of these two aspects illustrates how agroecology contributes both to support global efforts to counter climate change as well resilience of individual farms to extreme weather events facilitated by climate change. For example, farmers rated communication and collaboration with consumers and local communities very important, which contribute to greater awareness of the impact of agriculture on climate change and the importance of

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consumer choices and diets (Willett et al. 2019). Similar, local processing of produce reduces transport emissions and supports local communities and was rated with high importance. It is also notable how these practices linked to social aspects were among the five key CSA practices deemed 'very important' by farmers.

6.5 Do farmers value ecosystem services outside of provisioning services?

From the data, we can say that of the farmers interviewed, the value of ES was recognised. 37 (77%) out of the 48 respondents had plans to improve the ES on their farms in the next 5 years. 7 respondents did not, with one respondent indicating they were unable to improve the ES on their farm given strict inheritance agreements and family approval. For those farmers that did want to improve ES, money and time were the most cited requirements (25 each) and then knowledge (19). Finding ways to pay farmers upfront for ES provision could prove key to facilitating a transition to farms with broader ES.

Of the ES listed, carbon sequestration was cited the most times (21) as being desirable to improve, followed by carbon cycling (18), enhanced fertility (15), educational value (15) - interestingly the only cultural ES ranked in the top 14 ES - and nitrogen fixation (14) (see Table 15). The services match with CSA practices listed in Table 08 whereby enhanced soil fertility, carbon sequestration and cycling were deemed important.

These findings, that productivity cannot be the only yardstick, are in line with the literature, policies and overall gear change within the agricultural community. More and more we are seeing PES and companies innovating to provide farmers with financial incentives to introduce regenerative or climate-smart agricultural practices. "From government-backed schemes to voluntary private markets, there has been an explosion of interest in developing carbon and additional ecosystem service credits that could provide a new income stream for arable farmers worldwide" (Abram 2021). The article (from Farmers Weekly) goes on to detail 6 companies that are offering carbon-based payments to arable farmers. However, many of these PES focus purely on 'carbon farming'. The focus on carbon cycling and the potential for agriculture to sequester carbon is clearly recognised by farmers, industry and civil society, but we must be cautious of focussing too closely on just one element of the system; a holistic ecosystem approach must be held onto otherwise other key processes could be impacted in our drive to cycle more and more carbon into the soil.

6.6 Other salient points and limitations of the data

Given the remit of this report and time permitted, this study did not directly assess the relationship between AF/MF systems and their contribution to the SDGs, nor ask farmer's perceptions on the relationship between their farming systems, ES and ED and the SDGs. However, there is a clear link (apparent in the literature and detailed in Table 1) between agroecological cropping systems and the SDGs (including Goal 13 – Climate Action). This research could be taken further by incorporating a food systems approach to better understand the potential for AF/MF systems to support a just transition to sustainable food systems. From Table 1, we can say that investments in food systems and in AF/MF will drive change across multiple SDGs. As such, more

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focus is needed on the relationship between these systems and the goals and to see how much farmers feel they are contributing to and participating in, the global goals.

As mentioned above, there were limitations to the data which prevented more conclusive results and the ability to statistically compare the different systems with their respective ES and ED. More time, the ability to translate the survey (and results), more in-depth data regards climate events and location specific weather would have enabled a more robust analysis and ability to draw conclusions.

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7 Conclusion

Our survey provides an insight into the perception of ES and ED by farmers and how they may contribute to climate resilient agriculture. The AGROMIX experimental sites and farms were reviewed within a larger pool of farms to provide more robust data for analysis. ES and ED were deemed important in each context, with a clear understanding from farmers of the importance of these services on food production, resilience and biodiversity. As the data set was relatively small, it was not possible to directly compare the importance and prevalence of ES and ED in AF and MF systems. The similarities however, of taking a whole ecosystem approach was obvious both within AF and non-AF/MF systems, which is encouraging.

As a simple form of defining a rating system, farm practices were deemed either more or less important relative to the ES and ED they generate. Table 17 provides a simple rating system based on farmers' perceptions of the on-farm practices for delivering CSA relevant to ES and which practices are most important in terms of climate resilience. The following practices were deemed the most climate-smart: enhanced soil fertility; carbon sequestration; cultivated crops for nutrition; carbon cycling, and reduced erosion. Despite having identified which farming practices are most 'climate-smart' in the context of this work, it is important to continue taking a systems approach when making management and policy decisions around land use given the dynamic relationship and interconnectedness of multiple ES. Bennett *et al,* (2009) warn that, "an overly narrow focus on maximising a limited set of ES could lead to unexpected trade-offs or to undesirable and sudden declines in other ES".

While we set out initially to provide a benchmark for ES and ED in AF and MF systems within the AGROMIX project, we had to acknowledge that the farms within the project's network were mostly run as experimental farms and their assessment would not provide a valid benchmark for non-experimental working farms. By opening the survey instead to include farms outside the project network as well, we have achieved an overview of agricultural practices present on farms and considered by farmers to contribute to some extent to CSA. We hope to refer to these results while going forward with the project as well as re-open the survey with the aim of getting more responses.

Our results are of course limited in their interpretation with regard to ES and ED present on farms and to what extent the contribute to climate smart agriculture, as no actual on-farm assessments have been caried out. However, they are valuable for providing understanding of farmers' knowledge of agricultural practices that contribute to ES and ED and this will be useful for going forward and working with farmers to further advance the use of agroecological practices for climate smart agriculture in the future.

Whilst applying an ES assessment to farming systems is helpful, it is in no way the final way we should be assessing the suitability, sustainability, resilience and productivity of these systems. Maintaining a systems approach and incorporating principles for food systems transformation will be vital if we are to find an

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internationally agreed upon, contextually variable method of analysis that will facilitate and de-politicise decisions about land use and farming systems.

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9 Annex

Towards a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting.

Section	Division	Group	Class
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated plants (including fungi, algae) grown as a source of energy
Provisioning (Biotic)	Biomass	Cultivated aquatic plants for nutrition, materials or energy	Plants cultivated by in- situ aquaculture grown for nutritional purposes
Provisioning (Biotic)	Biomass	Cultivated aquatic plants for nutrition, materials or energy	Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Cultivated aquatic plants for nutrition, materials or energy	Plants cultivated by in- situ aquaculture grown as an energy source
Provisioning (Biotic)	Biomass	Reared animals for nutrition, materials or energy	Animals reared for nutritional purposes

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Provisioning (Biotic)	Biomass	Reared animals for nutrition, materials or energy	Fibres and other materials from reared animals for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Reared animals for nutrition, materials or energy	Animals reared to provide energy (including mechanical)
Provisioning (Biotic)	Biomass	Reared aquatic animals for nutrition, materials or energy	Animals reared by in-situ aquaculture for nutritional purposes
Provisioning (Biotic)	Biomass	Reared aquatic animals for nutrition, materials or energy	Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Reared aquatic animals for nutrition, materials or energy	Animals reared by in-situ aquaculture as an energy source
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Wild animals (terrestrial and aquatic) used for nutritional purposes
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Fibres and other materials from wild animals for direct use or processing

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			(excluding genetic materials)
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Wild animals (terrestrial and aquatic) used as a source of energy
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae or fungi	Seeds, spores and other plant materials collected for maintaining or establishing a population
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae or fungi	Higher and lower plants (whole organisms) used to breed new strains or varieties
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae or fungi	Individual genes extracted from higher and lower plants for the design and construction of new biological entities
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from animals	Animal material collected for the purposes of maintaining or establishing a population
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from animals	Wild animals (whole organisms) used to breed new strains or varieties
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from organisms	Individual genes extracted from organisms for the design and construction of new biological entities
Provisioning (Biotic)	Other types of provisioning service from biotic sources	Other	Other
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Surface water for drinking

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Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Surface water used as a material (non-drinking purposes)
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Freshwater surface water used as an energy source
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Coastal and marine water used as energy source
Provisioning (Abiotic)	Water	Ground water for used for nutrition, materials or energy	Ground (and subsurface) water for drinking
Provisioning (Abiotic)	Water	Ground water for used for nutrition, materials or energy	Ground water (and subsurface) used as a material (non-drinking purposes)
Provisioning (Abiotic)	Water	Ground water for used for nutrition, materials or energy	Ground water (and subsurface) used as an energy source
Provisioning (Abiotic)	Water	Other aqueous ecosystem outputs	Other
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals

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Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of nuisances of anthropogenic origin	Smell reduction
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of nuisances of anthropogenic origin	Noise attenuation
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of nuisances of anthropogenic origin	Visual screening
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Buffering and attenuation of mass movement
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Wind protection
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Fire protection
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context)
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Seed dispersal

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Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (Including gene pool protection)
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Pest and disease control	Pest control (including invasive species)
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Pest and disease control	Disease control
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of soil quality	Weathering processes and their effect on soil quality
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of soil quality	Decomposition and fixing processes and their effect on soil quality
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Water conditions	Regulation of the chemical condition of freshwaters by living processes
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Water conditions	Regulation of the chemical condition of salt waters by living processes
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of temperature and humidity, including ventilation and transpiration
Regulation & Maintenance (Biotic)	Other types of regulation and maintenance service by living processes	Other	Other

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Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable education and training
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that are resonant in terms of culture or heritage
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable aesthetic experiences
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have symbolic meaning

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Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have sacred or religious meaning
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems used for entertainment or representation
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an option or bequest value
Cultural (Biotic)	Other characteristics of living systems that have cultural significance	Other	Other

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