# D3.3: European Target Regions for Mixed Farming and Agroforestry

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| **Author(s)** | João Palma, Ana Tomás and Jo Smith, MVARC<br>Susanne Schnabel, J. Francisco Lavado Contador, Anthony Gabourel, UEX |
| **Contact** | josmith@mvarc.eu |
| **Reviewers** | Felix Herzog, Dennis Touliatos, Ulrich Schmutz |
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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent filings, videos, etc.; **OTHER**=other

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# 1 Executive Summary

## Context and Aim

In the face of current and future climate challenges, it is of the utmost importance to drive the transition towards more resilient and efficient land use in Europe. As part of the work developed in the AGROMIX EU Horizon-2020 project (2020-2024), we aimed to provide broader spatial contexts where agroforestry (AF) and mixed farming (MF) could be implemented to increase the environmental resilience of agricultural systems and provide effective climate change mitigation and adaptation strategies. This report is describing the methodological background of Deliverable 3.3, the AGROMIX Land Use Change Interactive Map, so called LUCIM. The deliverable itself is an online tool on the website and can be found here: **https://mvarc.eu/tools/dev/agromix_lucim**. The site is also embed in the main AGROMIX website and can be found here: **https://agromixproject.eu/tools/agromix-land-use-change-interactive-map**

The following report provides the methodological approach, key findings, description of the online interactive mapping tool, supporting tables, figures and references. Specifically, the report 1) delineates the integrated methodological framework employed for identifying suitable regions for AF/MF implementation, 2) implements a Delphi study on MF and AF to refine the higher spatial scales down to a close-up to practical and real examples, and 3) creates an interactive mapping tool that, contrary to narrowing down a single figure giving results based on predefined set of criteria (e.g. one size does not fit all), provides the underlying data for users to explore the different combinations of criteria and draw their own conclusions focused on their context.

## Methodology

The upscaling implemented a two-fold approach; the first part used a **spatial approach** to identify target areas in Europe where resilient and climate-smart AF/MF systems should have high priority for introduction, while the second part adopts an **expert-knowledge based approach** to develop future scenarios of land use/resilience strategies where different models of land use change are evaluated as pathways towards increased resilience to climate change, framed in a context of *Exposure*, *Sensitivity* and *Adaptive Capacity*.

The ***Spatial Approach*** identifies potential areas across Europe for the introduction of AF/MF systems. It involved selecting suitable areas, considering environmental, climate change risks, and socio-economic contexts, and defining target areas for intervention. The approach consisted of three steps: **(1)** selection of suitable potential areas from the total agricultural area in Europe, excluding nature conservation sites and AF/MF areas already identified in the land use/land cover cartography **(2)** analysis of environmental and climate change risks and socio-economic context in the potential areas, and **(3)** definition of target areas. The outcome of this analysis is a collection of maps that visually represent the convergence of environmental risks and socio-economic pressures, delineating priority areas for AF/MF implementation.

The ***Expert Knowledge-Based Approach*** complements the spatial analysis by detailing future scenarios of land use and resilience strategies by evaluating various models of land use change as pathways to enhance climate resilience. The ‘problem’ addressed is the impact of climate change on agricultural and forestry systems, and the ‘solution’ is the change in land-use towards a more resilient system. The Delphi method was used to seek and to bridge research and evidence gaps regarding the resilience of agroforestry and mixed farming land use models to climate change. The methodology underscores the importance of engaging

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stakeholders in developing problem-solution-based land use change models, supported by real-world examples and expert consensus. The real-world examples use case studies captured in the AGROMIX project as well as from other sources including other EU projects, EIP Focus Groups, European agroforestry associations, and from expert knowledge.

The ***Interactive website*** (**https://agromixproject.eu/tools/agromix-land-use-change-interactive-map)** brings the main findings of this report into an enhanced communication media to reach out a wider audience, employing a new dynamic for report visualisation. The tool used a state-of-the-art JavaScript interface designed for visualising the databases developed by this report, including on-the-fly responsive map visualisation, and linked related knowledge assets that build up the understanding of complex systems such as mixed farming and agroforestry systems.

## Key findings

**Potential Area for Implementation:** The spatial analysis identified approximately **1.5 million** $km^2$ in the EU27 Member States, United Kingdom, and Switzerland, as potential areas for the implementation of AF and MF systems.

**Environmental Challenges:** Of these 1.5 million $km^2$, over **0.5 million** $km^2$ suffer from significant environmental pressures, including soil degradation, biodiversity loss, and climate change, and were defined as target areas for introducing AF and MF systems. Furthermore, the socio-economic context of the target areas was characterised at the NUTS 2 scale aimed at identifying regions with particular need of policy support.

**Delphi Study Engagement:** The Delphi study engaged 60 experts through the process, resulting in over **7200 comments** identifying key themes of resilience while providing a consensus framework on the resilience of agroforestry and mixed farming land use models to climate impact drivers and associated impacts compared with baseline scenarios. For agroforestry, where consensus was reached, **in most cases (88%) the agroforestry land use models had higher resilience** to climate impact drivers than annual cropping and livestock-only baselines, but for transition from a tree-only (i.e. forestry or orchard) baseline, consensus was much lower (10%) or the resilience level was unknown (11%), suggesting much less is known about the impact of introducing livestock or cropping into existing forestry or orchards systems. For mixed farming, there was also **a strong consensus that mixed farming systems increased resilience** to climate impact drivers when compared with the agricultural baselines. However, there was some uncertainty about resilience to temperature and precipitation extremes, particularly for those systems that exchanged materials but kept the components separate spatially and temporally (i.e. between-farms and within-farm complementarity).

The Delphi study underlined **36 resilience themes** framed in vulnerability components of Exposure, Sensibility and Adaptive Capacity, including *Biodiversity Enhancement:* The critical role of AF and MF in increasing agrobiodiversity, functional biodiversity and ecosystem services; *Climate Adaptation Strategies:* The effectiveness of AF and MF in adapting to and mitigating the impacts of climate change; *Socio-Economic Benefits:* The potential of AF and MF to contribute to rural development, improve farmers' livelihoods, and enhance social resilience.

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## Deliverable

The primary outcome of this research is the Deliverable 3.3, featuring the Land Use Change Interactive Map (LUCIM) integrated in a new section on the AGROMIX project website:

**https://agromixproject.eu/tools/agromix-land-use-change-interactive-map**

This tool allows users to navigate through the project's findings; on one hand users are able to visualise the target areas depending on the environmental pressures as well as the socio-economic contexts, to enable them to identify and prioritise areas for AF/MF implementation; and on the other hand, users are presented with a navigation from 1) their current region, where they can 2) define their baseline system, 3) select the climate impact driver, and 4) see the options for changes towards resilient land use systems, while 5) visualising the resiliency consensus scores sourced by the Delphi study, as well as results from the thematic analysis. The tool serves as an educational resource, guiding users through "learning by example" scenarios. The tool is available at **https://agromixproject.eu/tools/agromix-land-use-change-interactive-map** being sourced by **https://mvarc.eu/tools/dev/agromix_lucim/**

## Final considerations

With a consistent methodological approach, both in spatial and non-spatial analysis described in this report, the AGROMIX Land Use Change Interactive Map (LUCIM) contributes as a resource for the strategic enhancement of agricultural resilience across Europe through the consideration of mixed farming systems and agroforestry. Stakeholders can now support their decisions by exploring contextual paths towards sustainable and resilient agricultural systems, bolstered by the practical toolset provided by LUCIM. The tool is available on the website for at least 5 years after project end and the use will be tracked for impact. It will also be used in interactive sessions and for policy meetings also after project end. Like this the impact of the tool can be tracked and further updates made. In addition, scientific publications based on these findings are being prepared.

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# 2 Introduction

The challenges of climate change, alongside the pressing needs for biodiversity conservation and food security, mandate a re-evaluation of agricultural practices within Europe. The AGROMIX project contributes to this challenge by assessing the viability and potential benefits of Mixed Farming (MF) and Agroforestry (AF) systems across diverse European contexts. This report 1) delineates the integrated methodological framework employed for identifying suitable regions for AF/MF implementation, 2) implements a Delphi study approach to refine the higher spatial scales down to a close-up to practical and real examples for land use change pathways for increased resilience, and 3) creates an interactive mapping tool that allows the reader/user to engage with the results. This report is supported, as the whole AGROMIX project, on the hypothesis that the integration of MF and AF systems can significantly enhance the resilience and sustainability of European agricultural landscapes. To this end, this report synthesises environmental, socio-economic, and climatic data with expert insights to pinpoint regions where the transition to MF and AF could yield environmental and socio-economic benefits.

Establishing a spatially explicit as well as a knowledge-based analysis, the framework integrates a diverse array of factors expressed as pressures, focusing on climate, soil, biodiversity, water resource management and socioeconomics, to assess the suitability of European regions for the incorporation of MF and AF systems. Central to refining the spatial analysis approach was the implementation of a Delphi study, which facilitated a structured communication process among a panel of experts. This iterative process sought to achieve consensus on key themes and variables relevant to the resilience and adaptability of MF and AF systems in the face of climate change. The Delphi study played a critical role in enhancing the robustness and validity of the project's findings, offering a comprehensive understanding of the expert-driven nuances influencing the potential success of these systems. This multifaceted approach ensured an overarching evaluation of the potential impacts and challenges associated with these MF and AF systems.

The AGROMIX Land Use Change Interactive Map (LUCIM) represents a pivotal tool developed to disseminate the project's spatial analysis results and the refined insights garnered from the Delphi study. LUCIM enables users to interactively explore identified target regions for MF and AF implementation, providing detailed environmental, socio-economic, and expert consensus information. This innovative tool serves as an essential resource for stakeholders, facilitating informed decision-making and fostering dialogue on sustainable agricultural transitions.

The integration of agroecological systems, as identified through the combined spatial, Delphi, and interactive mapping approaches, holds significant potential to enhance agricultural resilience to climate change and deliver multiple ecosystem services. The report explores these systems' capacity to improve soil health, biodiversity, water efficiency, and carbon sequestration, contributing to the sustainability of agricultural landscapes. The comprehensive methodology and the tools developed in this report provide a solid foundation for strategic planning and policy formulation aimed at promoting MF and AF systems in Europe. Engagement with a broad spectrum of stakeholders, including agricultural practitioners, consumers, policymakers, and the scientific community, is essential to advance the implementation of sustainable agricultural practices. The policy relevance of this work underscores the need for frameworks and incentives that encourage the adoption of MF and AF, aligning with the goals of the European Union's Green Deal and global sustainability targets.

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# 3 Target areas for introducing MF and AF systems in Europe (Sub-task 3.3.1)

Susanne Schnabel, J. Francisco Lavado Contador, Anthony Gabourel Landaverde
University of Extremadura

## 3.1 Overview

This section presents the methodology and the results for Sub-task 3.3.1 dedicated to the identification of target areas in Europe where resilient and climate-smart mixed farming or agroforestry systems would have high priority for introduction. It includes the European Union member states (EU-27), United Kingdom (UK) and Switzerland (CH). Necessary cartography and associated databases with the main characteristics of MF/AF over Europe were provided by WP1 task 4. Data mining and geo-spatial modelling were used to identify those target areas. The methodological framework applied is based on an adaptation of the one used by Kay et al. (2019) for agroforestry systems. The principal steps employed by these authors to define priority areas, i.e. where agroforestry could increase the provision of ecosystem services, consisted in the determination of (i) focus areas, (ii) pressure areas and (iii) priority areas. "Focus areas" were defined as European agricultural land excluding the areas of high nature value, such as Natura 2000, High Nature Value Farmland and the existing agroforestry areas. In the next step, the susceptibility of these "focus areas" to nine environmental pressures was determined and evaluated using predefined thresholds and added together to define "pressure areas". Finally, "priority areas" were those areas where the number of pressures exceeded a certain limit depending on whether it is arable land or pastureland.

The aim of our analysis is to define target areas where the introduction of mixed farming or agroforestry would provide environmental benefits and also be more resilient to climate change. The selection of these target areas is based on a spatial approach which consists of four steps (Figure 1): (1) selection of suitable potential areas from the total agricultural area in Europe, excluding nature conservation sites and MF/AF areas identified in the land use/land cover cartography, (2) analysis of environmental risks in the potential areas, (3) definition of target areas, and, finally, (4) analysis of the socio-economic context.

Although the basic approach follows the one of Kay et al. (2019) our study varies in several ways. Firstly, we do not only consider agroforestry as an alternative agricultural system but also mixed farming. Secondly, potential areas are agricultural areas that exclude those areas that are either protected nature reserves or are already MF/AF systems. There are basically two options to determine the spatial distribution of MF/AF areas: land use maps such as CORINE or LUISA and the LUCAS database. Both types of spatial datasets present some disadvantages. The land use maps do not include MF as a category and the category AF does not include all agroforestry areas. Also, the LUCAS database does not allow identification of most areas with MF, except for the combination of temporary cropland with grazing livestock (Schnabel *et al.*, 2022). Furthermore, LUCAS data are point data and its extrapolation to spatially explicit surface areas is difficult and impossible where AF point density is low. Contrary, land use maps are clearly defined polygons. Therefore, it was decided to use those in this study. Chapter 3.2 describes in more detail its application for the definition of potential areas.

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Thirdly, regarding suitable potential areas, Kay et al. (2019) differentiated between arable areas and pastureland. In our case, we consider three categories: grasslands, temporary crops and permanent crops. Finally, we include three more climate change variables in the analysis of environmental pressures, in addition to annual mean temperature, i.e., heavy precipitation, drought frequency and aridity index, as we consider relevant to assess the impact of climate change in the potential agricultural areas.

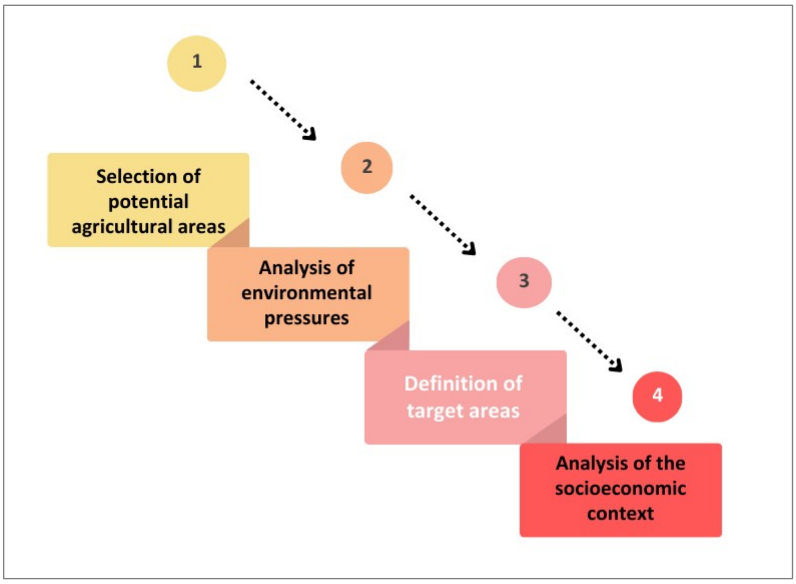


*Figure 1: Spatial approach for the definition of target areas for introducing MF/AF.*

The target areas to introduce MF/AF, along with a characterisation of the socio-economic context of the European regions, are presented in Chapter 3.3. While the analysis of environmental pressures allowed to identify agricultural areas that reported higher concentration of pressures, the characterisation of the socio-economic context showed that the social and economic factors varied across the European regions where those target areas were located. The relation between regions reporting higher environmental pressures and the different socio-economic factors that characterise them is key to identify opportunities for establishing MF/AF.

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## 3.2 Methodology

### 3.2.1 Selection of potential agricultural area

***Estimation of the total agricultural area***. Suitable potential areas were estimated from the total agricultural land of the European Union (EU) 27 Member States, the United Kingdom (UK) and Switzerland (CH). Croplands, permanent crops, and pastures were accounted for to estimate the total agricultural area, which are land cover/land use classes spatially distributed in the selected countries.

It should be noted that the outermost regions of the EU27, such as Guadeloupe, French Guiana, Réunion, Martinique, Mayotte and Saint-Martin (France); the Azores and Madeira (Portugal), and the Canary Islands (Spain), were not included for the estimation of the total agricultural area, as most of the available datasets at European scale used for the analysis of environmental pressures excluded these regions due to their geographical remoteness.

The Land-Use based Integrated Sustainability Assessment (LUISA) base map from 2018 (Batista and Pigaiani, 2021) was used to estimate the total agricultural area. The LUISA base map is a modified and improved version of the CORINE land cover 2018 map, with 17 artificial land use/cover categories (instead of 11 in CORINE), with a geographical coverage for all Europe and a spatial resolution of 100 m. This refined land cover map significantly enhances the resolution of the included classes, facilitating more accurate estimation of the total agricultural area. The following classes were included:

- Irrigated arable land
- Non irrigated arable land
- Rice fields
- Fruit trees and berry plantations
- Olive groves
- Pastures
- Natural grasslands

***Identification of nature conservation sites excluded from agricultural areas.*** Nature conservation areas are subject to specific rules and regulations due to legal agreements and conventions aimed at preserving biodiversity and natural habitats. Although land use changes may be allowed in some cases, it is not practical to consider regional regulations separately for all of Europe. Therefore, these areas were excluded from the estimated total agricultural land and were considered unsuitable for introducing MF/AF practices. The Natura 2000 Network (EEA, 2022b) and the RAMSAR sites maps (SISR, 2022) were used to determine these areas. In Switzerland, protected sites were identified using the Emerald Network of Areas of Special Conservation Interest (FOEN, 2018) – Table 1.

*Table 1. Base maps used for the selection of nature conservation areas in Europe.*

| Cartography | Data type | Source | Coverage | Resolution |
|---|---|---|---|---|
| Natura 2000 Network | Natural protected areas | (EEA, 2022b) | EU-27, UK | 100 m |
| Emerald network | Natural protected areas | (FOEN, 2018) | Switzerland | 100 m |
| Ramsar sites | Protected wetlands | (SISR, 2022) | All Europe | 100 m |

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***Identification and distribution of MF/AF classes from the LUISA Base map not considered as potential areas.*** Regarding the identification of areas with mixed farming and agroforestry using the LUISA base map, those can only be considered approximations because no mixed farming category exists and not all AF areas in Europe are represented. It was decided to include the following land uses as representative of MF/AF systems: *Annual crops associated with permanent crops* (silvoarable system), *Complex cultivation patterns* (combination of annual crops, pasture and/or permanent crops, including kitchen gardens, which are considered AF), *Land principally occupied by agriculture, with significant areas of natural vegetation (*mosaics of agricultural land combined with natural and semi-natural areas*)*, and *Agroforestry areas* (most of them *dehesas* and *montados* mainly located in the Southwest of the Iberian Peninsula, i.e. Portugal and Spain). It must be kept in mind that these classes do not correspond to the total MF/AF surface in Europe, only representing the areas that can be obtained from the LUISA map.

***Estimation of the suitable potential areas.*** Potential areas to introduce MF/AF were estimated from the total agricultural area excluding natural protected areas and MF/AF already identified in the LUISA base map. The analysis of environmental indicators was carried out in these areas, to finally identify target areas to introduce MF/AF in the EU27, UK and CH.

### 3.2.2 Definition of environmental indicators

A total of 14 environmental indicators were used to determine risks (Table 2) related to soils, biodiversity, water, and climate change in potential areas. Datasets of these indicators were gathered from cartographic products developed at European or national scales and available as public data or on demand. To evaluate the effects of those risks, threshold values were defined for each indicator, identifying the limits above or below which sustainability is compromised in potential areas.

Regarding soil risks, the European Union Soil Observatory (EUSO) reported that the most common types of soil degradation in Europe are the loss of soil organic carbon, the loss of soil biodiversity, and soil erosion by water (ESDAC, 2023). These processes have a significant impact on soil health, resulting in reduced crop productivity, increased soil losses, and degraded water quality. Furthermore, additional research showed that most unhealthy soils in Europe are affected by more than one type of soil degradation. In that sense, reducing soil erosion and increasing soil organic carbon stocks can enhance resilience by improving soil health, water and air quality, biodiversity, and crop productivity.

As for biodiversity-related variables, natural pest control is important for crop productivity and food security, as it reduces crop losses and the need for pesticides. Pollinators are necessary for crop yield and quality as many crops, such as fruits and vegetables, are dependent on pollinating insects to produce food for human consumption (Vallecillo *et al.*, 2020). Soil biodiversity is also essential for soil health, as it influences soil formation, decomposition, nutrient cycling, water regulation, and pest control (Orgiazzi *et al.*, 2016).

Another fundamental resource for trees, crops and livestock production is water, yet agriculture is both a significant contributor to water scarcity and a victim of it. This problem has been recognised by the United Nations Food and Agriculture Organization (FAO, 2019) and European Environmental Agency (EEA, 2021) (EEA, 2021), especially in southern and south-western Europe. In the context of agriculture, irrigation is the major cause of water consumption. Therefore, water abstraction for irrigation serves as a key indicator within the assessment of the Common Agricultural Policy (CAP), as water stress in Europe is expected to worsen and

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it is necessary to promote better water management into farm practices. Then, identifying agricultural areas with high demand of water is key for environmental protection and improvement.

In the EU27 Member States, Norway and United Kingdom water abstraction is considered a significant pressure, where up to 17% of the total groundwater body area and 10% of the total river length are affected (EEA, 2021). This is notably increased in southern-Europe, where the percentages are much higher (26% and 13% respectively). In this context, agriculture is the sector with the highest water consumption, when compared to the energy, industrial and transport sectors.

Reducing irrigated areas and managing other problems related with water quality, such as nitrogen excess, are crucial for building agricultural resilience. These actions improve water availability and quality, mitigate climate change, and boost biodiversity. Strategies like minimising nitrogen and phosphorus leaching, conserving soil moisture, diversifying crops, modifying microclimates, and adopting sustainable intensification methods further enhance this resilience, ensuring agriculture can adapt to a changing climate (Smith and Olesen, 2010; Godfray and Garnett, 2014).

Regarding climate change, the sixth Assessment Report published by the Intergovernmental Panel on Climate Change (Lee *et al.*, 2021) reported changes in key climate impacts within the different European sub-regions, including an increase in pluvial flooding in Northern, Western and Central Europe, an increase in fire weather in Eastern Europe and an increase in hydrological, agricultural, and ecological droughts in the Mediterranean bioregion.

Climate change affects agriculture in various ways, influencing several aspects such as altering crop phenology, water availability, pest and disease incidence, and – ultimately – crop yield and quality. Different studies have highlighted the significance of climate change on agricultural productivity through temperature increases, changes in water availability, and the occurrence of extreme environmental events like floods, droughts, storms, cyclones, and landslides (Awopegba, Fayose and Adeboye, 2022). However, climate change might also have some positive effects on the sector due to longer growing seasons and more suitable growing crop conditions in some regions (EEA, 2019a).

### Soil related risks

Maps at European scale of **soil erosion by water** (Panagos *et al.*, 2015)**, potential soil erosion by wind** (Borrelli *et al.*, 2017) and erosion risk for arable land in Switzerland (FOAG, 2019) were used to assess soil loss in agricultural land. Soil losses greater than 2 t $ha^{-1}$ $yr^{-1}$ were considered areas under higher risk of soil erosion (Panagos *et al.*, 2020).

The **soil organic carbon (SOC) saturation capacity** map was also considered in this analysis. This map expresses the ratio between actual and potential SOC stock in each pixel (Lugato, Bampa, *et al.*, 2014; Lugato, Panagos, *et al.*, 2014) where values close to 0 indicated a great potential of soil to store more carbon. Areas that showed a ratio below 0.4 were classified as pressure areas, since these agricultural areas were below 60% of their capacity to store carbon under optimal conditions as outlined by De Rosa et al. (2024).

### Risk of functional biodiversity loss

For the whole extent of the countries considered in this study, no consistent and detailed spatial data bases on species richness, diversity, or related direct indicators of biodiversity are available. Therefore, other

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indicators expressing functional aspects of biodiversity were used as proxies for biodiversity related risks which are available for Europe. One indicator reflects **the natural pest control** (Rega *et al.*, 2018) and the other represents **crop pollination potential** (Vallecillo *et al.*, 2020). Additionally, **potential threats to soil biodiversity** were assessed based on Orgiazzi et al.(2016). The three major components of soil biodiversity were analysed: **1) soil microorganisms, 2) soil fauna, and 3) biological functions**.

In this study, certain countries such as Croatia, Cyprus and Switzerland, lacked biodiversity-related data in the available European-scale datasets. To address this issue, average values for each risk indicator were computed across Europe's distinct environmental zones. Subsequently, these averages were extrapolated to analogous environmental zones within the countries lacking data. The environmental zones, as defined by Metzger (2018) in the Environmental Stratification of Europe, comprise 84 environmentally consistent strata, which can be grouped into 13 zones: Alpine North, Boreal, Nemoral, Atlantic North, Alpine South, Continental, Atlantic Central, Pannonian, Lusitanian, Anatolian, Mediterranean Mountains, Mediterranean North, and Mediterranean South.

For the pest control and the pollinator datasets, the first two quintiles of the values' distribution were used to identify areas under risk. This means that areas with lower values have a higher risk of pest outbreaks and reduced crop yields due to lower potential for supporting natural pest control services and pollinators, respectively. While for soil biodiversity, potential risk was ranked into five classes using the quantile classification method, according to Orgiazzi et al. (2016): low, low-moderate, moderate, moderate-high, and high levels. Areas falling into moderate-high and high levels were considered as areas under risk.

### Water related risks

The **Global Map of Irrigation Areas** version 5 (Siebert *et al.*, 2013) was used to find areas where the impact of irrigation on water resources was high. The map used stood for the total area equipped for irrigation around the year 2005 in percentage of the total area on a raster with a resolution of 5 minutes. Areas that presented more than 25% of its agricultural land equipped for irrigation were defined as pressure areas, as a critical threshold outlined by Kay *et al*. (2019).

The map of **nitrogen** (N) **surplus** (inputs minus crop removal) for the year 2010, as calculated with the model INTEGRATOR, was used to identify pressure areas with more than 50 kg N · $ha^{-1}$ $yr^{-1}$ (EEA, 2022a), as this critical threshold was recommended by the Knowledge for Integrated Nutrient Management Action Plan of the European Commission (Grizzetti *et al.*, 2023). In the case of Switzerland, the map of nitrogen input into water provided by the Federal Office of the Environmental (FOEN, 2015) was used.

### Climate change risks

To conduct an analysis of the risks associated with climate change, specific variables such as the **annual mean temperature, aridity index, drought frequency and heavy precipitation** were chosen. Some of these variables were used by Schnabel *et al.* (2022) to describe climate change in Europe and its effects on MF/AF systems. By comparing present climate conditions with projected future conditions, an estimation of the net change was assessed.

Climate datasets were obtained from the Copernicus Climate Change Service (Nobakht *et al.*, 2019; Berg, Franssen, *et al.*, 2021; Berg, Photiadou, *et al.*, 2021) (Nobakht *et al.*, 2019; Berg, Franssen, *et al.*, 2021; Berg,

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Photiadou, *et al.*, 2021)and the European Environmental Agency (EEA, 2019b). To compare current climate and future climate conditions, the reference period of 1971-2000 and the forecast for 2041-2070 were used to predict change in annual mean temperature, aridity index and heavy precipitation days. While for the indicator of drought frequency, the reference period was 1981-2010 and the forecast was 2041-2070, due to data availability. In both cases, the Representative Concentration Pathway (RCP) 8.5 and the HadGEM2-ES model were used.

**Annual mean temperature** is defined as the daily mean air temperature measured at 2 m, averaged over a 30-year period. This dataset was obtained from the Copernicus Climate Change Service (Berg, Photiadou, *et al.*, 2021). Agricultural areas reporting an increase between 2 and 4 °C would be defined as areas under risk. Agroforestry systems could have a key role in these areas as they are reported to remain robust within an average temperature increase of up to 4 °C (Hart *et al.*, 2012).

**Aridity index** is calculated as the monthly mean values of the ratio between actual evapotranspiration and precipitation over a 30-year period. Actual evapotranspiration is the modelled evapotranspiration computed only with available water (Berg, Photiadou, *et al.*, 2021). The threshold values were defined as the two upper quintiles.

The projected change in meteorological **drought frequency** was also analysed. Present conditions were obtained from the period 1981-2010 and future conditions from the period 2041-2070. To identify pressure areas with a projected increase in drought frequency, the upper two quintiles of the values' distribution were chosen. The data were obtained from the European Environmental Agency (EEA, 2019b).

**Heavy precipitation days** was estimated as the number of days per 10 days when the daily precipitation sum is more than 10 mm. This indicator provides information on the increase of the frequency of large magnitude rainfall amounts that can produce crop damage and increase runoff losses. Datasets were obtained from the Copernicus Climate Change Service (Nobakht *et al.*, 2019). The two upper quintiles were selected to identify areas with a significant increase in heavy precipitation.

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*Table 2. Selection of environmental indicators to assess areas under risk in Europe, according to soil, biodiversity, water, and climate change variables.*

| Risk indicator | Description | Source | Coverage* | Resolution (m) | Threshold | Threshold source |
|---|---|---|---|---|---|---|
| **Soil** | Water erosion | (Panagos *et al.*, 2015; FOAG, 2019) | EU 27, UK, CH | 100 | > 2 t $ha^{-1}$ $yr^{-1}$ | (Panagos *et al.*, 2020) |
| | Wind erosion | (Borrelli *et al.*, 2017; FOAG, 2019) | EU 27, UK, CH | 1000 | > 2 t $ha^{-1}$ $yr^{-1}$ | (Borrelli *et al.*, 2017) |
| | Soil Organic Carbon (SOC) saturation capacity | (Lugato, Bampa, *et al.*, 2014; Lugato, Panagos, *et al.*, 2014) | EU27, UK (without CH) | 1000 | < 0.4 Ratio between actual and potential SOC stock | (De Rosa *et al.*, 2024) |
| **Biodiversity** | Potential threats to soil biodiversity, 3 indicators: fauna, microorganisms, and biological functions | (Orgiazzi *et al.*, 2016) | EU 26, UK (without HR and CH) | 500 | Upper two quintiles of the values' distribution | (Orgiazzi *et al.*, 2016) |
| | Pest control index | (Rega *et al.*, 2018) | All Europe (without CY) | 100 | First two quintiles of the values' distribution | (Rega *et al.*, 2018) |
| | Pollinator potential | (Vallecillo *et al.*, 2020) | EU 27, UK (without CH) | 1000 | First two quintiles of the values' distribution | (Vallecillo *et al.*, 2020) |
| **Water** | Irrigated areas | (Siebert *et al.*, 2013) | World | 100 | >25% irrigated land | (Kay *et al.*, 2019) |
| | Nitrogen surplus | (EEA, 2022a; FOEN, 2022) | EU 27, UK, CH | 100 | > 50 kg N $ha^{-1}$ $yr^{-1}$ | (Grizzetti *et al.*, 2023) |
| **Climate change** | Annual mean temperature | (Berg, Photiadou, Simonsson, *et al.*, 2021) | All Europe | 100 | 2-4ºC | (Hart *et al.*, 2012) |
| | Aridity index | (Berg, Photiadou, Bartosova, *et al.*, 2021) | All Europe | 100 | Upper two quintiles of the values' distribution | Based on the values' distribution |
| | Drought frequency | (EEA, 2019) | All Europe | 100 | Upper two quintiles of the values' distribution | Based on the values' distribution |
| | Heavy precipitation | (Nobakht *et al.*, 2019) | All Europe | 100 | Upper two quintiles of the values' distribution | Based on the values' distribution |

*EU 27: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden; CH: Switzerland; CY: Cyprus; HR: Croatia; UK: United Kingdom.

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### 3.2.3 Determination of target areas

After combining the environmental indicators related to soil, biodiversity, water, and climate, heat maps were produced to highlight the intensity of a total of 14 environmental risks. Areas showing seven or more accumulated pressures were defined as target areas to introduce MF/AF. This threshold was applied according to the spatial distribution of pressures in the potential areas, selecting only those areas that were found between the upper two quintiles of the value's distribution, i.e., areas reporting between seven and 14 environmental pressures.

Different surface analyses were performed by country, identifying the total area affected in proportion to the extent of each country, the agricultural area, and the potential land to introduce MF/AF. Additionally, the mean of pressures by land use and land cover category were estimated, considering croplands, permanent crops, and pasture lands separately. These analyses were useful to identify the extent of the area affected and those land use categories that were more endangered.

### 3.2.4 Definition of the socio-economic factors

The analysis of the socio-economic context provided insights into the social and economic determinants posed to the possibilities of introducing MF/AF. A total of six social and economic variables, related to economy (economic size and unemployment rate), training and willingness of farmers to change (training of farm managers, number of organic farming holdings) and demography (ratio of young farm managers to elderly farm managers, degree of urbanisation), were selected to characterise these aspects in the NUTS 2 regions of the EU27, Switzerland and United Kingdom (Table 3). These indicators were spatially combined to characterise the social and economic conditions, using the data available in Eurostat for the European regions. Each indicator was analysed individually to identify regions with different socio-economic backgrounds. The selected factors are also socio-economic and sectoral indicators used in the context of the CAP to provide information and economic trends on the agricultural sector.

In terms of economic viability, the mean economic size of farms serves as a crucial indicator. Regions with higher agricultural outputs can be better positioned to adopt MF/AF practices due to their sufficient economic capacity. Conversely, regions with lower economic outputs would require additional financial support to successfully implement MF/AF initiatives. In this context, the potential contribution of small farms for the transition to a more sustainable agriculture has been recognised. However, this typology of farms may struggle to access subsides and other types of financial support due to their size or the lack of assets (Guarín *et al.*, 2020).

Regarding job creation, MF/AF may require more work than conventional agriculture due to the integration of trees with crops or livestock. This could potentially create jobs in areas with high unemployment, increasing job opportunities that might also benefit women as they can be involved in the production activities (Mukhlis, Syamsu Rizaludin and Hidayah, 2022). However, this also poses various challenges, such as the lack of training, financial barriers and potential workforce decline due to rural exodus. Government support and training programs can help overcome these gaps and make MF/AF more viable options in areas with high unemployment rates.

In the context of farm management training, it is considered that farmers with higher education levels in agriculture are more likely to possess the knowledge required for managing MF/AF, thus increasing their

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potential to adopt MF/AF practices. Additionally, another variable indicative of farmers' willingness to adopt MF/AF is the proportion of organic farming within European regions. Regions with a higher concentration of organic farming holdings are more likely to adopt new practices and adapt to change (Rosati, Borek and Canali, 2021). This can be attributed to the shared principles between organic farming and agroforestry, such as enhancing biodiversity and improving soil health. Moreover, agroforestry can contribute to closing the yield gap often associated with organic farming, by improving productivity through ecological interactions between trees, crops, and livestock (Sollen-Norrlin *et al.*, 2020). Despite the benefits, there are challenges in adoption, including the need for specific knowledge and the initial investment required.

Some other indicators are related to demography, such as the ratio of young to old farm managers. Regions with higher proportions of young farmers are more likely to have sufficient generational renewal to support a potential implementation of MF/AF in those regions. On the contrary, regions where the proportion of elderly farm managers is higher probably will lack sufficient generation renewal, thus increasing land abandonment. Additionally, the degree of urbanisation offers a comprehensive classification of population distribution and concentration across European regions. It is useful to understand the character of a territory, since it allows us to identify if target areas to introduce MF/AF are located in regions dominated by rural landscapes or regions which are highly populated and concentrated, or intermediate regions.

The character of a territory, whether rural or urban, significantly influences the possibilities of practicing agroforestry in agriculture. For example, in rural areas, agroforestry can be a viable approach to enhance socio-economic and environmental outcomes. It has the potential to improve smallholders' income, increase food security, promote gender equality, and stimulate cultural activities (Mukhlis, Syamsu Rizaludin and Hidayah, 2022). However, the adoption of agroforestry in rural communities is often limited due to factors like the absence of agroforestry in public policy, which leads to little recognition of this system to tackle climate crises and improve livelihoods.

The spatial resolution of the social and economic datasets presents a challenge for integrating it with the environmental datasets. While the environmental data provides a higher spatial resolution, Eurostat's data on socio-economic variables is only available at the NUTS 2 regional level. This discrepancy in spatial resolution makes it difficult to directly combine the environmental pressure analysis with a detailed characterisation of the socio-economic background in the target areas. Furthermore, the lack of updated data limited the actual characterisation of the social and economic factors in some countries and regions, such as the UK, since Eurostat is no longer disseminating new data for this country.

#### Economic variables

The **economic size of farms** is an indicator of the standard economic output reported for a year. In 2020, 3.3 out of 9.1 million farms in the EU had a standard output below 2000 euros per year and were responsible for only 1% of the EU's total agricultural economic output (Eurostat, 2022). This means that approximately 35% of the total farms in the EU are semi-subsistence or small farms.

The standard output of an agricultural product is the average monetary value of the agricultural output at farm-gate price, in euro per hectare or per head of livestock (Eurostat, 2020). In this sense, regions were classified according to their economic size, using the mean economic size as a representative value of each region (Eurostat, 2023a). This is also one of the sectoral indicators used to assess the implementation of the CAP.

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For the normalisation of the data, a regional standard output coefficient is applied for each product, which is the average value over a reference period of 5 years. Then, the economic size is the sum of all the standard output per hectare of crop and per head of livestock in a farm, expressed in euro (Eurostat, 2020).

Data were provided by Eurostat (Eurostat, 2023a) in euros, ranging from 0 to 500,000 or more euros, as the economic output. For each region mean values were calculated and then 6 classes were defined according to the level of income:

$$Mean\ economic\ size\ of\ farm = \frac{Total\ agricultural\ output\ in\ euros}{Number\ of\ holdings}$$

**Unemployment rates** were obtained at the NUTS 2 level from Eurostat (2024). These represented the total unemployed persons as a percentage of the labour force. The labour force is the total number of people employed and unemployed. Unemployed persons comprise persons aged 15 to 74 who were: without work during the reference week, currently available for work, or actively seeking work.

This indicator is calculated as follows:

$$Unemployment\ rate = \frac{Unemployed\ persons}{Employed + unemployed\ persons}\ x\ 100$$

### Training and willingness of farmers to change

**The ratio of farm managers with full training to farm managers with basic knowledge and practical experience only** provides information on the proportion of farm managers who have attained full and basic education levels in agriculture. This indicator is used as a sectoral indicator in the CAP and it classifies farm managers into three categories:

- **Full agricultural training**. Farm managers who have attained any training course continuing for the equivalent of at least two years full time training after the end of compulsory education and completed at an agricultural college, university of other institute of higher education.
- **Basic agricultural training**. Meaning any training courses completed at a general agricultural college and/or an institution specialising in certain subject.
- **Only practical experience**. This category encompasses farm managers who have gained expertise solely through practical work on an agricultural holding.

Datasets were provided by Eurostat, (2023b) and the values were calculated using the following equation:

$$Ratio\ = \frac{Farm\ managers\ with\ full\ training}{Farm\ managers\ with\ basic\ knowledge + farm\ managers\ with\ practical\ experience\ only}$$

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**The share of organic farming holdings** represented the agricultural area under organic farming as a proportion of the utilised agricultural area. Farming is considered organic if it complies with the EU regulations.

Datasets were provided by Eurostat and the values were estimated as follows:

$$Share\ of\ organic\ farming\ holdings = \frac{Number\ of\ organic\ farming\ holdings}{Total\ holdings} \times 100$$

### Demographic variables

**Ratio of young farm managers to elderly farm managers.** The indicator shows the ratio between young farm managers (< 40 years old) and elderly (> 65 years old) farm managers. Datasets were provided by Eurostat (2023b).

$$Ratio = \frac{Farm\ managers\ aged\ less\ than\ 40\ years\ old}{Farm\ managers\ aged\ more\ than\ 65\ years\ old}$$

**Degree of urbanisation (DEGURBA)** is based on population density and size. This methodology captures settlements of different sizes and economic relations between cities and their surroundings (Eurostat, 2021). It classifies the territory of a country as an urban-rural continuum. The dataset used for this indicator was developed by de Beer, van der Gaag and van der Erf (2014) at the NUTS 2 level to maintain consistency with the spatial resolution of the rest of economic and social variables.

DEGURBA combines the population size and the population density thresholds to establish 3 mutually exclusive classes: cities, towns and suburbs, and rural areas. Based on these categories, regions are classified in three degrees of urbanisation**: predominantly urban, intermediate and predominantly rural regions**. The methodology for the classification of population grids is explained in Figure 2**Error! Reference source not found.**, which is based on cluster of cells to define population size thresholds and the population density of cells (inhabitants per km$^2$).

| Population density of cells, inhabitants per km² | Population size thresholds of the cluster of cells (settlement size): >= 50,000 | 5,000 - 49,999 | 500 - 4,999 | No population size criterion (not a settlement) |
|---|---|---|---|---|
| >= 1500 | Urban centre | Dense urban cluster | | |
| >= 300 | | Semi-dense urban cluster* | Rural cluster | Suburban or peri-urban grid cells |
| >= 50 | | | | Low density rural grid cells |
| <50 | | | | Very low density rural grid cells |

* Semi-dense urban clusters can have a population of more than 49,999

*Figure 2. Methodology for the degree of urbanisation. Source: (Eurostat, 2021).*

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*Table 3. Selection of variables to characterise the socio-economic context in the EU27, UK and CH at NUTS 2 level.*

| Topic | Indicator* | Temporal coverage |
|---|---|---|
| Education | Ratio of farm managers with full training to farmers with basic knowledge and practical experience only | 2020, 2016 |
| | Share of organic farming holdings in proportion to total farms (%) | 2020, 2016 |
| Economy | Mean economic size of farms (Standard Output in Euro) | 2020, 2016 |
| | Unemployment rate (%) | 2021, 2016 |
| Demography | Ratio of young (< 40 years old) to elderly (>65 years old) farm managers | 2020, 2016 |
| | Degree of urbanisation (three degrees: predominantly urban, intermediate, predominantly rural) | 2014 |

*The geographical coverage of all indicators were the NUTS 2 regions of the EU27 member states, United Kingdom, and Switzerland. The source of the data was Eurostat.

## 3.3 Results

### 3.3.1 Estimation of the potential agricultural area

The total agricultural area for the EU-27, the United Kingdom and Switzerland was 1,722,866 km$^2$. Cropland classes included non-irrigated arable land, permanently irrigated arable land and rice fields. Permanent crops included vineyards, fruit trees and berry plantations and olive groves. The third group consisted of pastures and natural grasslands. The most frequent classes were non-irrigated arable land, pastures, and natural grasslands, which, in combination, represented more than 90% of the total agricultural area. Concerning the groups of analysis, croplands represented (62%), pastures (32%) and permanent crops (6%) (Table 4).

*Table 4. Total agricultural area in the EU27, United Kingdom and Switzerland based on the land cover classes of the LUISA Base map.*

| Agricultural land use | Total area km$^2$ | Total area % |
|---|---|---|
| Non irrigated arable land | 1,018,692 | 59.1 |
| Permanently irrigated land | 39,860 | 2.3 |
| Rice fields | 6,370 | 0.4 |
| ***Total Cropland*** | ***1,064,922*** | ***61.8*** |
| Pastures | 447,854 | 26.0 |
| Natural grassland | 104,901 | 6.1 |
| ***Total Pastures*** | ***552,755*** | ***32.1*** |
| Vineyards | 34,385 | 2.0 |
| Fruit trees and berry plantations | 25,527 | 1.5 |
| Olive groves | 45,277 | 2.6 |
| ***Total permanent crops*** | ***105,189*** | ***6.1*** |
| **Total EU 27, UK, CH** | **1,722,866** | **100.0** |

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Some MF/AF related classes were also identified in the land cover map. While these classes were not considered for the estimation of the suitable potential areas in Europe, they are also part of the agricultural land. MF/AF classes together represented a total area of 249,472 $km^2$, being the most prevalent class complex cultivation patterns (45.3%) and land principally occupied by agriculture (41.1%). Agroforestry areas represented 12.1% of the land, while annual crops associated with permanent crops were only 1.6% of the area (Table 5).

*Table 5. Mixed farming and agroforestry related classes identified in the land cover map developed in the Land-Use based Integrated Sustainability Assessment modelling platform (LUISA) for the year 2018. These land cover classes only represented a proportion of the total agricultural area and were excluded from the suitable potential area to introduce mixed farming and agroforestry systems, as those are already characterised by different combinations of trees, permanent and temporary crops, or pastures.*

| **Land cover class** | **Total area ($km^2$)** | **Total area (%)** |
|---|---|---|
| Annual crops associated with permanent crops | 3,901 | 1.6 |
| Complex cultivation patterns (kitchen gardens) | 113,036 | 45.3 |
| Land principally occupied by agriculture | 102,424 | 41.1 |
| Agroforestry areas | 30,110 | 12.1 |
| **Total area** | 249,472 | 100.0 |

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Once nature conservation sites and MF/AF classes were subtracted from the total agricultural area, potential areas for introducing MF/AF systems amounted to a total of **1,537,326 km**$^2$ (Table 6) which represented a total of 34.9% of the total surface in the EU27, United Kingdom and Switzerland (Figure 3).

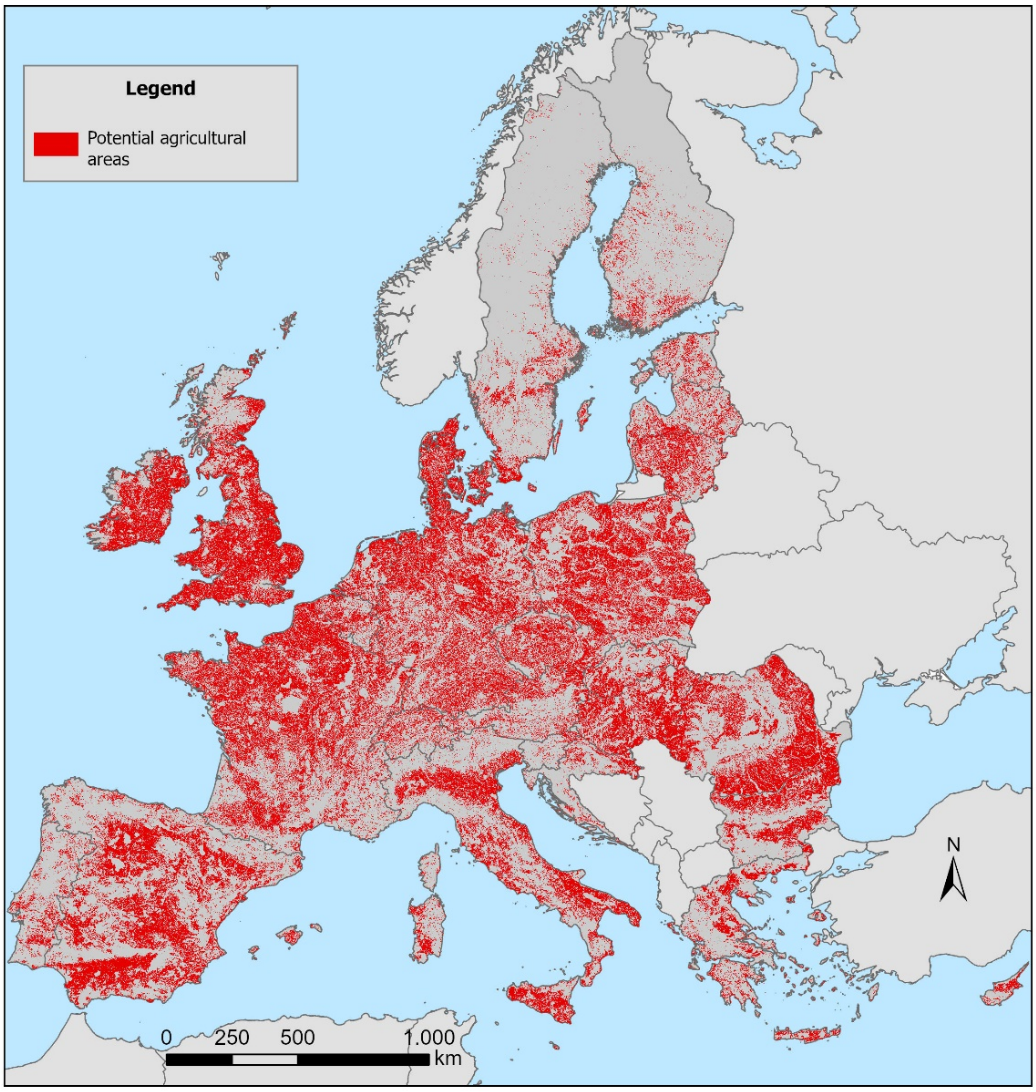


*Figure 3. Suitable potential areas to introduce MF/AF in the EU27, United Kingdom and Switzerland.*

*Table 6. Surface area occupied by non-agricultural land, potential MF/AF areas, current MF/AF and protected agricultural land in the EU, UK and CH.*

| | Non-agricultural land | Potential MF/AF areas | Current MF/AF areas | Protected agricultural land | Total |
|---|---|---|---|---|---|
| **Extent (km²)** | 2,439,557 | 1,537,326 | 216,380 | 217,197 | 4,410,460 |
| **Proportion (%)** | 55.3 | 34.9 | 4.9 | 4.9 | 100.0 |

An additional table is presented in the annex section (Annex 1. Extent (km2) of EU countries, UK and CH, and surface area occupied by agricultural land, potential areas, MF/AF areas and protected agricultural land.

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According to the distribution of potential areas by country, Denmark (61.8%), Ireland (56.4%), United Kingdom (55.8%), Hungary (53.4%) and Netherlands (49.1%) had the largest share of the potential area in proportion to the surface area of the country (**Error! Reference source not found.**). On the other hand, Croatia (18.8%), Portugal (18.2%), Slovenia (12.4%), Sweden (7.1%) and Finland (5.1%) reported a smaller share of potential agricultural area to introduce agroforestry and mixed farming due to climate, topographic conditions, or the country's extension (Table 7).

*Table 7. Potential MF/AF areas, current MF/AF areas, protected agricultural land areas and non-agricultural land as a proportion (%) of total country surface areas in the EU, CH and UK. The data is ordered according to potential areas.*

| Country | Potential MF/AF areas | Current MF/AF areas | Protected agricultural land | Non-agricultural land |
|---|---|---|---|---|
| Denmark | 61.8 | 4.2 | 3.5 | 30.5 |
| Ireland | 56.4 | 5.5 | 2.4 | 35.7 |
| United Kingdom | 55.8 | 0.4 | 1.6 | 42.2 |
| Hungary | 53.4 | 2.0 | 9.2 | 35.3 |
| Netherlands | 49.1 | 5.8 | 2.8 | 42.4 |
| Poland | 47.1 | 2.8 | 6.3 | 43.7 |
| Germany | 47.1 | 0.1 | 5.9 | 46.9 |
| Czechia | 45.4 | 4.8 | 3.4 | 46.4 |
| Romania | 44.5 | 5.5 | 6.9 | 43.1 |
| France | 43.7 | 7.5 | 5.1 | 43.7 |
| Lithuania | 42.7 | 11.8 | 2.5 | 42.9 |
| Luxembourg | 38.3 | 0.1 | 10.6 | 51.1 |
| Spain | 37.3 | 7.3 | 9.1 | 46.4 |
| Belgium | 36.2 | 11.8 | 3.8 | 48.2 |
| Bulgaria | 36.1 | 4.8 | 11.6 | 47.5 |
| Cyprus | 35.7 | 6.9 | 2.9 | 54.6 |
| Italy | 34.8 | 8.2 | 4.7 | 52.3 |
| Slovakia | 32.6 | 4.7 | 7.0 | 55.7 |
| Switzerland | 31.1 | 3.0 | 0.5 | 65.3 |
| Malta | 30.6 | 10.3 | 4.1 | 55.0 |
| Austria | 28.8 | 3.3 | 4.6 | 63.4 |
| Latvia | 28.7 | 6.6 | 2.4 | 62.2 |
| Greece | 25.3 | 9.3 | 8.2 | 57.2 |
| Estonia | 22.6 | 5.7 | 1.6 | 70.1 |
| Croatia | 18.8 | 10.4 | 10.3 | 60.5 |
| Portugal | 18.2 | 17.9 | 8.4 | 55.5 |
| Slovenia | 12.4 | 8.7 | 6.7 | 72.2 |
| Sweden | 7.1 | 0.9 | 0.4 | 91.5 |
| Finland | 5.7 | 2.1 | 0.1 | 92.2 |
| EU27, UK, CH Average | 35.4 | 5.9 | 5.1 | 53.6 |

The majority of the potential agricultural area was found in France, Spain, Germany, Poland, and the United Kingdom, which together account for 64% of the total. Conversely, despite their extensive land area, Finland and Sweden contributed just 1.2% and 2.1% respectively to the potential agricultural area. This is attributed

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to the predominance of forests over croplands and pastures in these nations. Meanwhile, countries like Portugal and Croatia, despite having a smaller share of potential area, possessed a relatively higher percentage of MF/AF (Figure 4).

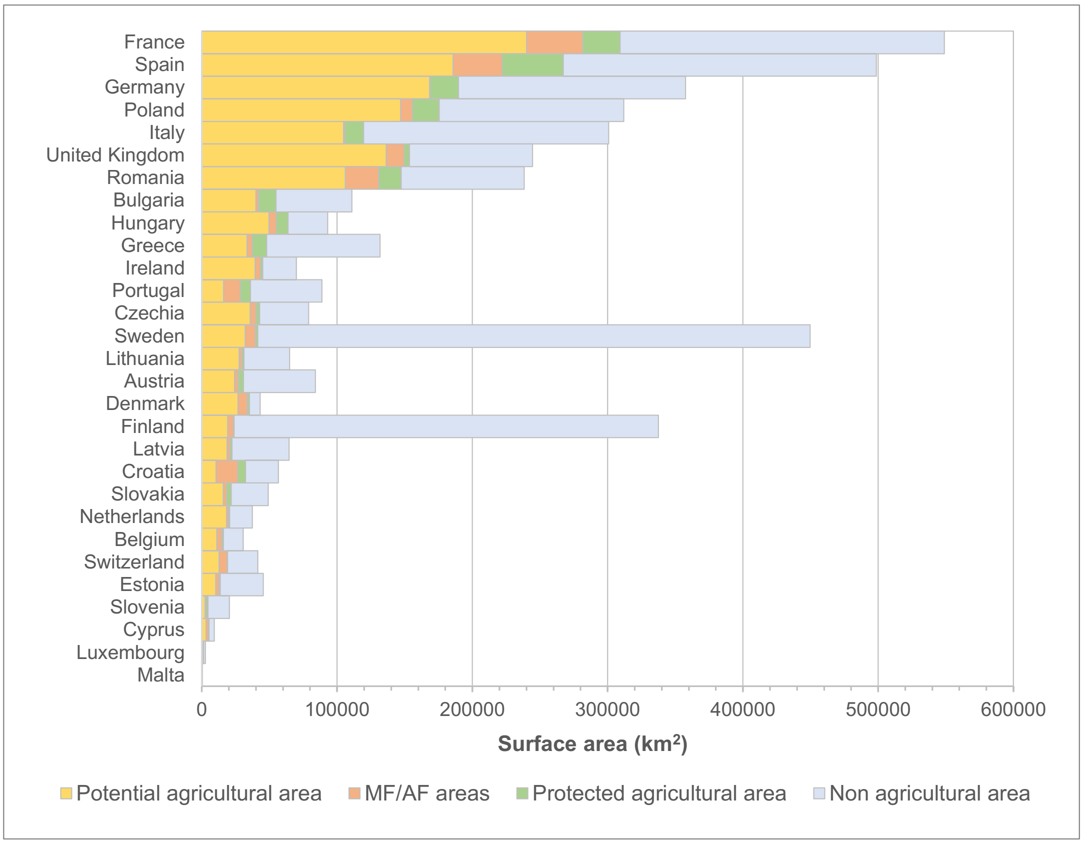


*Figure 4. Extent (km²) of potential areas, MF/AF areas, protected agricultural areas and non-agricultural land in the EU, UK and CH.*

Figure 5 shows the potential area to introduce MF/AF, the MF/AF area, and the protected agricultural area as a proportion of the total agricultural land in the EU-27, United Kingdom, and Switzerland. While the highest proportions of potential area were identified in the UK (97%), Switzerland (90%), and Denmark (89%), some other countries presented lower values, such as Croatia (48%), Slovenia (45%) and Portugal (41%), where MF/AF and protected areas occupied a higher proportion of the total agricultural land.

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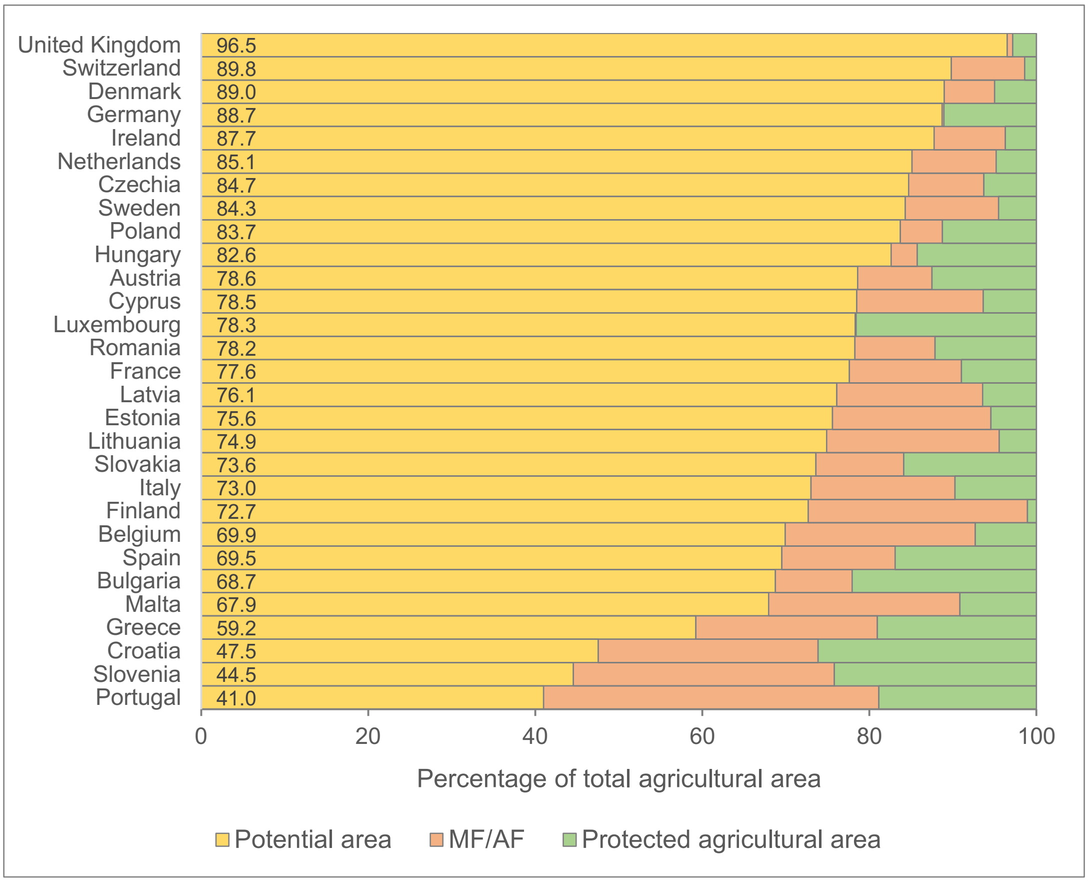


*Figure 5. Potential areas, MF/AF areas and protected agricultural areas as a proportion (%) of total agricultural land in the EU, UK and CH.*

### 3.3.2 Extent and spatial distribution of target areas to introduce MF/AF

The spatial distribution of 14 environmental pressures is shown in Figure 6. These areas represent the distribution of different accumulations of pressures according to the selected indicators, which are related to soil (water erosion, wind erosion and soil organic carbon saturation capacity), water (irrigated areas and nitrogen surplus), climate change (annual mean temperature, aridity index, drought frequency and heavy precipitation days) and biodiversity (pollinator potential, pest control index and potential threats to soil biodiversity). While in a small proportion of land no pressures were identified, conversely, some potential areas are affected by the 14 environmental pressures simultaneously.

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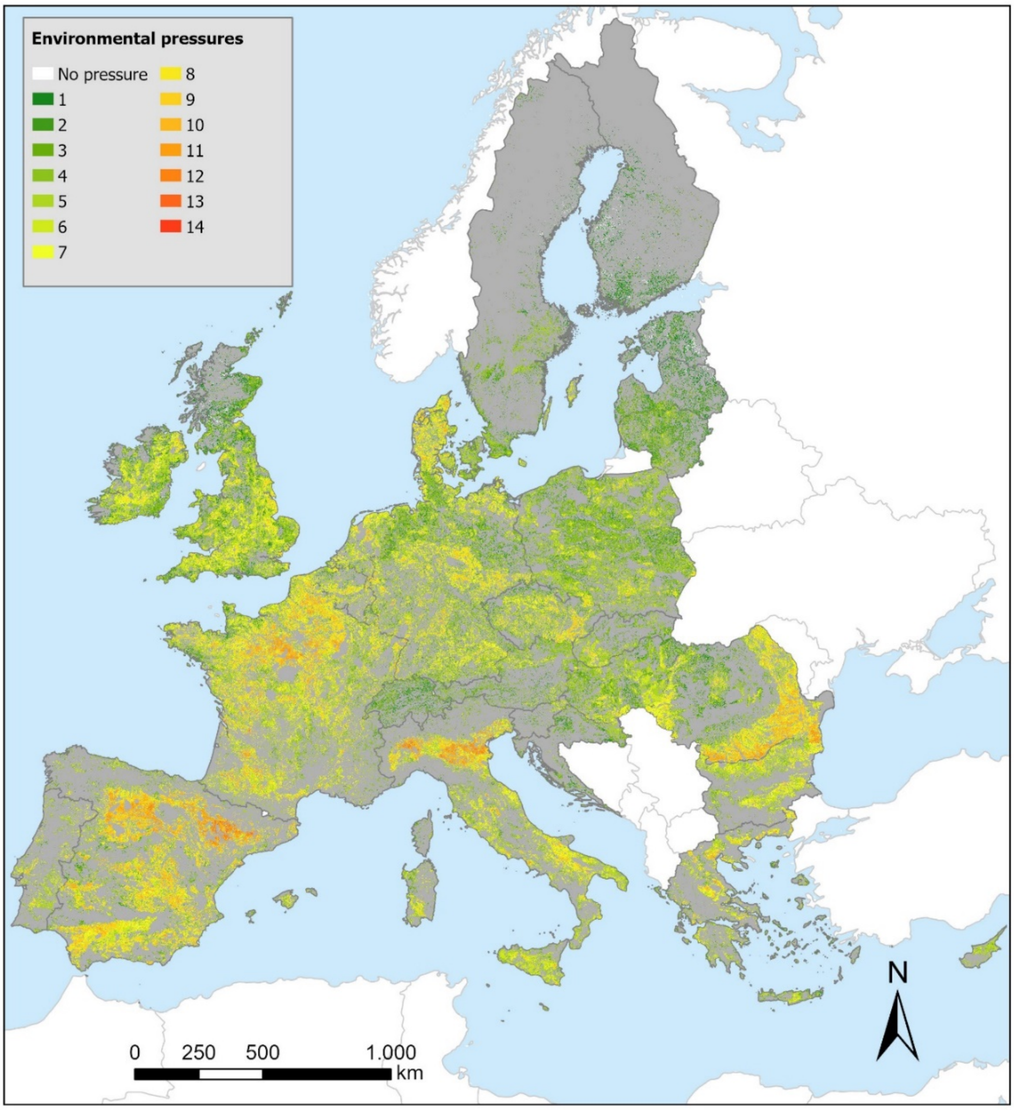


*Figure 6. Spatial distribution of accumulated environmental pressures (0-14) in the potential agricultural area to introduce MF/AF in the EU27, United Kingdom and Switzerland.*

The total potential agricultural area amounted to 1,537,326 km$^2$. The number of environmental and climate change pressures assessed in these areas ranged from 0 to 14. Then these pressures were aggregated to obtain a final map of 14 accumulated pressures, showing areas with no pressures (0.4%, 6,066 km$^2$) and a very small proportion of land where up to 14 pressures were computed (0.001%, 13 km$^2$). On the other side, the highest proportion of affected land corresponded to areas where 5 aggregated environmental pressures were observed, amounting to 15.9% of the potential area (244,390 km$^2$) (Table 8).

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*Table 8. Extent of the area affected by the sum of environmental pressures (0-14) and the proportion with respect to the total potential agricultural area.*

| Accumulated environmental pressures | Area (km$^2$) | Area (%) |
|---|---|---|
| 0 | 6,066 | 0.395 |
| 1 | 32,649 | 2.124 |
| 2 | 93,607 | 6.089 |
| 3 | 178,783 | 11.630 |
| 4 | 238,572 | 15.519 |
| 5 | 244,390 | 15.898 |
| 6 | 236,965 | 15.415 |
| 7 | 200,000 | 13.010 |
| 8 | 140,477 | 9.138 |
| 9 | 92,959 | 6.047 |
| 10 | 50,681 | 3.297 |
| 11 | 17,902 | 1.165 |
| 12 | 3,856 | 0.251 |
| 13 | 362 | 0.024 |
| 14 | 13 | 0.001 |
| **Total area** | **1,537,326** | **100.000** |

### Extent of the affected potential area by pressure

The area affected for each of the 14 selected environmental and climate change pressures in the study area (EU, United Kingdom and Switzerland), is presented in Table 9. It must be kept in mind that the surface areas are only presented for the potential agricultural areas that total 1,537,326 km$^2$. The future projection of mean annual temperature increase (2$^o$ C to 4$^o$ C degrees for the period 2041-2070) almost affects the complete potential agricultural land (91.3%). In contrast, wind erosion only affects 3.8% of the potential areas, followed by the indicator that presents the area equipped for irrigation which represents 9.0%. The rest of the indicators represent variable percentages of the potential agricultural areas, between 32 and 50 %, as illustrated in Figure 7.

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*Table 9. Potential area affected for each of the 14 environmental and climate change pressures, in km² and proportional to the total potential area.*

| Pressure types | Pressure indicator | Area affected (km²) | Proportion affected (%) |
|---|---|---|---|
| Climate change | Temperature change | 1,402,828 | 91.3 |
| | Aridity index change | 612,307 | 39.8 |
| | Heavy precipitation days change | 644,890 | 41.9 |
| | Drought risk change | 618,271 | 40.2 |
| Water | Nitrogen surplus | 577,370 | 37.6 |
| | Area equipped for irrigation | 138,614 | 9.0 |
| Biodiversity | Potential threats to soil fauna | 600,861 | 39.1 |
| | Potential threats to soil microorganisms | 598,645 | 38.9 |
| | Potential threats to soil biological functions | 603,046 | 39.2 |
| | Pollinator potential | 611,496 | 39.8 |
| | Pest control index | 766,852 | 49.9 |
| Soil | Soil organic carbon stocks | 736,128 | 47.9 |
| | Water erosion | 497,642 | 32.4 |
| | Wind erosion | 58,709 | 3.8 |

In general, the potential area affected by climate change (annual mean temperature change, heavy precipitation days, drought frequency change and aridity index change) and by the biodiversity-related pressures (pest control index, pollinator potential and potential threats to soil biodiversity) was greater than the potential area affected by water or soil-related variables. As commented, annual mean temperature change affected 91.3% of the total potential areas (Figure 7), being the variable that most affected the study area. In 19 out of 29 countries considered, more than 90% of the total potential was endangered by an annual mean temperature increase above 2°C.

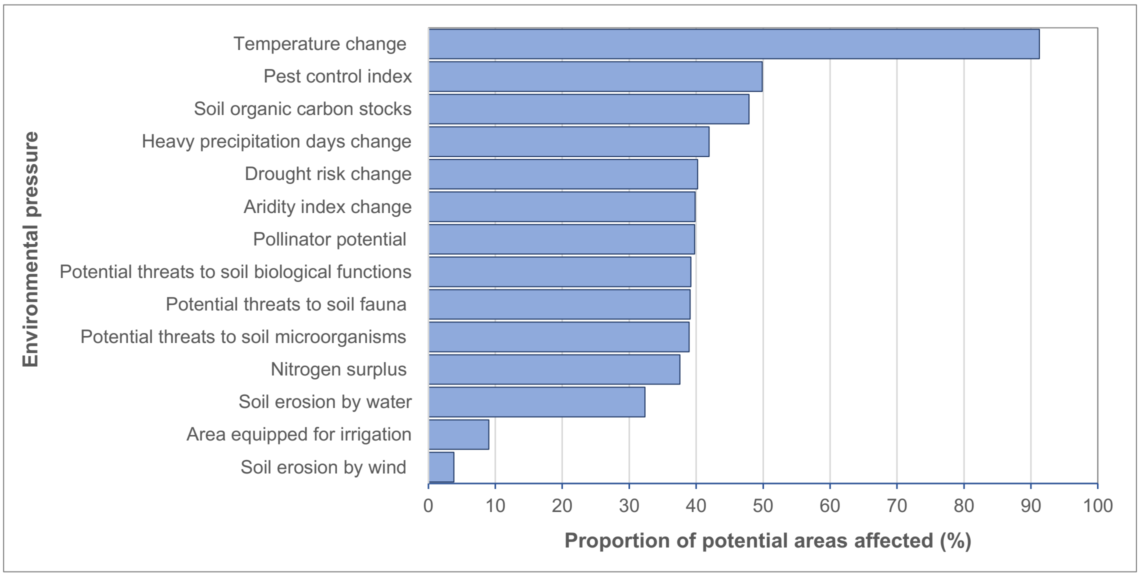


*Figure 7. Proportion of the potential areas affected by environmental pressures in the EU, CH and UK.*

Additional tables are presented in the Annex chapter showing the percentage of area affected by each indicator in each country in the study area (Annex 2. Percentage of the area affected by annual mean

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temperature increase, drought frequency, aridity, and irrigation in proportion to the total potential area by country., Annex 3. Percentage of the area affected by nitrogen surplus, potential threats to soil biological functions, potential threats to soil fauna, and potential threats to soil microorganisms, in proportion to the total potential area by country. and Annex 4. Percentage of the area affected by pollinator potential, water erosion, and wind erosion, in proportion to the total potential area by country.), as well as additional maps showing the spatial distribution over the potential areas of different types of pressures, grouped according to the nature of the different variables, i.e. biodiversity (Annex 5. Map of accumulated biodiversity-related pressures (0-5 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: pest control index, pollinator potential, potential threats to soil biological functions, potential threats to soil fauna and potential threats to soil microorganisms.), climate change (Annex 6. Map of accumulated climate change pressures (0-4 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: annual mean temperature change, aridity index, drought frequency and heavy precipitation days.), soil (Annex 7. Map of accumulated soil pressures (0-3 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: water erosion, wind erosion, and soil organic carbon (SOC) saturation capacity.) and water-related (

Annex 8. Map of accumulated water pressures (0-2 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: nitrogen surplus and percentage of irrigated areas.). Another map was generated that shows only the potential areas affected by the biodiversity, climate soil, and water-related pressures, once the set of climate change pressures were excluded (

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Annex 9. Map of accumulated biodiversity, soil and water-related pressures (0-10 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming. Soils: water erosion, wind erosion, and soil organic carbon (SOC) saturation capacity. Biodiversity: pest control index, pollinator potential, potential threats to soil biological functions, potential threats to soil fauna and potential threats to soil microorganisms. Water: nitrogen surplus and percentage of irrigated areas.).

**Extent of the potential area affected by country**

Figure 8 presents the number of environmental risk indicators that simultaneously affected more than 75% of the potential area of each country. In the case of Spain, a set of 9 environmental risk indicators each affected more than 75% of the potential area in the country. Bulgaria, Germany, France, Ireland, Italy and the Netherlands followed Spain as the countries showing more environmental pressures affecting more than 75% of the potential areas. Low numbers of environmental pressure types that exceeded two thirds of the potential area were Lithuania, where none of the pressure indicators exceeded this threshold, and Croatia, Finland, and Estonia with only one pressure indicators exceeding this value.

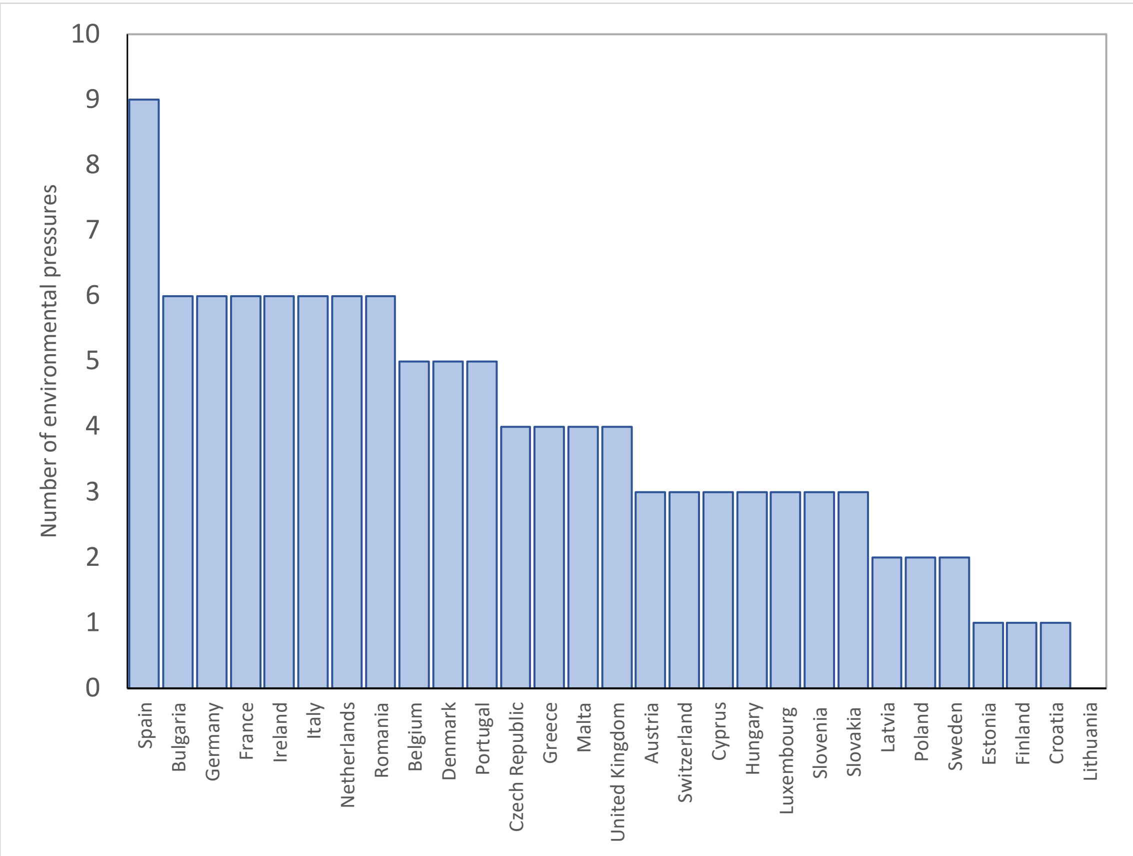


*Figure 8. Number of risk indicators that affected more than 75% of the potential area of each country.*

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**Extent of the potential area affected by land use/cover type**

Potential agricultural area to introduce MF/AF included different classes of temporary crops (non-irrigated arable land, permanently irrigated arable land and rice fields), permanent crops (vineyards, olive groves, fruit trees and berry plantations) and grasslands (pastures and natural grasslands). The mean environmental pressures for the selected land cover classes, together with the percentage of tree cover density, are presented in Figure 9.

The highest mean pressure values correspond to rice fields (8.5) followed by permanently irrigated arable land (8.0). However, it should be noted that these two classes only represented 0.3% and 2.4% of the total potential area, respectively. Fairly high values also correspond to permanent crops, which accounted for 6.3% of the total potential area. Non irrigated arable land, which constitutes the majority of the potential area (61.3%), showed a mean value of 5.8. Conversely, grasslands exhibited a relatively low mean of environmental pressures, despite covering a significant portion (29.8%) of the potential area.

Regarding tree cover density, potential agricultural areas with higher tree cover densities presented lower mean values of accumulated environmental pressures compared to those areas with lower tree densities. The highest values were reported in some permanent crops, such as olive groves and fruit trees and berry plantations, while the lowest values were reported in temporary crops, like permanently irrigated arable land and rice fields.

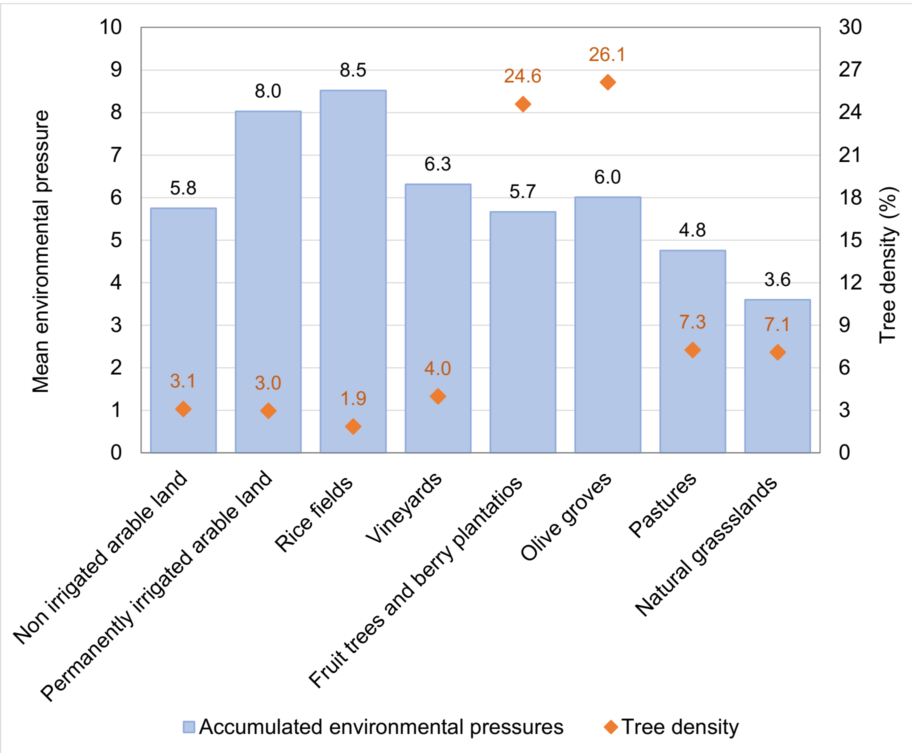


*Figure 9. Mean values of environmental pressures for different land uses in the EU, UK and CH. Also included are the mean tree cover densities (Source: European Environment Agency, 2020).*

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### Definition of target areas to introduce MF/AF

Potential areas reporting between 7 and 14 accumulated environmental pressures were selected as target areas to introduce MF/AF (Figure 10). The rationale for the selection of these areas was based on the values of the frequency distribution, only choosing those areas that were identified in the upper two quintiles, as the most affected land. Target areas amounted to a total of 506,249 km$^2$, representing 32.9% of the total potential area.

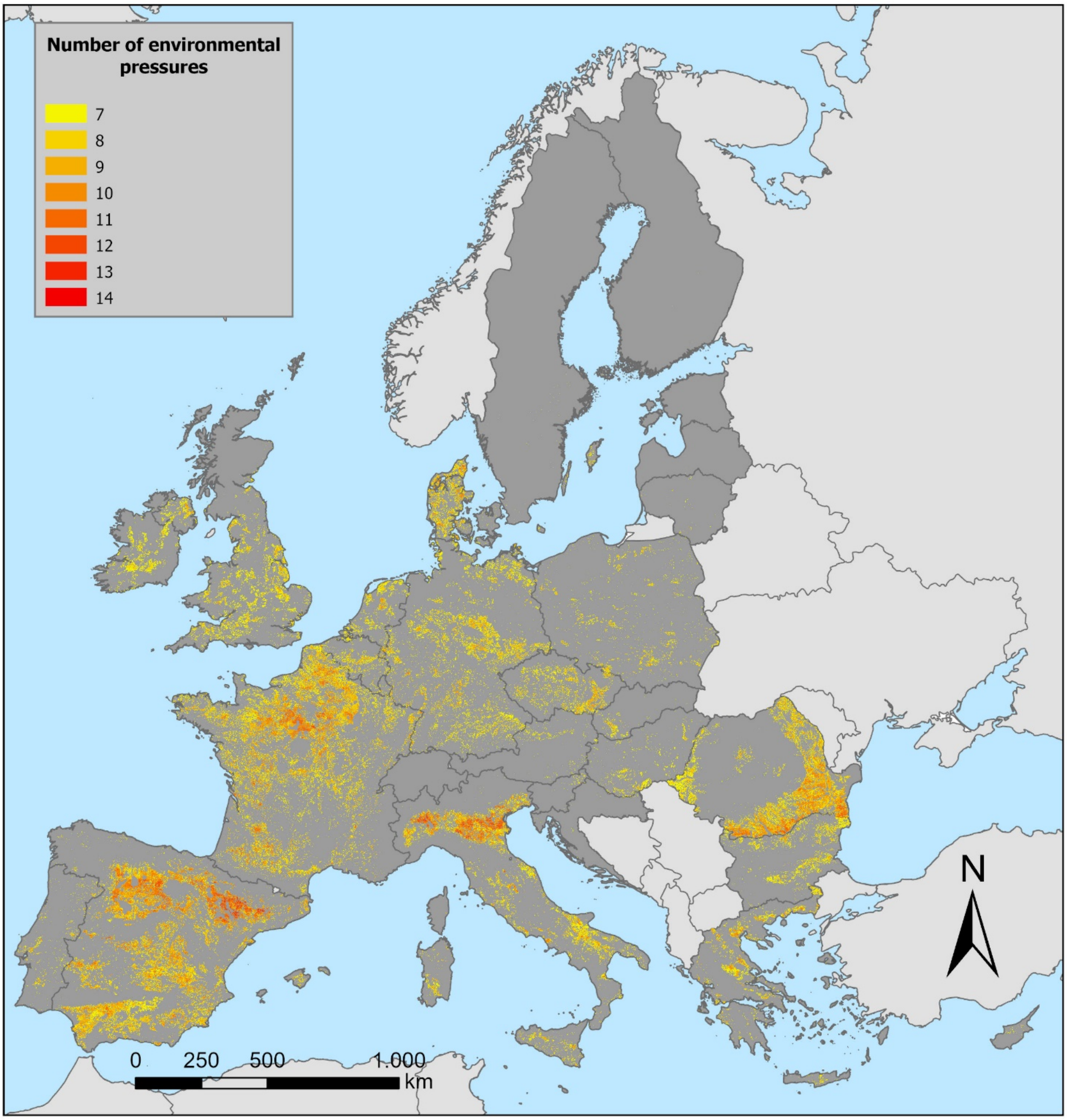


*Figure 10. Target areas to introduce MF/AF. Only areas showing between 7 and 14 accumulated environmental pressures were selected.*

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Regarding the spatial distribution of target areas by country, France (123,924 km$^2$), Spain (118,030 km$^2$), Romania (57,047 km$^2$), Germany (47,441 km$^2$), Italy (45,132 km$^2$) and United Kingdom (26,060 km$^2$) showed the highest values. In contrast, Latvia (14 km$^2$), Finland (10 km$^2$), Switzerland (2 km$^2$), Malta (1 km$^2$) and Estonia (0 km$^2$) reported very few or no areas with 7 or more cumulative pressures (Table 10).

*Table 10. Total agricultural land, potential area, target area and potential area not considered target in km$^2$ in EU-27, UK and CH (=Total).*

| Country | Agricultural land (km$^2$) | Potential area (km$^2$) | Target area (km$^2$) | Potential area not considered target area (km$^2$) |
|---|---|---|---|---|
| France | 309,202 | 240,005 | 123,924 | 116,081 |
| Spain | 267,190 | 185,759 | 118,030 | 67,729 |
| Romania | 135,607 | 106,110 | 57,047 | 49,063 |
| Germany | 189,741 | 168,304 | 47,441 | 120,863 |
| Italy | 143,525 | 104,769 | 45,132 | 59,637 |
| United Kingdom | 141,392 | 136,434 | 26,060 | 110,375 |
| Bulgaria | 58,276 | 40,062 | 12,399 | 27,663 |
| Greece | 56,371 | 33,393 | 12,161 | 21,232 |
| Czechia | 42,283 | 35,817 | 12,091 | 23,726 |
| Denmark | 30,014 | 26,700 | 11,289 | 15,411 |
| Poland | 175,492 | 146,907 | 10,559 | 136,348 |
| Ireland | 44,962 | 39,448 | 7,313 | 32,135 |
| Netherlands | 21,546 | 18,335 | 6,150 | 12,185 |
| Belgium | 15,876 | 11,103 | 4,344 | 6,759 |
| Hungary | 60,156 | 49,696 | 4,217 | 45,479 |
| Portugal | 39,517 | 16,195 | 3,364 | 12,831 |
| Austria | 30,705 | 24,138 | 1,609 | 22,529 |
| Slovakia | 21,712 | 15,981 | 1,596 | 14,385 |
| Sweden | 38,028 | 32,053 | 595 | 31,458 |
| Slovenia | 5,638 | 2,511 | 288 | 2,223 |
| Luxembourg | 1,271 | 995 | 186 | 809 |
| Lithuania | 37,027 | 27,731 | 186 | 27,545 |
| Cyprus | 4,206 | 3,301 | 171 | 3,130 |
| Croatia | 22,331 | 10,612 | 71 | 10,541 |
| Latvia | 24,394 | 18,561 | 14 | 18,547 |
| Finland | 26,412 | 19,195 | 10 | 19,185 |
| Switzerland | 14,310 | 12,849 | 2 | 12,847 |
| Malta | 141 | 96 | 1 | 95 |
| Estonia | 13,579 | 10,266 | 0 | 10,266 |
| **Total EU 27, UK, CH** | **1,970,903** | **1,537,326** | **506,249** | **1,031,077** |

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Although for some countries the potential area was larger, the corresponding target area was relatively low. This was the case of Poland, a country that reported a total potential area of 146,907 km$^2$, but the target area amounted to only 10,559 km$^2$, which represented 7.2% of the potential area of the country (Figure 11). This has to do with the mean of environmental pressures observed in each of the countries, being the countries with relatively low mean environmental pressures those that also reported fewer target areas. In Poland the mean of environmental pressures was 4.28, while in United Kingdom, a country with a similar potential area (136,434 km$^2$), the mean of environmental pressures was 4.67 and the target area of this country amounted to 26,060 km$^2$.

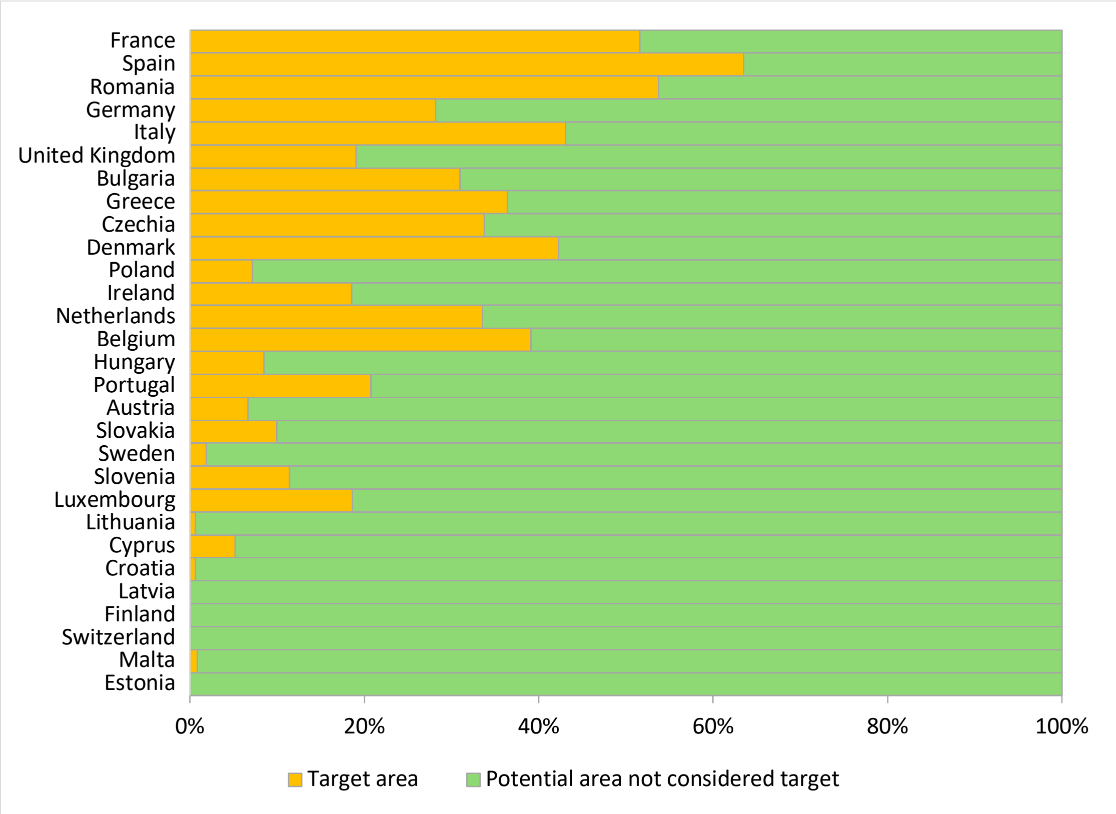


*Figure 11. Target areas and potential areas not considered target in %.*

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### 3.3.3 Characterisation of the socio-economic context

Different variables related to economy, demography and willingness of farmers to change were considered for the analysis of the socio-economic context of the 282 NUTS 2 regions in the EU-27, United Kingdom, and Switzerland. These variables were selected as describing the socio-economic factors in what regards to employment, economic size of farms, renewal of farm managers, distribution of the population in the rural-urban continuum, training of farm managers, organic farming. As a set, those variables could describe as depicting high, intermediate, or low profiles in terms of characterising contrasting socio-economic contexts.

The set of above-mentioned variables were classified into six classes, according to the distribution of values, from the lowest to the highest, except for the degree of urbanisation, that was classified into three classes: predominantly rural, intermediate, and predominantly urban regions. The variables were spatially combined to characterise the socio-economic contexts that were more or less favourable in terms of the socio-economic conditions. Different maps are presented in this chapter, showing the spatial distribution of the individual variables, different sets of variables and the whole socioeconomic contexts, herein described as high, intermediate, or low profiles.

**Set of economic variables**

**The mean economic size of farms (Standard output in Euro)** was calculated to describe the agricultural economic output or turnover per farm in the NUTS 2 regions. Values ranged from very small (3,118-22,783 Euro per farm) to very large (214,602-859,896 Euro) economic size of farms (Table 11). The size of farms varied across the European regions. In countries like Romania and Poland, there is a relatively high concentration of farms with very low and low economic size. Many of these farms function as semi-subsistence farms. Conversely, regions reporting large and very large economic size are concentrated in France, Belgium, Netherlands, United Kingdom, and Germany (Figure 12).

*Table 11. Mean economic size of farms (Standard output in Euro) at NUTS 2 level for the years 2020 (EU27, CH) and 2016 (UK only). Values were subdivided into six classes (Source:* Eurostat, 2023b).

| Classes | (Standard Output in Euro) | NUTS 2 | NUTS 2 (%) |
|---|---|---|---|
| **Very small** | 3,118 - 22,783 | 45 | 16.0 |
| **Small** | 22,898 - 43,571 | 46 | 16.3 |
| **Medium to small** | 46,390 - 90,038 | 45 | 16.0 |
| **Medium to large** | 90,046 - 149,386 | 45 | 16.0 |
| **Large** | 151,630 - 213,856 | 46 | 16.3 |
| **Very large** | 214,602 - 859,896 | 45 | 16.0 |
| **No data** | - | 10 | 3.5 |
| **Total** | | 282 | 100.0 |

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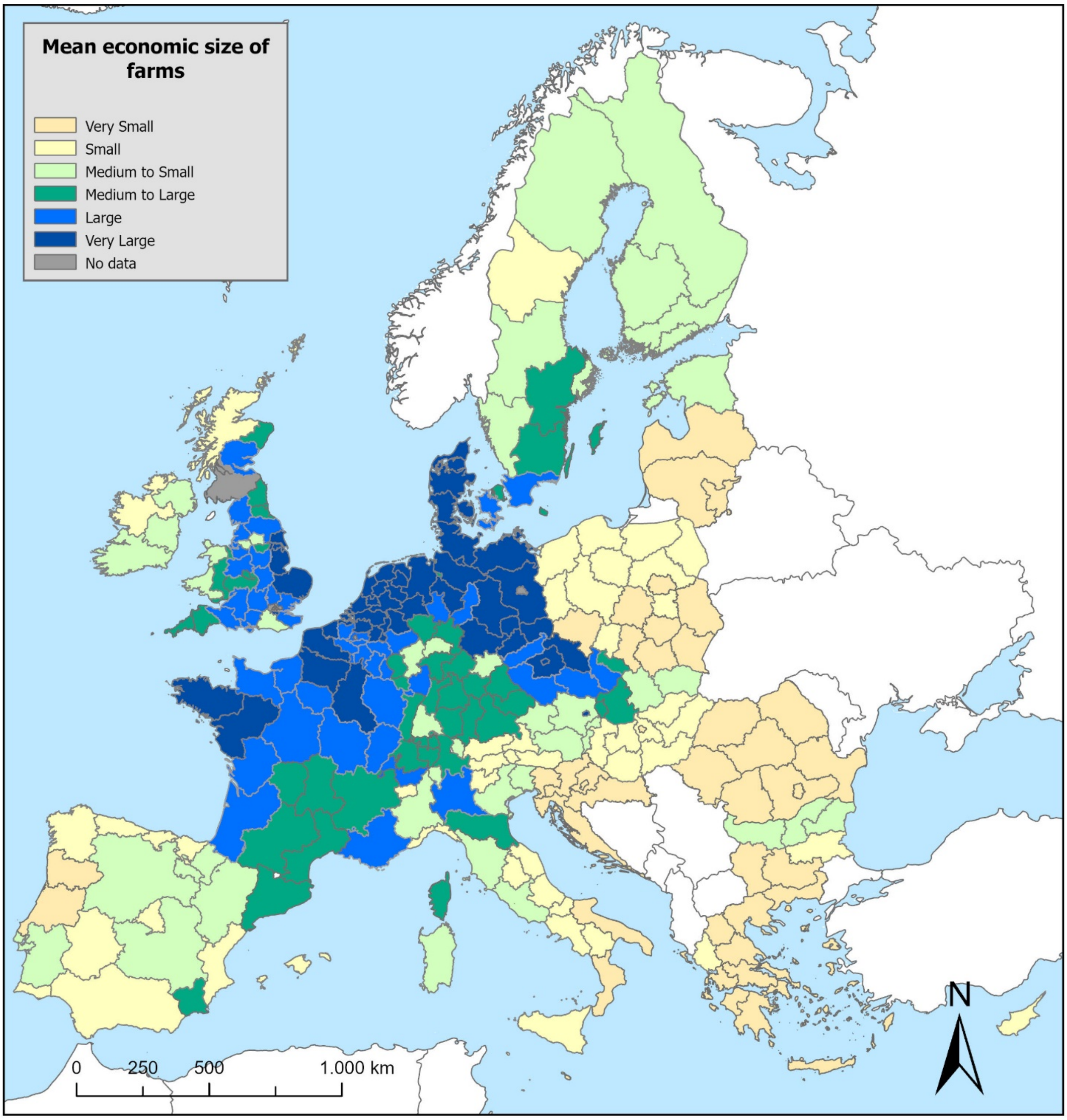


*Figure 12. Mean economic size of farms of the NUTS 2 regions for the years 2020 (EU27, CH) and 2016 (UK only) (Source:* Eurostat, 2023b)

**Unemployment rates (%)** varied between 1.2 to 28.4 % in the NUTS 2 regions (Table 12), with Spain and Greece showing the highest unemployment rates. Southern and Northern Europe countries reported more unemployment than those of Central Europe and the UK (Figure 13). This highlights a north-south division in unemployment rates across Europe. Regions in Southern Europe, which are often characterised by a larger agricultural sector and reliance on tourism, tend to have higher unemployment compared to more industrialized regions in Central Europe and the UK.

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*Table 12. Unemployment rate (%) at NUTS 2 level for the years 2021 (EU27, CH) and 2016 (UK only). Values were subdivided in six classes from very low to very high (Source:* Eurostat, 2024).

| Classes | (%) | NUTS 2 | NUTS 2 (%) |
|---|---|---|---|
| **Very low** | 1.2 - 2.7 | 47 | 16.7 |
| **Low** | 2.7 - 3.5 | 47 | 16.7 |
| **Medium to low** | 3.6 - 4.3 | 46 | 16.3 |
| **Medium to high** | 4.3 - 6.1 | 47 | 16.7 |
| **High** | 6.2 - 8.7 | 47 | 16.7 |
| **Very high** | 8.8 - 28.4 | 47 | 16.7 |
| **No data** | | 1 | 0.4 |
| **Total** | | 282 | 100.0 |

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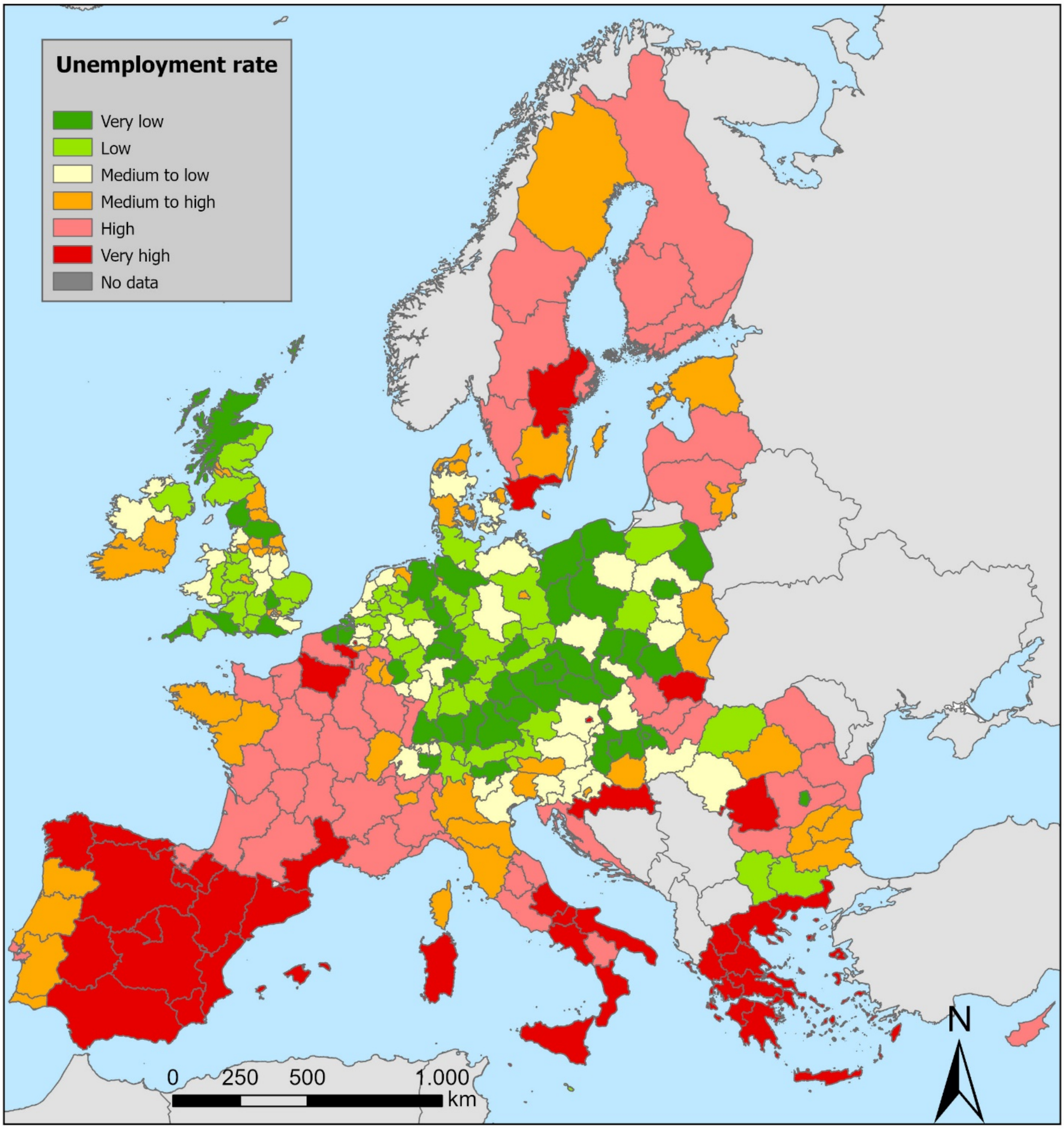


*Figure 13. Unemployment rates of the NUTS 2 regions for the years 2021 (EU27, CH) and 2016 (UK only) (Source: Eurostat, 2024).*

At a later stage, the economic size of farms and unemployment rates were combined to identify regions with similar characteristics (Figure 14). The approach for combining the variables and classifying the regions according to their economic character was based on grouping regions that reported higher economic income and that, at the same time, were characterized by low unemployment rates. In contrast, regions with low economic output and high unemployment rates were grouped together. Intermediate regions were also characterized, where unemployment rates were not so high and the agricultural output of farms was of medium size, including other regions with high unemployment rates and high economic size, or low unemployment rates and low economic size.

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Initially, the variables were classified into six categories to distinguish the different levels of economic performance. However, for analysis purposes these classes were combined into three (high, medium, and low), as shown in Table 13. Then, a numeric value was assigned (between 1 and 3) to each class, giving higher values to those classes that corresponded to a better economic performance, i.e., low unemployment rates = 3, high economic output = 3; and conversely, low values were assigned to classes corresponding to a less favourable economic performance, i.e., high unemployment = 1 and low economic output = 1. When combined, these classes were added to obtain a final classification of the regions according to their economic performance.

*Table 13. Classification of the economic variables (economic size of farms) according to the distribution of values*

| Variable | Classes | Final class | Value |
|---|---|---|---|
| Economic size of farms | Very large and large | High | 3 |
| | Medium to large and medium to small | Medium | 2 |
| | Very small and small | Low | 1 |
| Unemployment rate | Very high and high | High | 1 |
| | Medium to high and medium to low | Medium | 2 |
| | Very low and low | Low | 3 |

The sum of the values corresponding to each of the classes resulted in final values that ranged between 6 and 2, meaning that regions with higher values presented a good economic context, while regions with lower values presented a less favourable economic context. Hereafter, the regions that reported values between 5 and 6 were classified as "high profile" in reference to their economic characteristics, those showing values of 4 were characterized as "medium profile" and, finally, the regions showing values between 3 and 2 were classified as "low profile", since those areas presented the less favourable economic context (Table 14).

*Table 14. Classification of NUTS 2 regions according to their economic context.*

| Final class in map | Description | Value |
|---|---|---|
| **High profile** | Regions with a good economic context, characterized by lower unemployment rates and larger economic size of farms. | 6 |
| | | 5 |
| **Medium profile** | Intermediate regions are characterized by a combination of factors where unemployment rates can be higher but still have a good economic output, or vice versa. | 4 |
| **Low profile** | Regions with a less favourable economic context that reported higher unemployment rates and smaller economic size of farms. | 3 |
| | | 2 |

Figure 14 presents the results of the spatial analysis. However, data limitations in some regions prevented classification using both variables. In these cases, the available data, for any of the two variables, was used to assign the class and characterize those regions. Those regions are described in Figure 14 as those considering one variable.

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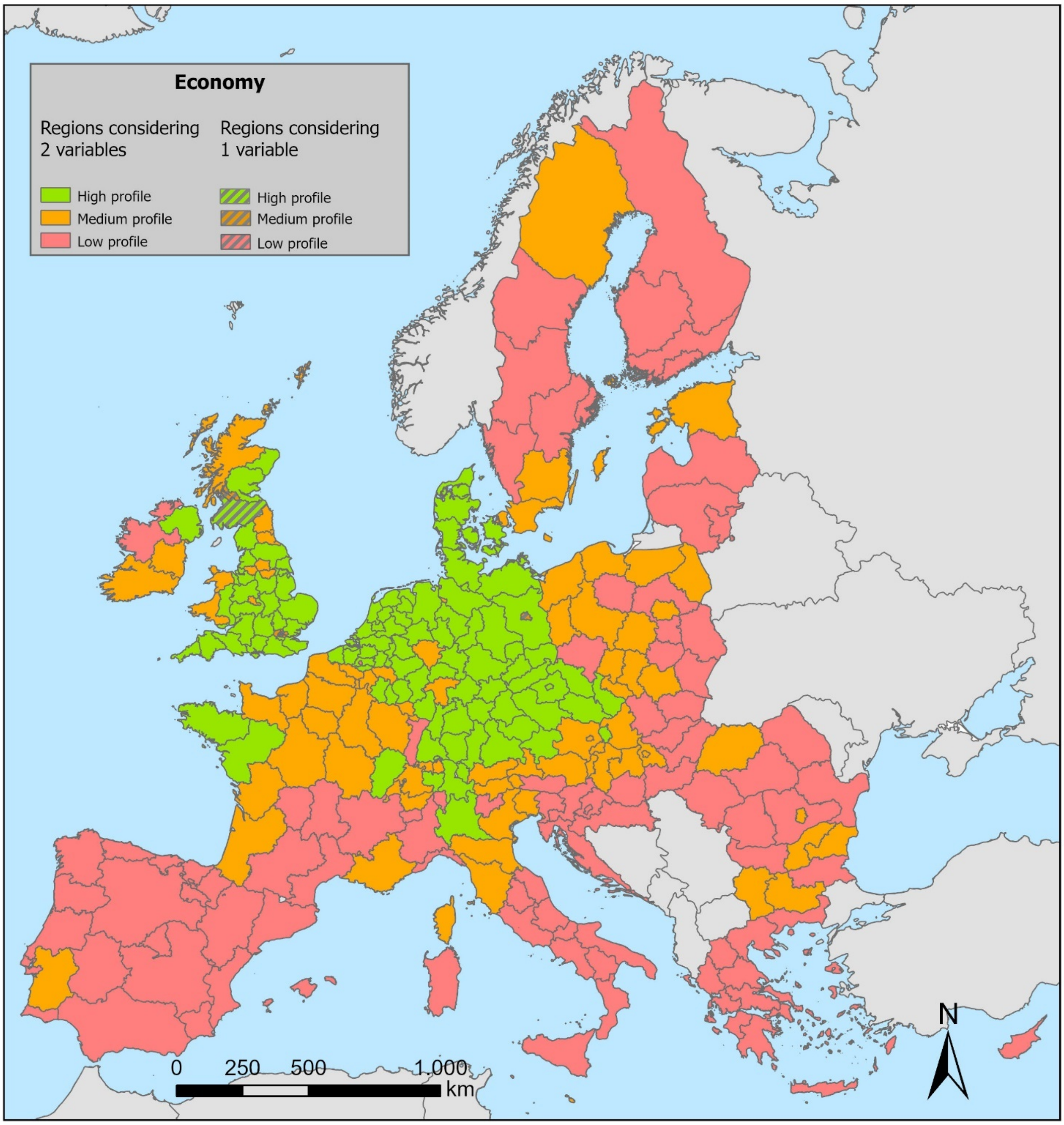


*Figure 14. Combination of the economic variables (unemployment rate and mean economic size of farms) to characterise NUTS 2 regions in different profiles. Data limitations in some regions prevented classification using both variables. In these cases, the available data, for any of the two variables, was used to assign the class and characterise those regions.*

**Set of variables related to farmers' willingness to change**

**The ratio of farm managers with full agricultural training to those with only basic knowledge and practical experience** varied greatly across Europe (Table 15). This ratio ranged from a very low 0.003-0.0046 (meaning for every 10,000 farm managers with basic experience, there were only 3-4.6 with full training) to a very high 0.510-8.167 (indicating 510-816.7 fully trained managers per 10,000 with basic experience). Countries in Southern and Eastern Europe, such as Spain, Greece, Italy, Cyprus and Bulgaria, generally showed the lowest

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ratios, suggesting a lower prevalence of formal agricultural training among farm managers. In contrast, North-western and Central European countries, including France, Germany, Poland, and the Netherlands, exhibited the highest ratios, highlighting a stronger training background for farm management (Figure 15).

*Table 15. Ratio of farm managers with full training to farm managers with basic knowledge and practical experience only at NUTS 2 level for the years 2020 (EU27, CH) and 2016 (UK only). Values were subdivided in six classes (Source:* Eurostat, 2023b*).*

| Classes | | NUTS 2 | NUTS 2 (%) |
|---|---|---|---|
| **Very low** | 0.003 - 0.046 | 46 | 16.3 |
| **Low** | 0.047 - 0.102 | 46 | 16.3 |
| **Medium to low** | 0.103 - 0.190 | 46 | 16.3 |
| **Medium to high** | 0.194 - 0.317 | 46 | 16.3 |
| **High** | 0.318 - 0.502 | 46 | 16.3 |
| **Very high** | 0.510 - 8.167 | 46 | 16.3 |
| **No data** | | 6 | 2.1 |
| **Total** | | 282 | 100.0 |

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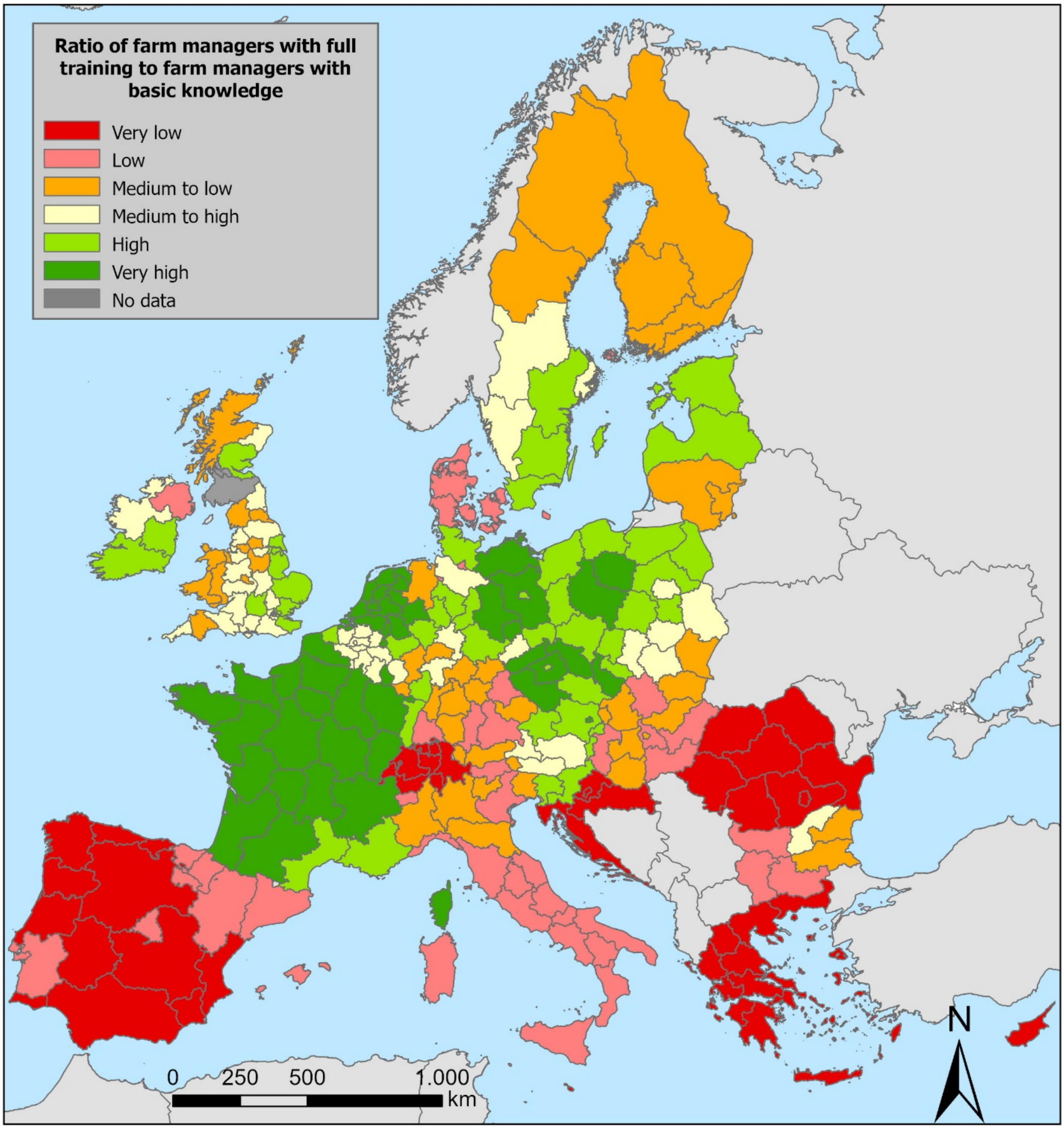


*Figure 15. Ratio of farm managers with full training to farm managers with basic knowledge and practical experience only in the NUTS 2 regions for the years 2020 (EU27, CH) and 2016 (UK only) (Source:* Eurostat, 2023b*).*

**Share of organic farming holdings (%)** as a proportion of the total farms was also considered in the group of variables related to farmers' willingness to change (Table 16). Organic farming in Europe has experienced significant growth in recent years, driven by increasing consumer demand for sustainable and environmentally friendly agricultural practices. However, regional disparities were identified, as organic farming was notably less prevalent in Southern and Eastern European regions, including Greece, Spain, Bulgaria, and Romania. Conversely, Northern, Central, and North-western Europe exhibited a greater prevalence of organic farming, showcasing higher proportions in these areas (Figure 16).

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*Table 16. Share of organic farming holdings (%) at NUTS 2 level for the years 2020 (EU27, CH) and 2016 (UK only). Values were subdivided in six classes (Source:* Eurostat, 2024a).

| Classes | (%) | NUTS 2 | NUTS 2 (%) |
|---|---|---|---|
| **Very low** | 0.00 - 1.09 | 46 | 16.3 |
| **Low** | 1.09 - 2.38 | 45 | 16.0 |
| **Medium to low** | 2.41 - 4.78 | 45 | 16.0 |
| **Medium to high** | 4.84 - 8.74 | 46 | 16.3 |
| **High** | 8.77 - 12.30 | 46 | 16.3 |
| **Very high** | 12.33 - 51.86 | 45 | 16.0 |
| **No data** | - | 9 | 3.2 |
| **Total** | | 282 | 100.0 |

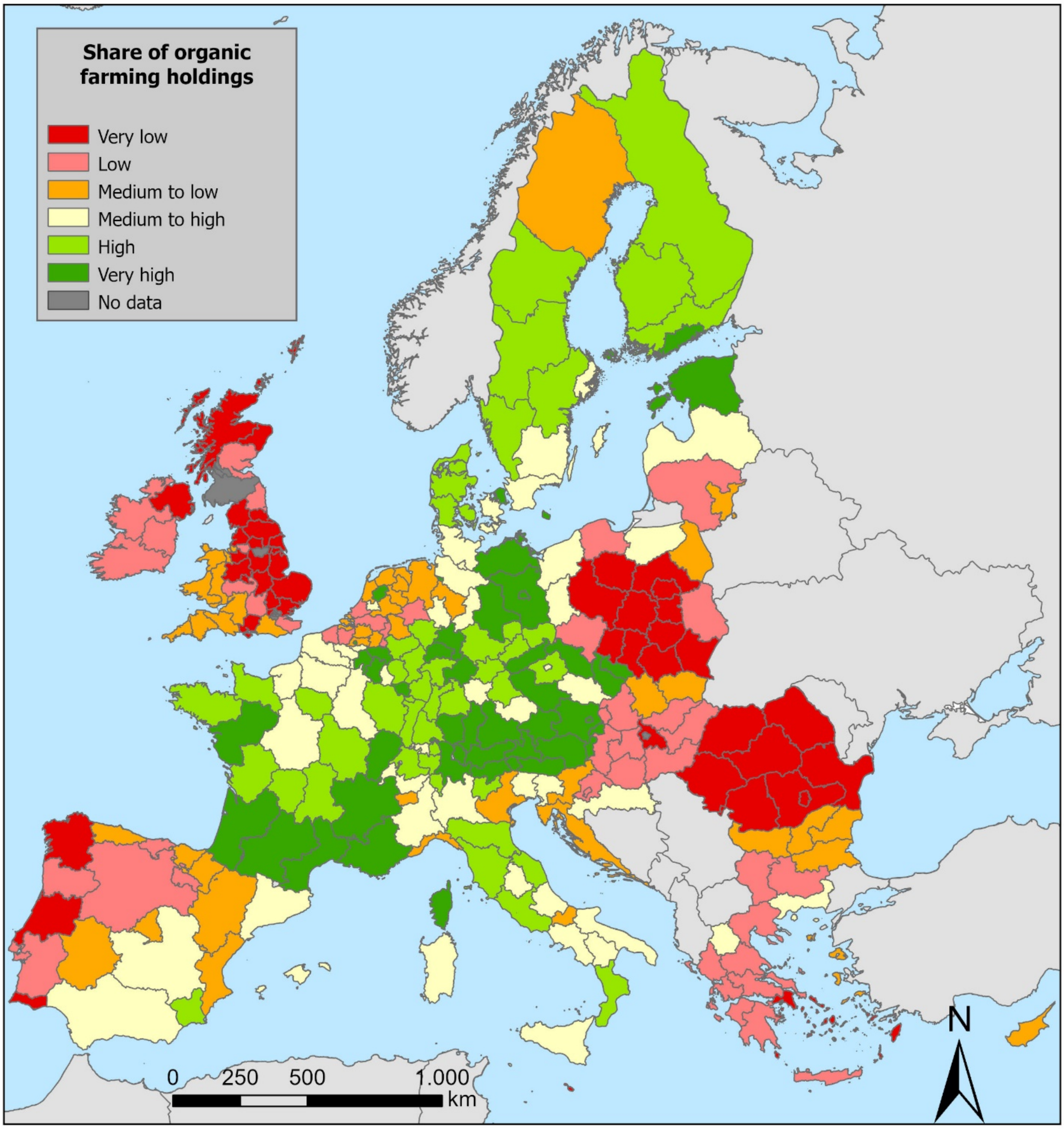


*Figure 16. Share of organic farming holdings (%) in the NUTS 2 regions for the years 2020 (EU27, CH) and 2016 (UK only) (Source:* (Eurostat, 2024a)*.*

To capture both, training and organic farming, a later combination of the two variables, i.e., the share of organic farming holdings with the ratio of farm managers with full training to those with basic knowledge, was made as expressed in Table 17. These combined values of were then reclassified into three categories (high = 3, medium = 2, low = 1). The high score indicates regions with a higher proportion of organic farms and a larger share of farm managers with formal agricultural training, suggesting a potentially more modern and trained agricultural sector.

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*Table 17. Classification of the variables related to farmers' willingness to change according to the distribution of values.*

| Variable | Classes | Final class | Value |
|---|---|---|---|
| Share of organic farming holdings | Very high and high | High | 3 |
| | Medium to high and medium to low | Medium | 2 |
| | Very low and low | Low | 1 |
| Ratio of farm managers with full training to farm managers with basic knowledge and practical experience only | Very high and high | High | 3 |
| | Medium to high and medium to low | Medium | 2 |
| | Very low and low | Low | 1 |

The classes resulting as described (Table 17) were combined, and the values aggregated to obtain a final classification (Table 18). Values ranged between 6 and 2. Regions reporting values of 6 and 5 were classified as high profile, meaning that in those regions there are more trained farmers and higher proportions of organic farming area. Regions with a value of 4 were classified as "medium profile", as those are intermediate regions that are characterised by a combination of factors where training background can be higher but still have low organic farming ratios, or vice versa. Finally, regions with values of 3 and 2 were characterised as "low profile" regions, conformed by a less proportion of farmers with full training and less organic farming holdings.

*Table 18. Classification of NUTS 2 regions according to the context of variables related to training of farm managers and organic farming holdings.*

| Final class in map | Description | Value |
|---|---|---|
| **High profile** | Regions with more trained farmers and higher proportions of organic farming area. | 6 |
| | | 5 |
| **Medium profile** | Intermediate regions are characterised by a combination of factors where training ratios can be higher but still have low organic farming, or vice versa. | 4 |
| **Low profile** | Regions with a less trained farmers and less organic farming holdings. | 3 |
| | | 2 |

In Figure 17 the combination of variables related to farmers' willingness to change is presented. Regions with a low profile are concentrated in Southern and Eastern Europe, while regions in North, Central and North-western Europe showed a higher educational profile. In the same way as in the case of the map characterising the economic context (Figure 14), some of the NUTS 2 regions had to be classified according to values of just one of the two variables.

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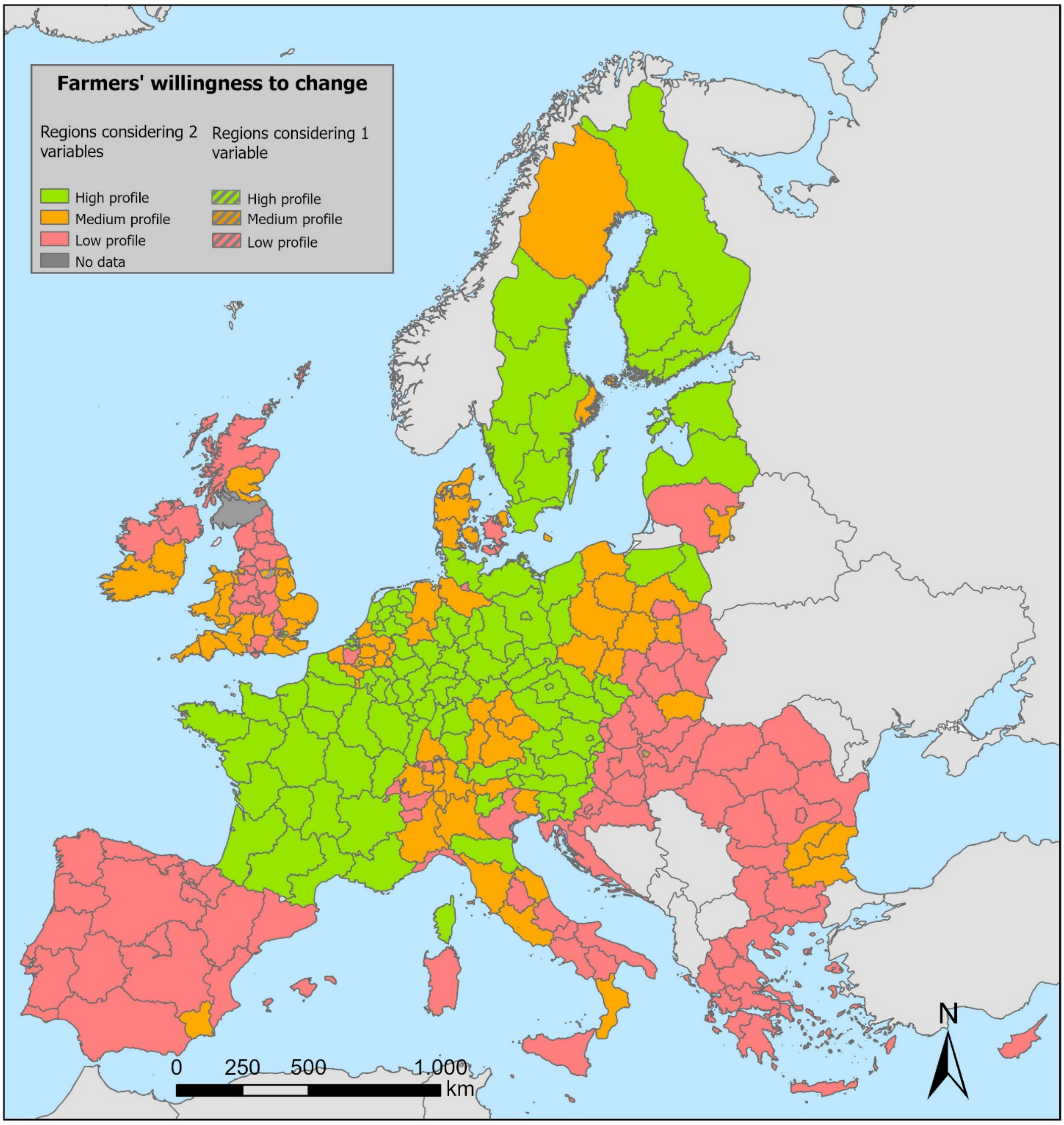


*Figure 17. Combination of variables related to farmers' willingness to change (share of organic farming holdings and ratio of farm managers with full training to farm managers with basic knowledge and practical experience only) to characterise NUTS 2 regions in different profiles.*

**Set of demographic variables**

The **degree of urbanisation** classified the territory into three categories along the urban-rural continuum (Table 19). Nearly a third (34.8%) of the NUTS 2 regions, or 98 regions, were classified as predominantly urban. A similar proportion (34.0%, or 96 regions) fell into the predominantly rural category. The remaining regions (78, or 27.7%) were classified as intermediate. The analysis revealed a relatively balanced distribution

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between predominantly urban (34.8%) and predominantly rural (34.0%) regions across the study area (Figure 18).

*Table 19. Degree of urbanisation at NUTS 2 level for the year 2014. Values were subdivided into three classes. Source: de Beer et al. (2014)*

| Classes | | NUTS 2 | NUTS 2 (%) |
|---|---|---|---|
| **Predominantly rural** | 3 | 96 | 34.0 |
| **Intermediate** | 2 | 78 | 27.7 |
| **Predominantly urban** | 1 | 98 | 34.8 |
| **No data** | - | 10 | 3.5 |
| **Total** | | 282 | 100.0 |

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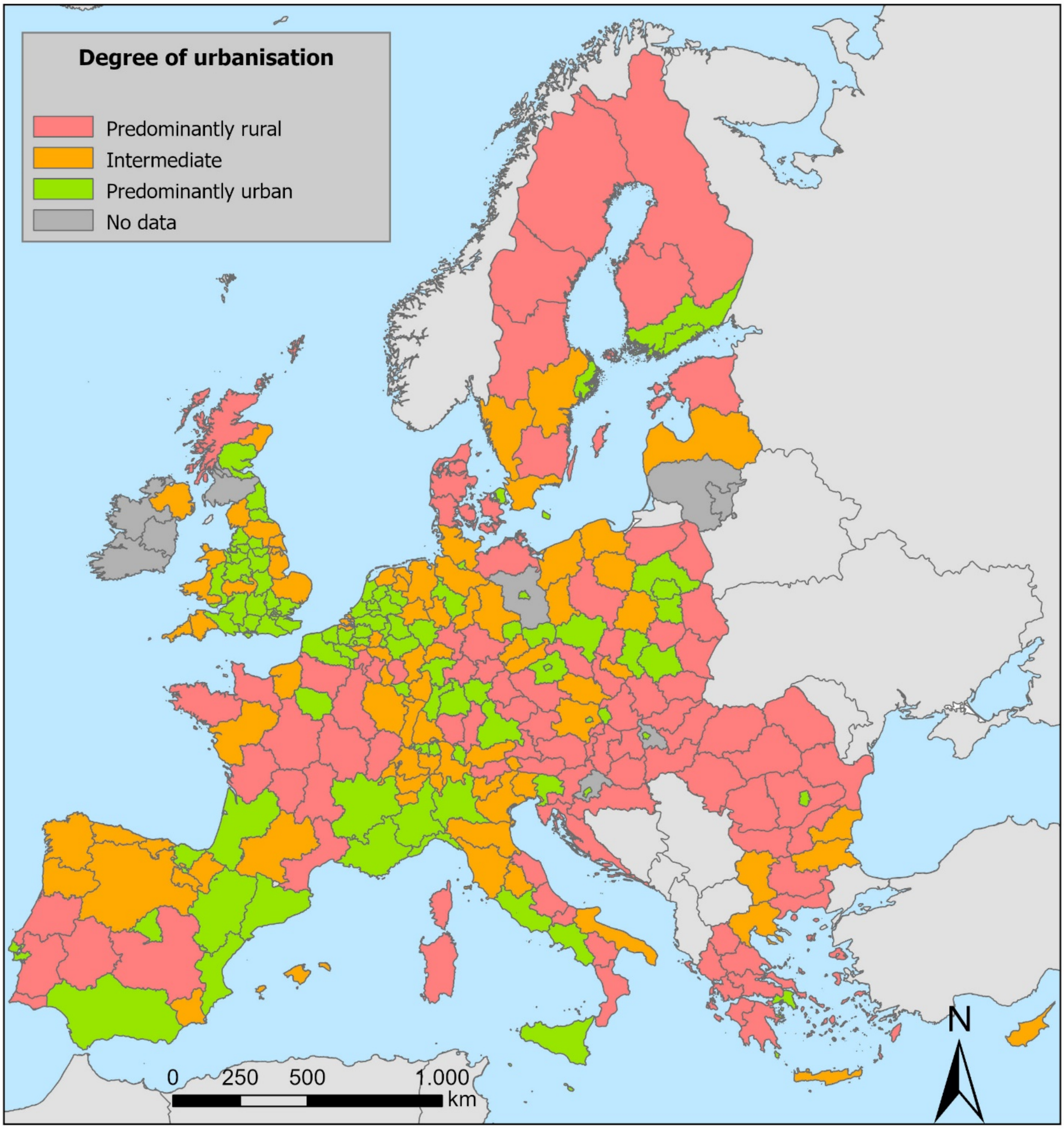


*Figure 18. Degree of urbanisation at NUTS 2 level for the year. Values were subdivided into three classes. Source: de Beer et al. (2014).*

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**Ratio of young to elderly farmers**

**The ratio of young farmers (under 40) to elderly farmers (over 65)** ranged from very low values from 0.061 and high values to 5.959 (Table 20). **Southern, Northern Europe, and the British Isles** face a challenge of **ageing farmers populations**, as evidenced by their low ratios. In contrast, **France and Central European countries** including Austria, Germany, Switzerland, Poland, and the Czech Republic boast a significantly higher proportion of young farm managers. This is reflected in Figure 19, which visually depicts these regional differences.

*Table 20. Ratio of young farm managers to elderly farm managers at NUTS 2 level for the years 2020 (EU27, CH) and 2016 (UK only). Values were subdivided in six classes (Source:* Eurostat, 2023b).

| Classes | | NUTS 2 | NUTS 2 (%) |
|---|---|---|---|
| **Very low** | 0.061 - 0.151 | 44 | 15.6 |
| **Low** | 0.154 - 0.274 | 43 | 15.2 |
| **Medium to low** | 0.274 - 0.431 | 44 | 15.6 |
| **Medium to high** | 0.442 - 0.947 | 44 | 15.6 |
| **High** | 0.957 - 1.385 | 43 | 15.2 |
| **Very high** | 1.426 - 5.959 | 44 | 15.6 |
| **No data** | - | 20 | 7.1 |
| **Total** | | 282 | 100.0 |

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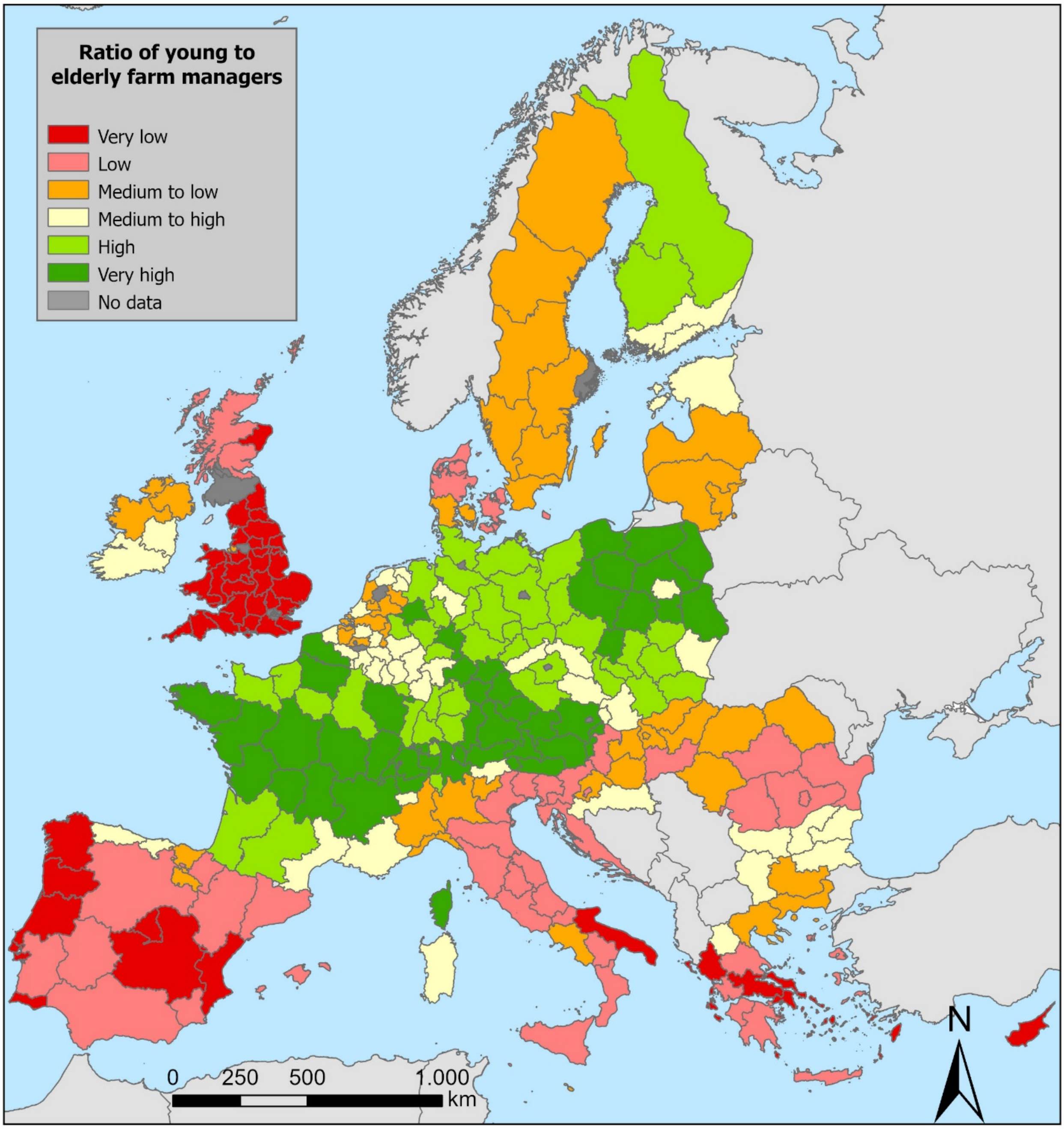


*Figure 19. Ratio of young farm managers to elderly farm managers in the NUTS 2 regions for the years 2020 (EU27, CH) and 2016 (UK only) (Source:* Eurostat, 2023a*).*

Demography-related variables were spatially combined into a single map, as shown in Figure 20. The degree of urbanisation was classified into 3 classes: predominantly urban as "high" and values of 3, intermediate regions as "medium" and values of 2, and predominantly rural regions as "low" and values of 1. Urban regions were scored higher than rural regions for analysis purposes. Regarding the ratio of young to elderly farmers, the initial six classes were simplified into 3 classes: high (3), medium (2) and low (1), as shown in Table 21.

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*Table 21. Classification of demography-related variables according to the distribution of values.*

| Variable | Classes | Final class | Value |
|---|---|---|---|
| **Degree of urbanisation** | Predominantly urban | High | 3 |
| | Intermediate | Medium | 2 |
| | Predominantly rural | Low | 1 |
| **Ratio of young to elderly farmers** | Very high and high | High | 3 |
| | Medium to high and medium to low | Medium | 2 |
| | Very low and low | Low | 1 |

In the final map (Figure 20), predominantly urban regions with younger farmers (values 6 and 5) were classified as "high profile" in the demographic context. A medium profile was defined was those regions reporting values of 4, characterised with medium ratios of young farmers to elderly farmers. Rural regions with lower proportion of farmers were defined as "low profile", as those regions exhibited values of 3 and 2 (Table 22).

*Table 22. Classification of NUTS 2 regions according to the context of demography-related variables.*

| Final class in map | Description | Value |
|---|---|---|
| **High profile** | Predominantly urban regions with younger farmers. | 6 |
| | | 5 |
| **Medium profile** | Intermediate regions are characterised by a medium ratio of young farmers to elderly farmers. | 4 |
| **Low profile** | Rural regions with lower proportions of young farmers. | 3 |
| | | 2 |

The results showed that the distribution the degree or urbanisation and the proportion of young farmers to elderly farmers had a similar distribution, since regions with ageing populations of farmers were mostly predominantly rural regions (Figure 20). Data not available in some regions prevented the classification using both variables. In these cases, any available data was used to assign a class and characterise those regions.

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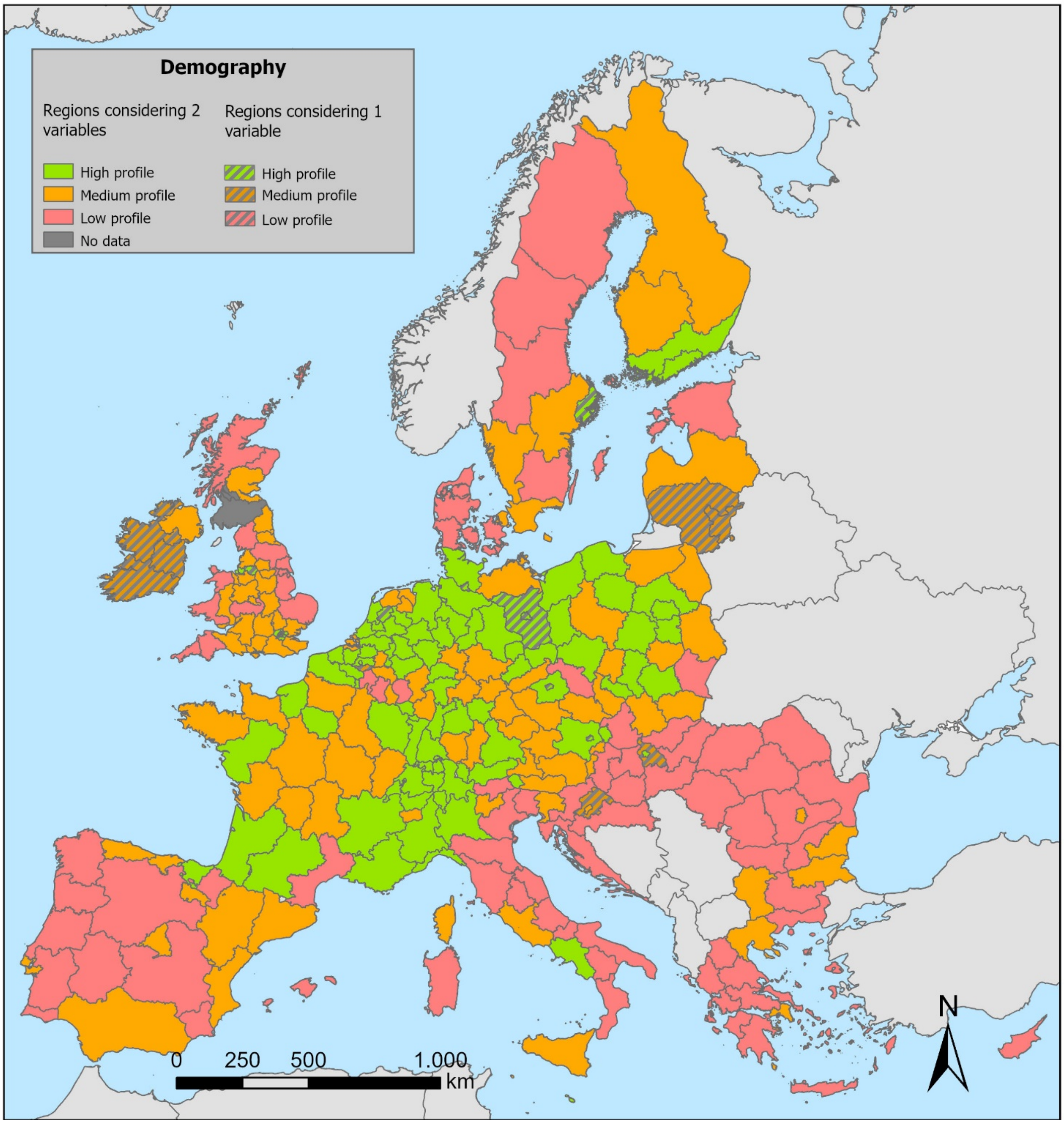


*Figure 20. Combination of demography-related variables (degree of urbanisation and ratio of young farm managers to elderly farm managers) to characterise NUTS 2 regions in different profiles.*

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**Analysis of the socioeconomic contexts**

The analysis of the socio-economic context aimed at the characterisation of the European regions. In that sense, different contexts were considered as a combination of the whole set of variables related to economy, farmers' willingness to change, and demography. Those variables have been described in previous paragraphs, and jointly regards the socioeconomic conditions or characteristics of the NUTS 2 regions across the European Union, Switzerland, and the United Kingdom. The rules for combining the variables that were used to conform the final three contexts (C1, C2 and C3) are listed in Table 23 and mapped in Figure 21, characterising those NUTS 2 presenting a high, low, or intermediate socio-economic profile.

Context number 1 captures regions with a confluence of positive characteristics, therefore, it was categorised as a "high profile" context. These regions are characterised by a higher prevalence of organic farming, a more trained and younger farm management population, larger farms in terms of economic size, lower unemployment rates, and a predominantly urban character. These combined factors suggest a strong economic base, a modern and potentially more productive agricultural sector, and a favourable demographic profile.

Context number 3 encompasses regions facing several challenges, so it was categorised as "low profile". These regions tend to have lower adoption of organic farming practices, a less proportion of farm managers who attained full agricultural training and likely older farmer population, smaller farms in terms of economic size, higher unemployment rates, and a predominantly rural character. This combination suggests a potentially weaker economic base, a less modern agricultural sector, and a demographic profile that might face challenges in attracting young talent.

Context 2 encompasses all regions not accounted for in contexts 1 and 3. While it serves as an intermediary between the two, it also encompasses unique combinations of attributes not present in either extreme. Notably, regions are classified into context 1 or 3 based on meeting a minimum of four (up to six) specified socioeconomic factors outlined in Table 23. Regions failing to meet this criterion for either context are categorised as context 2 regions.

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*Table 23. Description of the socio-economic contexts, including classes and profiles.*

| Context (C) | Sum of classes | Socio-economic factors | Profile |
|---|---|---|---|
| **C1** | **Very high** and **high** share/ratio: organic farming holdings **+** farmers with full training **+** young farmers **+**<br>**Very large** and **large** economic size **+**<br>**Very low** and **low** unemployment rates **+**<br>**Urban** | More organic farming,<br>More trained farmers,<br>Younger farmers,<br>Larger farms,<br>Lower unemployment rates,<br>Predominantly urban regions. | High profile |
| **C2** | Regions not included in C1 or C3. | This is an intermediate context. | Intermediate profile |
| **C3** | **Very low** and **low** share/ratio: organic farming holdings **+** farmers with full training **+** young farmers **+**<br>**Small** and **very small** size farms **+**<br>**Very high** and **high** unemployment rates **+**<br>**Rural** | Less organic farming,<br>Less trained farmers,<br>Older farmers,<br>Smaller farms,<br>Higher unemployment rates,<br>Predominantly rural regions. | Low profile |

Figure 21 presents the spatial distribution of the 282 NUTS 2 regions across the three identified socioeconomic contexts. Nearly a fifth (48) fall into the "high-profile" category (Context 1). The majority (181) belong to the "intermediate context" (Context 2). Finally, 53 regions exhibit the characteristics of the "low-profile" context (Context 3).

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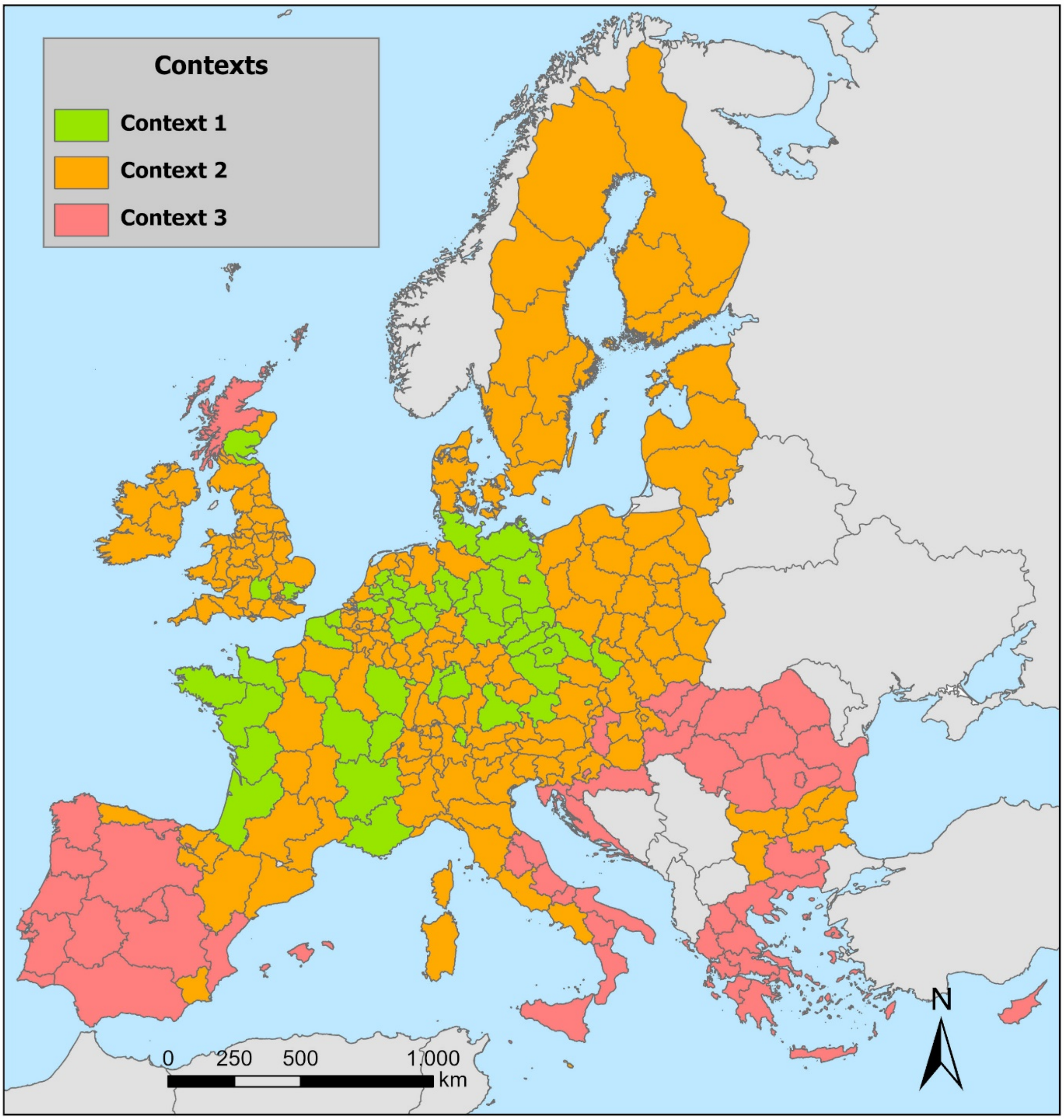


*Figure 21. Socio-economic contexts 1, 2 and 3 in the EU27, UK and CH.*

### 3.3.4 Target areas to introduce MF/AF in different socio-economic contexts

The analysis indicated that the socio-economic backgrounds differed across European regions, prompting their classification into three distinct contexts based on similar social and economic characteristics. Within each context, target areas to introduce MF/AF were identified. However, the different characteristics of each context would help define the type of support required to implement MF/AF.

If MF/AF is implemented in C1, it must be considered that these regions have a stronger economic base, a favourable demographic profile, a higher prevalence of organic farming, and higher proportions of farmers with complete agricultural training. Conversely, regions in C3 are facing demographic and economic

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challenges and presented lower levels of organic farming and less proportions of farm managers who have attained full education levels in agriculture. Context 2 occupies an intermediate position between C1 and C3.

Finally, the target areas to introduce MF/AF amounted to 506,249 km$^2$ across all NUTS 2 regions, where the average environmental pressures were estimated at 5.51. Considering each socio-economic context, 35.6% of the target area was identified in C3 regions, which reported a higher mean of environmental pressures (6.21). Conversely, regions in C1 reported a 22.4% of the target area and exhibited a mean of environmental pressures of 5.82. The majority of the target area (42%) was found in C2 regions, which reported a lower mean of environmental pressures (5.1) (Figure 22). As a conclusion, regions facing more social and economic challenges (C3) also presented a higher concentration of environmental pressures compared to regions in C1 and C2.

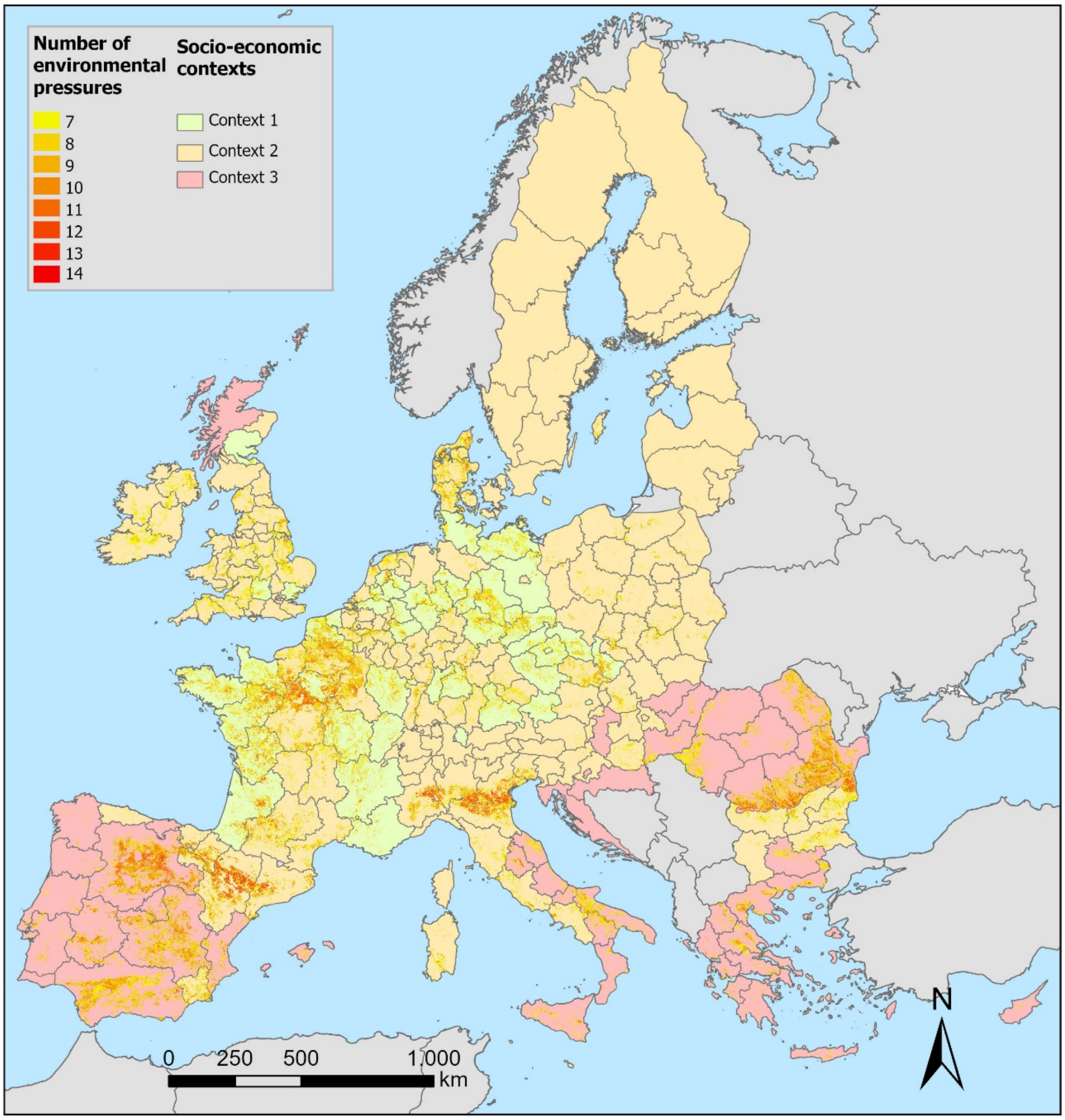


*Figure 22. Target areas to introduce MF/AF in different socioeconomic context in the EU27, UK and CH.*

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# 4 Land use change models for increased resilience to climate change (Sub-task 3.3.2)

*Jo Smith, Ana Tomás and João Palma*

*Moinhos de Vento Agroecology Research Centre*

## 4.1 Overview

While target regions for introducing MF/AF systems to increase resilience have been identified spatially in Sub-task 3.3.1, the focus of Sub-task 3.3.2 has been on identifying different models of land use change to evaluate pathways towards increased resilience to climate change. As there are significant research and evidence gaps in knowledge concerning the resilience of mixed farming and agroforestry land use models to climate change, an iterative expert knowledge-based Delphi method was used.

The objectives of the Delphi study were:
1) To reach consensus on the resilience of agroforestry and mixed farming types to climate impact drivers (mean warming, heat extremes, cold extremes, mean precipitation, heavy precipitation, drought, and severe windstorms) and associated impacts compared with baseline scenarios (i.e. annual crops /livestock /orchards/forestry).
2) To identify key mechanisms and properties of agroforestry and mixed farming types that impact resilience.
3) To reach consensus on the implementation, management, and economic implications of a change in land-use towards a more climate change resilient land use model.
3) To create a knowledge base for farmers, policy makers and researchers on the resilience of agroforestry and mixed farming to climate change.

The Framework setting out the background and rationale for the approach taken in this sub-task was set out in detail in Deliverable 3.5 (April 2023). Therefore, in the sections below, we focus on the methodology and results of the Delphi study that contribute to Deliverable 3.3, the Land Use Change Interactive Map.

## 4.2 Methodology

### 4.2.1 Definitions and land use change pathways

As discussed in D3.5, we based our definition of agroforestry land use types (or models) on the AGROMIX classification, with a few modifications to align with the classification adopted by the European Agroforestry Federation. The final classification (Table 24) reflects the balance of the three components (trees, livestock and annual crops) which can also be considered on a gradient of tree cover, ranging from potentially closed canopies in forest farming and forest grazing systems, through to lower levels of canopy cover in wood pastures and grazed or intercropped orchards, to alley cropping and linear woody features where the agricultural components are dominant.

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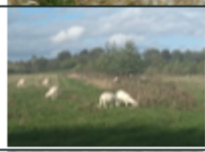
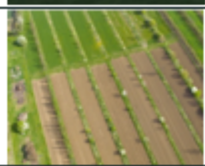
*Table 24. Definitions of agroforestry types included in the Delphi study.*

| Agroforestry type | Description | Illustration |
|---|---|---|
| Forest grazing | Livestock incorporated into woodland or forests. |  |
| Forest farming | Cultivation of high-value crops under the protection of a managed tree canopy. |  |
| Grazed orchards | Permanent woody crops (top fruit, nuts, vines, olives) with livestock. |  |
| Wood pasture | Livestock with scattered trees. The trees can be productive (e.g. fruit, timber, cork, fodder) or not. |  |
| Intercropped orchards | Permanent woody crops (top fruit, nuts, vines, olives) with temporary crops (arable, vegetables). |  |
| Alley cropping - arable | Within-field linear systems with temporary crops (arable, vegetables) grown in alleys between tree rows. Trees can be productive (e.g. fruit, timber, short rotation coppice) or not. |  |
| Alley cropping - livestock | Within-field linear systems with pasture or forage grown in alleys between tree rows. Trees can be productive (e.g. fruit, timber, short rotation coppice, fodder) or not. |  |
| Agrosilvopastoral | Combination of trees, livestock, and temporary crops (arable, vegetables) within the same system, usually on a rotation. Trees can be productive (e.g., fruit, timber, short rotation coppice, fodder) or not. |  |
| Hedgerows, riparian buffers, and shelterbelts | Linear systems of shrubs and trees around field perimeters or adjacent to streams, rivers, lakes, or wetlands. Trees can be productive (e.g., fruit, timber, short rotation coppice, fodder) or not. |  |

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For the classification of mixed farming systems, we further developed the AGROMIX definition of '*the practice of deliberately integrating crop and livestock production to benefit from the resulting ecological and economic interactions*' (Puttsepp *et al.*, 2022) to account for different scales and levels of integration, building on work by Martin et al (2016) and Watson et al (2018). This results in four 'types' that characterise mixed farming by scale (within-farm to between-farms) and level of integration (complementarity vs synergy; Martin *et al.*, 2016; Watson et al, 2018 (Table 25)). As there was some confusion about the term 'mixed farming systems' (for many people, mixed farming systems also include agroforestry), for the Delphi it was decided to use the more precise term 'Integrated Crops and Livestock Systems' or ICLS.

*Table 25. The four types of Integrated Crop-Livestock Systems (building on Martin et al, 2016)*

| | **Scale** | |
|---|---|---|
| **Level of Integration** | **Within Farm** | **Between Farms: Region** |
| **Synergy** | Strong temporal and spatial integration between crops, grasslands and animals on a single farm. Involves resource sharing, mainly land sharing and planning of land use of each field and animal movements. Based on practices such as stubble grazing; sacrificial grazing of grain crops; introducing intercropped forage crops and leys, temporary grazed grasslands, and forage legumes in crop rotations. | Strong temporal and spatial integration between crops, grasslands, and animals among farms. Involves resource sharing, mainly land sharing: farmers group their respective land areas and collectively plan land use of each field and animal movements. Based on practices such as stubble grazing; sacrificial grazing of grain crops; introducing intercropped forage crops, temporary grasslands, and forage legumes in crop rotations; grazing animals from livestock farms on crop farms and arrangements such as potato–dairy systems. Coordination between farmers must be strong and long-lasting to manage rotational manure application and occurrence of grasslands in crop rotations. |
| **Complementarity** | Involves temporal coordination of one-way flow or exchanges of raw materials between spatially segregated farm components. Involves strategic planning among crop and livestock components to match supply and demand for feedstuff through adapted crop rotations including grasslands, forage crops, and cover crops that produce forage, and optimize manure allocation based on needs of field soils of the farm. | Direct exchange of raw materials between farms. Involves strategic planning among crop and livestock farmers to match supply and demand for feedstuff through adapted crop rotations including grasslands, forage crops, and cover crops that produce forage. It can also optimize manure allocation based on comparative advantages of field soils of participating farms. Involves temporal coordination of one-way flow or exchanges of raw materials between spatially segregated farms. Requires direct and frequent coordination between farmers for strategic planning to respond to variability in quantity and quality of exchangeable materials. |

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The resilience of the agroforestry and mixed farming types to the climate impact drivers and associated impacts were compared with baseline land-use scenarios. The baseline land-use systems considered were 'non-mixed' systems, whereby the introduction of additional components will potentially increase resilience to climate change impacts. In addition to three agricultural baselines (arable, livestock and orchards (includes vines and olives)), we also included a forestry baseline (Table 26).

*Table 26. Land use change pathways from agricultural and forestry baselines (ICLS: integrated crop/livestock systems)*

| Baseline system | Agroforestry or mixed farming (ICLS) land use type |
|---|---|
| Annual crops (arable/horticultural) | ICLS: Between-farms complementarity |
| | ICLS: Between-farms synergy |
| | ICLS: Within-farm complementarity |
| | ICLS: Within-farm synergy |
| | Hedgerows, windbreaks & riparian buffers |
| | Alley cropping |
| | Agro-silvopastoral |
| | Intercropped orchards |
| | Forest farming |
| Livestock | ICLS: Between-farms complementarity |
| | ICLS: Between-farms synergy |
| | ICLS: Within-farm complementarity |
| | ICLS: Within-farm synergy |
| | Hedgerows, windbreaks & riparian buffers |
| | Alley systems with livestock |
| | Agro-silvopastoral |
| | Grazed orchards |
| | Wood pasture |
| | Forest grazing |
| Orchard | Intercropped orchards |
| | Grazed orchards |
| Forestry | Forest farming |
| | Forest grazing |

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### 4.2.2 Climate impact drivers, impacts and risks

In this study, we focused on the resilience of agroforestry and mixed farming types to climate impact drivers and associated observed impacts and projected risk. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment report (AR6) defines climate impact-drivers as conditions of the physical climate system (e.g., means, events, extremes) that affect society and/or ecosystems (Bednar-Friedl *et al.*, 2022). There are seven climate impact drivers that were considered: mean warming, heat extremes, cold extremes, mean precipitation, heavy precipitation, drought, and severe windstorms Figure 23. The IPCC AR6 also identified observed impacts and projected risks of the climate impact drivers, with many impacts/risks having multiple drivers which may interact to either exacerbate or mitigate any potential impact.

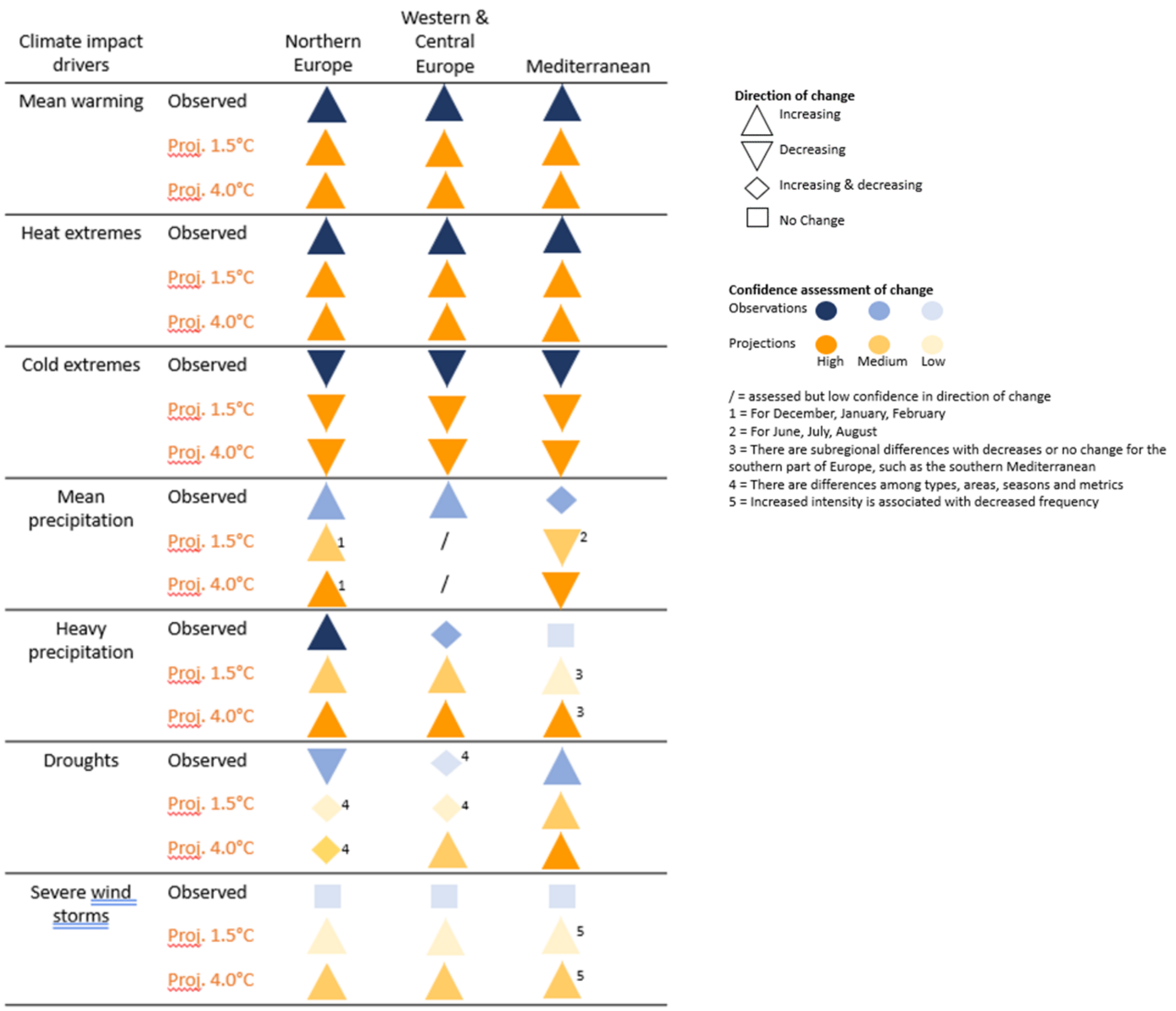


*Figure 23. Observed and projected direction of change in climate-impact drivers at 1.5°C and 4°C GWL for European sub-regions (Bednar-Friedl et al 2022)*

As the direction of change for some climate impact drivers differs between regions of Europe (Figure 23), for agroforestry we conducted three separate Delphi's (Northern Europe, Southern Europe (Mediterranean) and Western & Central Europe), based on the IPCC AR6 subdivisions of Europe (Bednar-Friedl *et al.*, 2022). However, for the Mixed Farming systems, due to the limited pool of experts, only a single Delphi covering all of Europe was conducted.

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### 4.2.3 The Delphi Study

The Delphi technique is "a method of structuring a group communication process so that the process is effective in allowing a group of individuals as a whole to deal with a complex problem" (Hugé *et al.*, 2010). By organising and structuring expert group debates on complex issues, the Delphi method makes it possible to channel often diverse views and opinions into a consensus through an iterative feedback process. Delphi studies typically consist of two or three rounds of structured questionnaires, each followed by aggregation of responses and anonymous feedback to the participants (Mukherjee *et al.*, 2015). After each questionnaire round, participants can review and confirm or amend their previous responses, considering the opinions and elements that were suggested by the other participants during the preceding round. The process is repeated until a consensus emerges; this is usually achieved after two or three rounds of questionnaires (Diamond *et al.*, 2014). This Delphi was carried out entirely online, to make it efficient in terms of both time and costs, and throughout the process, all participants remained anonymous to other participants.

#### 4.2.3.1 Participant selection

The selection of 'experts' for participation in the Delphi process was based on objective criteria defined prior to the study. Experts needed to have knowledge and understanding of (1) European agroforestry or mixed farming systems, (2) climate impact drivers and climate change impacts and (3) concepts of resilience of farming systems to climate change. For the three agroforestry Delphis, we primarily selected experts within the EU project AGROMIX consortium and complemented with other experts from current and previous projects (MIXED, DigitAF, ReForest) and country delegates of the European Agroforestry Federation, to ensure Europe-wide coverage. For the Mixed Farming systems Delphi, in addition to experts from the AGROMIX and MIXED projects and the previous CANTOGETHER project, additional potential participants were identified from the list of members involved in the EIP-AGRI Focus Group on Mixed farming systems and authors from recent research papers on mixed farming. An email was sent to the identified experts, explaining the goal and protocol of the Delphi studies and inviting them to sign up to participate in the study. To encourage engagement throughout the multiple rounds of surveys, there was an invitation for those who contributed fully to be added as co-authors to a peer-reviewed paper that is foreseen as an output of the study. When signing up, participants of the agroforestry Delphi studies were asked to indicate which of the climatic regions they were most familiar with, with the option to choose more than one. This enabled us to ensure adequate coverage of all three climate zones ensuring a minimum of seven experts per zone (Powell, 2003).

#### 4.2.3.2 Questionnaire development and testing

The questionnaire was developed and then piloted with four volunteers from AGROMIX WP3 who provided valuable feedback on the flow, content and scope of the questionnaire and accompanying support material. The final questionnaire contained seven questions relating to resilience of each of the agroforestry and mixed farming types to climate impact drivers and their associated impacts, and four questions relating to cost of implementation, ease of management and financial viability with and without subsidies compared to the baseline. For the Agroforestry Delphi studies, each question was divided into three subsections; the first subsection focused on agroforestry types compared with an annual crop (arable/vegetable)-only baseline, the second on agroforestry types compared with a livestock-only baseline, and the third on agroforestry types compared with a tree-only baseline (i.e. orchard or forestry). For the Mixed Farming Delphi, there were only the first two subsections (annual crop and livestock baselines).

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The first seven questions on resilience had a five-point scale answer ranging from 'Much lower resilience' to 'Much higher resilience', as well as options to choose 'I don't know' or 'There is no evidence'. Participants were asked to suggest the mechanisms or properties of the land use type that determines the level of resilience, with references where possible (in any language), plus the opportunity to add notes, limitations or caveats. The next four questions related to the implementation, management and profitability of the land use types and also had a five-point scale answer, adapted to the question, and again, participants were asked for further information justifying their score, with the possibility to add references and notes where appropriate. In the first Delphi round, it was compulsory for participants to add justifications for each score, while for subsequent rounds, this was made optional. In the final Round, participants were also asked to describe real-life examples of agroforestry or mixed farming systems in their country to contribute to the case studies for the interactive map.

After each Round, responses were aggregated, and anonymous feedback provided to the participants. Participants were asked to review and confirm or amend their previous responses, considering the opinions and elements that were suggested by the other participants during the preceding round.

The Delphi process was managed using the online platform 'Welphi' (**www.welphi.com**). This facilitated the entire process, from coordinating email invitations and follow up reminders to participants, to creating and implementing rules of consensus for developing subsequent Rounds, to analysing results and providing anonymous comments for each Round.

### 4.2.4 Data analysis

#### 4.2.4.1 Reaching consensus

There are different approaches to defining consensus in Delphi studies including formal measures of agreement, degree of uncertainty around a point estimate, decreases in variance of group responses, or the proportion of participants agreeing to a particular viewpoint; the most common definition used is percent agreement (Diamond *et al.*, 2014). In this study, we defined consensus as 70%, i.e. when at least 70% of participants agreed on the same level of resilience for a particular agroforestry or mixed farming type. We also decided that consensus has been reached when the combination of participants answering, "I don't know" or "There is no evidence" was at least 70%.

#### 4.2.4.2 Identifying key mechanisms and properties - thematic content analysis

Thematic content analysis was carried out on the participant comments. Thematic content analysis is a commonly used method in qualitative research that first identifies patterns in meaning across the data and develops codes to describe these patterns. Through an iterative process, these codes are refined and grouped into overarching themes that ultimately relate directly to the research question (Braun and Clarke, 2006), in this case, to identify key mechanisms and properties of agroforestry and mixed farming types that impact resilience to climate change impacts.

As an inductive (i.e. ground-up) approach (Vears and Gillam, 2022), the initial round of coding was carried out without any preconceived notions of what the codes should be, i.e. the patterns came from the data itself; subsequently, aligning and grouping codes into themes was a reflexive process, where the researcher's subjective experience played an inherent part in making meaning from the data.

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To efficiently process the large volume of data generated by the Delphi, artificial intelligence (AI) was employed in the Thematic Content Analysis. AI has recently become part of the toolbox of software packages for qualitative analysis, using AI to automatically generate codes (e.g. ATLAS.ti, NVIVO) or to identify and summarise data related to specific codes (MAXQDA). There are, understandably, concerns about the use of AI programmes such as Chat GPT in qualitative research; as a 'black box' the underlying methodology is somewhat ambiguous and can potentially return biased or nonsensical results (Morgan, 2023). A comparison between ChatGPT and manual thematic content analysis, however, concluded that ChatGPT performed well, but was better at reproducing concrete, descriptive themes, rather than subtle, interpretative themes (Morgan, 2023). In the case of our data, where we were aiming to identify key factors affecting resilience, rather than more nuanced interpretations of people's perceptions or feelings, this bias towards more descriptive concrete themes seems to further support the case for using AI as a tool within this analysis. In our study, we employed ChatGPT at the first stage of generating and aligning initial codes. This was complemented by manual verification of codes to ensure ChatGPT was identifying codes correctly, manual interpretation of codes into themes, and subsequently, applying the themes within the 'Vulnerability' (Fellmann, 2012) and 'Resilience' (Meuwissen *et al.*, 2019) frameworks.

#### 4.2.4.3 Collating the evidence base

Participants were asked to support their comments on key mechanisms and properties of agroforestry and mixed farming types that impact resilience to climate change impacts with scientific references to provide an evidence base, or conversely to help identify knowledge gaps. References were collated into a Mendeley group (Mendeley Desktop Version 1.19.8 2008-2020 Mendeley Ltd). References were then allocated to either the themes developed from the comments, or the agroforestry or mixed farming types, or both.

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## 4.3 Results

### 4.3.1 Participant engagement

The Delphi studies ran from September to December 2023. Between 1st to 4th September, invitations were sent to 89 agroforestry experts and 45 mixed farming experts, and they were given until 24th September to indicate their participation via a google form. Round 1 opened on 25th September and ran for three weeks, Round 2 opened on 30th October and ran for three weeks, while the final round, Round 3, opened on 29th November and closed on 15th December. In all, 60 participants completed the three rounds (Table 27), exceeding the minimum requirement of seven participants for each Delphi (Powell, 2003). For the agroforestry Delphis, nineteen countries were represented by those completing Round 1, while for the mixed farming Delphi, there were five countries represented.

*Table 27. Expert participation in the different stages of the Delphi studies.*

| Delphi study | Invited | Completed Round 1 | Completed Round 2 | Completed Round 3 |
|---|---|---|---|---|
| Agroforestry: Northern Europe | 23 | 17 | 16 | 16 |
| Agroforestry: Western & Central | 39 | 21 | 18 | 19 |
| Agroforestry: Southern Europe | 27 | 15 | 12 | 11 |
| Integrated Crop/Livestock Systems | 45 | 17 | 15 | 14 |

### 4.3.2 Reaching consensus on the resilience of land use types to climate impact drivers and associated impacts compared with baseline scenarios

After the first round, only 16 combinations (i.e. climate*baseline*agroforestry or mixed farming type) reached a consensus of greater than 70%. After the second round, it was decided to modify the consensus rule so that if the levels 'Higher' and 'Much higher' combined exceeded 70%, this was a consensus of 'Higher' resilience; similarly, if the levels 'Lower' and 'Much lower' combined exceeded 70%, this was a consensus of 'Lower'. Following this rule, after the second round, 285 combinations reached consensus. After the third and final round, an additional 87 combinations reached consensus, while the remaining 228 combinations did not reach a consensus. Table 28-30 show the consensus on resilience of agroforestry types to climate impact drivers for Northern, Western & Central, and Southern Europe, while Table 31 shows the consensus on resilience of mixed farming types to climate impact drivers in Europe.

For the agroforestry types, where consensus was reached, in most cases (88%) the agroforestry land use models had higher resilience to climate impact drivers than annual cropping and livestock-only baselines. The main exception was for the climate impact driver 'reduction in cold extremes' where consensus was not reached for the majority of land use types. For transition from a tree-only (i.e. forestry or orchard) baseline, consensus was much lower (10%) or the resilience level was unknown (11%), suggesting much less is known about the impact of introducing livestock or cropping into existing forestry or orchards systems. However, in Southern Europe, there was consensus of higher resilience of agroforestry systems compared with tree-only baselines, to increases in droughts, decreases in mean precipitation, and increases in heat extremes and mean temperatures (Table 30).

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*Table 28. Northern Europe consensus on resilience of agroforestry types to climate impact drivers. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers.*

| Baseline system | Type | Mean temperature | Heat extremes | Cold extremes | Mean precipitation | Extreme precipitation | Drought | Windstorms |
|---|---|---|---|---|---|---|---|---|
| Annual crops | Agrosilvopastoral | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Alley cropping | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Forest farming | Higher | Higher | No consensus | Higher | Higher | No consensus | Higher |
| | Linear features | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Intercropped orchards | Higher | Higher | No consensus | Higher | Higher | No consensus | Higher |
| Livestock | Agrosilvopastoral | Higher | Higher | No consensus | Higher | Higher | Higher | No consensus |
| | Alley systems | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Forest grazing | Higher | Higher | No consensus | Higher | Higher | Higher | No consensus |
| | Grazed orchards | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Linear features | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Wood pasture | Higher | Higher | No consensus | Higher | Higher | Higher | No consensus |
| Orchards | Grazed orchards | No consensus | No consensus | Unknown | No consensus | No consensus | No consensus | No consensus |
| | Intercropped orchards | Unknown | No consensus | Unknown | No consensus | No consensus | No consensus | No consensus |
| Forestry | Forest farming | Unknown | No consensus | Unknown | No consensus | No consensus | No consensus | No consensus |
| | Forest grazing | No consensus | No consensus | Unknown | No consensus | No consensus | No consensus | No consensus |
| | Wood pasture | No consensus | No consensus | No consensus | No consensus | No consensus | No consensus | No consensus |

*Table 29. Western & Central Europe consensus on resilience of agroforestry types to climate impact drivers. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers.*

| Baseline system | Type | Mean temperature | Heat extremes | Cold extremes | Mean precipitation | Extreme precipitation | Drought | Windstorms |
|---|---|---|---|---|---|---|---|---|
| Annual crops | Agrosilvopastoral | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Alley cropping | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Forest farming | Higher | Much higher | No consensus | Higher | Much higher | Much higher | Higher |
| | Linear features | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Intercropped orchards | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| Livestock | Agrosilvopastoral | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Alley systems | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Forest grazing | Higher | Much higher | No consensus | Higher | Higher | Higher | Higher |
| | Grazed orchards | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Linear features | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Wood pasture | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| Orchards | Grazed orchards | No consensus | No consensus | No consensus | No consensus | Same | No consensus | No consensus |
| | Intercropped orchards | No consensus | No consensus | No consensus | No consensus | No consensus | No consensus | No consensus |
| Forestry | Forest farming | No consensus | No consensus | No consensus | No consensus | No consensus | No consensus | No consensus |
| | Forest grazing | Same | Same | No consensus | No consensus | Same | Same | No consensus |
| | Wood pasture | Same | Unknown | No consensus | No consensus | Same | No consensus | No consensus |

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

*Table 30. Southern Europe consensus on resilience of agroforestry types to climate impact drivers. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers.*

| Baseline system | Type | Mean temperature | Heat extremes | Cold extremes | Mean precipitation | Extreme precipitation | Drought | Windstorms |
|---|---|---|---|---|---|---|---|---|
| Annual crops | Agrosilvopastoral | Much higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Alley cropping | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Forest farming | Higher | Much higher | No consensus | Higher | Higher | Much higher | Higher |
| | Linear features | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Intercropped orchards | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| Livestock | Agrosilvopastoral | Higher | Much higher | Higher | Higher | Higher | Higher | Higher |
| | Alley systems | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Forest grazing | Much higher | Much higher | No consensus | Higher | Higher | Higher | Higher |
| | Grazed orchards | Higher | Higher | No consensus | Higher | Higher | Higher | Higher |
| | Linear features | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Wood pasture | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| Orchards | Grazed orchards | No consensus | No consensus | Unknown | Higher | No consensus | No consensus | No consensus |
| | Intercropped orchards | Higher | No consensus | Unknown | No consensus | No consensus | Higher | No consensus |
| Forestry | Forest farming | Higher | No consensus | Unknown | No consensus | No consensus | Higher | No consensus |
| | Forest grazing | Higher | No consensus | Unknown | No consensus | No consensus | Higher | No consensus |
| | Wood pasture | Higher | Higher | Unknown | Higher | No consensus | Higher | No consensus |

*Table 31. Consensus on resilience of mixed farming types to climate impact drivers in Europe. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers.*

| Baseline system | Type | Mean temperature | Heat extremes | Cold extremes | Mean precipitation | Extreme precipitation | Drought | Windstorms |
|---|---|---|---|---|---|---|---|---|
| Annual crops | Between-farms complementarity | Higher | Higher | No consensus | Higher | Higher | Higher | Same |
| | Between-farms synergy | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Within-farm complementarity | Higher | Higher | Same | Higher | Higher | Higher | Same |
| | Within-farm synergy | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| Livestock | Between-farms complementarity | Higher | Higher | Higher | Higher | No consensus | Higher | Higher |
| | Between-farms synergy | Higher | Higher | Higher | Higher | Higher | Higher | Higher |
| | Within-farm complementarity | Higher | No consensus | No consensus | Higher | No consensus | Higher | Same |
| | Within-farm synergy | Higher | Higher | Higher | Higher | Higher | Higher | Higher |

For mixed farming types, there was also a strong consensus that mixed farming systems increased resilience to climate impact drivers when compared with the agricultural baselines (Table 31). However, there was some uncertainty about resilience to temperature and precipitation extremes, particularly for those systems that exchanged materials but kept the components separate spatially and temporally (i.e. between-farms and within-farm complementarity).

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### 4.3.3 Key mechanisms and properties of land use types that impact resilience

There was a total of over 7,200 comments made in response to the agroforestry questions and just under 1,400 in response to the mixed farming questions. Thematic content analysis identified key mechanisms and properties, mechanisms and impacts underpinning the resilience of agroforestry systems and mixed farming systems, when compared with agricultural or forestry/orchard baselines. These themes have been grouped into the three components of the 'Vulnerability' framework (IPCC 2007, 2007): *exposure* i.e., in what way and to what extent a system is exposed to climate variations, *sensitivity* i.e. the extent to which a system is affected (negatively or positively) by climate variability or change, and *adaptive capacity* i.e. the potential of a system to adjust to climate change (Table 32-36). While themes for the agroforestry types map across all three components of Vulnerability, those of the mixed farming types relate either to reducing sensitivity or increasing adaptive capacity, reflecting the advantages trees bring to farming systems by reducing exposure to climate impact drivers. There is some overlap in themes between the agroforestry and mixed farming types, particularly where the themes are related to increased diversity.

In addition to these themes, which identify how these agroecological systems increase resilience to climate change, thematic analysis also identified caveats and trade-offs, which could influence resilience (Table 32-36). Caveats are mainly focused on the characteristics of the components and the design of the system, e.g. tree species, densities, location, heights, canopy area and management; livestock species, breeds, stocking densities, browse preferences and management; crop species, varieties and management, or social interactions dependant on the farmer and local community. Trade-offs relate to potential for competition for resources reducing yields, functional disservices from increased biodiversity (e.g. increased pests & diseases) or an altered microclimate (e.g. reducing the cooling effect of wind in hot conditions).

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*Table 32. Themes describing key mechanisms and properties of agroforestry types that impact resilience by reducing exposure to climate impact drivers*

| Component of Vulnerability | Theme | Description | Caveats and trade-offs |
|---|---|---|---|
| **Exposure**<br>The way and extent to which a system is exposed to climate variations | Trees provide **shelter** which reduces exposure to wind and the risk of wind damage. | Reduces the risk of wind damage to crops, soil (i.e. reduces soil erosion) and farming infrastructure. | Depends on tree densities and heights, and orientation of tree lines.<br>Falling trees and branches can cause damage to buildings, crops and livestock. |
| | Trees provide **shelter** which reduces exposure to wind and wind chill. | Reduces wind chill impacts on livestock, crops and humans. This increases crop and livestock health and welfare and impacts survival, fertilisation, growth and productivity. | Depends on tree densities and heights, and orientation of tree lines.<br>In hot conditions, wind speed reductions can have a negative effect by reducing the cooling effect of wind on livestock. |
| | Trees provide **shelter** which reduces exposure to wind and water loss from soil and vegetation. | Reduces water loss from soil and vegetation by reducing vapour pressure deficit. | Depends on tree densities and heights, and orientation of tree lines. |
| | Trees provide **shelter** which reduces exposure to extreme precipitation. | Reduces the impact of heavy rainfall on the understorey which reduces the risk of soil erosion. | Depends on tree densities, canopy size, leaf area index (leaf area per m2), tree distribution, tree species.<br>Depends on soil texture (hydraulic conductivity) and ground cover |
| | Trees provide **shelter** which reduces exposure to cold nights. | Increases temperature in cold nights under the canopy increasing livestock health and welfare and impacts survival, growth and productivity. | Depends on tree canopy size, leaf area index (leaf area per m2), height, tree species. |
| | Trees provide **shade** which reduces exposure to temperature extremes. | Increases livestock health and welfare and impacts survival, growth and productivity. | Depends on tree densities, canopy size, pruning tree height, leaf area index, tree distribution, tree species. |
| | Trees provide **shade** which reduces exposure to radiation. | Reduces soil evaporation and vegetation evapotranspiration which impacts tree, crop and grass growth and productivity. | Depends on tree densities, canopy size, leaf area index, tree distribution, tree species.<br>Can reduce crop and pasture growth due to competition for radiation and reduced air and soil temperatures. |
| | Trees act as **barriers** to reduce exposure to pests and diseases. | Reduces the risk of crop and livestock pests or diseases and impacts crop and livestock health, survival, growth and productivity. | Depends on tree densities and location.<br>Can also increase spread of some diseases by providing shelter for animal vectors. |
| | **Active management** by agroforestry reduces exposure to wildfires. | Reduces the risk of wildfires in forests due to reduced fuel load (by grazing livestock) and lower tree densities. This impacts tree survival, growth and productivity, and human health. | Depends on livestock densities and species, tree densities and management. |

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*Table 33. Themes describing key mechanisms and properties of agroforestry types that impact resilience by reducing sensitivity to climate impact drivers*

| Component of Vulnerability | Theme | Description | Caveats and trade-offs |
|---|---|---|---|
| **Sensitivity** The extent to which a system is affected (negatively or positively) by climate variability or change | Tree roots reduce sensitivity to precipitation changes and extremes by **increasing water infiltration and enhancing soil structure.** | Reduces flooding and waterlogging, water run-off, soil erosion and nutrient loss through leaching. This impacts crop and pasture health, survival, growth and productivity. | Depends on tree species and densities, slope, geomorphology, soil compaction, tilling regimes, grazing intensity (rotation returning period) |
| | Trees reduce sensitivity to precipitation changes and extremes by **increasing soil organic matter**. | Leaf fall and root turnover increase soil organic matter which increases water holding capacity and soil biodiversity. This impacts crop and pasture health, survival, growth and productivity. | Depends on tree species, densities. Also depends on pruning and thinning regime and destination of removed biomass from stand |
| | Livestock reduce sensitivity to climate impacts on trees **by increasing nutrient cycling.** | Integrating livestock into tree systems increases nutrient cycling through grazing and manure deposition. This impacts tree health, growth and productivity. | Potential browsing damage to trees. |
| | Trees reduce sensitivity to climate impacts on forage availability by providing **alternative fodder resources**. | Impacts livestock health, survival, growth and productivity, by enabling forage in periods of scarcity | Depends on tree species and management and livestock species, breeds and preferences (palatability). |
| | Trees reduce sensitivity to climate impacts on livestock by **improving livestock health & welfare**. | Tree fodder provides nutritional and medicinal resources, and trees provide structures for improved body care and better social interactions. This increases livestock health and welfare and impacts survival, growth and productivity. | Depends on tree species, tree distribution and management, livestock species, breeds and management. |
| | Increased habitat diversity reduces sensitivity to climate impacts by **increasing functional biodiversity.** | System complexity increases habitat diversity and ecological niches which increases diversity of functional groups including pollinators and natural enemies. This provides functional redundancy therefore stabilises the provision of regulating ecosystem services including pest control and pollination, leading to impacts on crop and pasture health, survival, growth and productivity | Can also increase the abundance of some pests by providing refuges or modifying the microclimate e.g. increased fly pests due to shelter from wind. |
| | Increased system diversity reduces sensitivity to climate impacts by **increasing agrobiodiversity**. | Diversity of system components (trees, crops, livestock) increases stability in production, due to complementarity in resource use. | Depends on species, breeds, design and management of components. |
| | Increased system diversity reduces sensitivity to climate impacts by **increasing income diversity.** | Diversity of system components (trees, crops, livestock) increases stability in income, due to complementarity in resource use and compensation in varying climate conditions. | Depends on species, breeds, design and management of components. |
| | Livestock grazing reduces sensitivity to climate impacts by **reducing pests and diseases.** | Livestock control weeds and pests (through browsing on diseased leaves and fruits) therefore increasing tree health, growth and productivity. | Potential browsing damage to the woody components (e.g. trees, vines, berries) |
| | System complexity reduces sensitivity to climate impacts by **increasing resource use efficiency.** | Complementarity in resource use (water, nutrients, space, radiation) leads to efficient systems that can buffer impacts of climate change. | Depends on species, breeds, design and management of components. Competition for resources can reduce productivity of some components. |

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*Table 34. Themes describing key mechanisms and properties of **agroforestry** types that impact resilience by increasing adaptive capacity to climate impact drivers*

| Component of Vulnerability | Theme | Description | Caveats and trade-offs |
|---|---|---|---|
| **Adaptive capacity**<br>The ability of a system to adjust to climate change by:<br>*Moderating potential damages<br>*Taking advantages of opportunities<br>*Coping with the consequences | System diversity increases adaptive capacity by **increasing agrobiodiversity.** | Diversity of system components (trees, crops, livestock) increases ability of the system to moderate potential damage by spreading risk of climate change impacts on yields and taking advantage of variable conditions whereby productivity of one component can compensate for others impacted by climate. | Depends on species, breeds, design and management of components. Competition for resources can reduce productivity of some components. |
| | System diversity increases adaptive capacity through **income diversification** | Diversifying income sources reduces dependency on single crops and allows the system to adapt to changing conditions. | Depends on species, breeds, design and management of components. Competition for resources can reduce productivity of some components. |
| | System diversity increases adaptive capacity by **increasing livelihood opportunities.** | Diversity of system components (trees, crops, livestock) increases livelihood opportunities, strengthening local communities therefore increasing the ability to adjust to climate change by being able to take advantage of opportunities. | Depends on system components and availability of workers. |
| | System diversity increases adaptive capacity by **increasing local economic opportunities.** | Diversifying income sources contributes to and strengthens local economies which in turn provides a supportive environment that can help farms adapt to changing conditions. | Depends on system components and interactions with local communities. |
| | **Strong community engagement and collaboration** increases adaptive capacity by increasing the ability to cope with consequences of climate change. | Agroecological approaches encourage community engagement and collaboration in their design, establishment and management. In turn, this provides a supportive environment that can help farms adapt to changing conditions. | Depends on farmer engagement with local community. |
| | Traditional agroforestry systems increase adaptive capacity by building on a **strong knowledge base and indigenous experience** | Traditional and indigenous knowledge, as well as local practices and experiences, play a valuable role in informing the design, implementation, and management of agroforestry systems, therefore contributing to their success and resilience in diverse contexts. | Depends on system type and availability of indigenous knowledge. |

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*Table 35. Themes describing key mechanisms and properties of **mixed farming** types that impact resilience by reducing sensitivity to climate impact drivers*

| Component of Vulnerability | Theme | Description | Caveats and trade-offs |
|---|---|---|---|
| **Sensitivity**<br>The extent to which a system is affected (negatively or positively) by climate variability or change | Increased habitat diversity reduces sensitivity to climate impacts by **increasing functional biodiversity.** | System complexity increases habitat diversity and ecological niches which increases diversity of functional groups including pollinators and natural enemies. This provides functional redundancy therefore stabilises the provision of regulating ecosystem services including pest control and pollination, leading to impacts on crop and pasture health, survival, growth and productivity | Can also increase the abundance of some pests by providing refuges or modifying the microclimate e.g. increased fly pests due to shelter from wind. |
| | Increased system diversity reduces sensitivity to climate impacts by **increasing agrobiodiversity**. | Diversity of system components (trees, crops, livestock) increases stability in production, due to complementarity in resource use. | Depends on species, breeds, design and management of components. |
| | Livestock grazing reduces sensitivity to climate impacts by **reducing pests and diseases.** | Livestock control weeds and pests (through browsing on diseased leaves and fruits) therefore increasing tree health, growth and productivity. | Potential browsing damage to the woody components (e.g. trees, vines, berries) |
| | System complexity reduces sensitivity to climate impacts by **increasing resource use efficiency.** | Complementarity in resource use (water, nutrients, space, radiation) leads to efficient systems that can buffer impacts of climate change. | Depends on species, breeds, design and management of components. Competition for resources can reduce productivity of some components. |
| | Increased system diversity reduces sensitivity to climate impacts by **increasing income diversity.** | Diversity of system components (trees, crops, livestock) increases stability in income, due to complementarity in resource use and compensation in varying climate conditions. | Depends on species, breeds, design and management of components. |
| | Livestock manure and grassland reduce sensitivity to precipitation changes and extremes by **increasing soil organic matter.** | Addition of manure and/or establishment of grassland increase soil organic matter which increases water holding capacity and soil biodiversity. This impacts crop and pasture health, survival, growth and productivity. | |
| | **Cycling of materials** reduces reliance on external inputs which reduces sensitivity to impacts of climate change on external supply chains. | Exchange of feed and manure at a local level reduces the need for external inputs such as fertilisers and feed, and less reliant on transport services, therefore making the farm less sensitive to price changes or availability shortages caused by climate change impacts on the supply chain. | |
| | **Regional agricultural diversity and collaboration between farms** reduces sensitivity to climate impacts at a landscape scale. | At a landscape scale, a diversity of farming systems working together increases stability in production, due to complementarity in resource use and compensation in varying climate conditions. | |

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

*Table 36. Themes describing key mechanisms and properties of mixed farming types that impact resilience by increasing adaptive capacity to climate impact drivers*

| Component of Vulnerability | Theme | Description | Caveats and trade-offs |
|---|---|---|---|
| **Adaptive capacity**<br>The ability of a system to adjust to climate change by:<br>*Moderating potential damages<br>*Taking advantages of opportunities<br>*Coping with the consequences | System diversity increases adaptive capacity by **increasing agrobiodiversity.** | Diversity of system components (trees, crops, livestock) increases ability of the system to moderate potential damage by spreading risk of climate change impacts on yields and taking advantage of variable conditions whereby productivity of one component can compensate for others impacted by climate. | Depends on species, breeds, design and management of components.<br>Competition for resources can reduce productivity of some components. |
| | System diversity increases adaptive capacity through **income diversification** | Diversifying income sources reduces dependency on single crops and allows the system to adapt to changing conditions. | Depends on species, breeds, design and management of components.<br>Competition for resources can reduce productivity of some components. |
| | **Strong collaboration and coordination with other** farmers increase adaptive capacity by increasing the ability to cope with consequences of climate change. | Synergies between farms with regards resource use requires reliable collaboration between farmers. This builds strong relationships that provide a supportive environment that can help farms adapt to changing conditions. | Depends on maintenance of good working relationships with other farmers. |

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### 4.3.4 Reaching consensus on the implementation, management and economic implications of a change in land-use towards a more climate change resilient land use model.

Regarding the implementation, management and economic implications of a change in land-use towards a more climate change resilient land use model, there was a strong consensus that most of the agroforestry models are harder to manage than the baseline systems, and for several combinations, expensive to establish (Table 37-39). By contrast, there was an almost complete lack of consensus regarding financial performance of the land use models, both with and without subsidies, in comparison with baseline systems (Tables 37-39).

*Table 37. Northern Europe consensus on implementation, management and financial performance questions for agroforestry. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers.*

| Baseline system | Type | Establishment costs | Management ease | Financial performance | |
|---|---|---|---|---|---|
| | | | | With subsidies | No subsidies |
| Annual crops | Agrosilvopastoral | Expensive | Harder | No consensus | No consensus |
| | Alley cropping | Expensive | Harder | No consensus | No consensus |
| | Forest farming | No consensus | No consensus | No consensus | Unknown |
| | Linear features | No consensus | Harder | No consensus | No consensus |
| | Intercropped orchards | Expensive | No consensus | No consensus | No consensus |
| Livestock | Agrosilvopastoral | No consensus | Harder | No consensus | No consensus |
| | Alley systems | No consensus | Harder | No consensus | No consensus |
| | Forest grazing | No consensus | No consensus | No consensus | No consensus |
| | Grazed orchards | No consensus | Harder | No consensus | No consensus |
| | Linear features | No consensus | Harder | More profitable | No consensus |
| | Wood pasture | No consensus | Harder | No consensus | No consensus |
| Orchards | Grazed orchards | No consensus | Harder | No consensus | No consensus |
| | Intercropped orchards | No consensus | Harder | More profitable | No consensus |
| Forestry | Forest farming | No consensus | No consensus | No consensus | No consensus |
| | Forest grazing | No consensus | No consensus | No consensus | No consensus |
| | Wood pasture | No consensus | No consensus | No consensus | No consensus |

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

*Table 38. Western & Central Europe consensus on implementation, management and financial performance questions for agroforestry. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers.*

| Baseline system | Type | Establishment costs | Management ease | Financial performance With subsidies | Financial performance No subsidies |
|---|---|---|---|---|---|
| Annual crops | Agrosilvopastoral | Expensive | Harder | No consensus | Unknown |
| | Alley cropping | Expensive | Harder | No consensus | No consensus |
| | Forest farming | Expensive | Harder | No consensus | Unknown |
| | Linear features | Expensive | Harder | No consensus | No consensus |
| | Intercropped orchards | Expensive | Harder | No consensus | No consensus |
| Livestock | Agrosilvopastoral | Expensive | Harder | Unknown | No consensus |
| | Alley systems | Expensive | Harder | Unknown | No consensus |
| | Forest grazing | Expensive | Harder | Unknown | No consensus |
| | Grazed orchards | Expensive | Harder | Unknown | No consensus |
| | Linear features | Expensive | Harder | Unknown | No consensus |
| | Wood pasture | Expensive | Harder | Unknown | No consensus |
| Orchards | Grazed orchards | Expensive | Harder | Unknown | No consensus |
| | Intercropped orchards | No consensus | Harder | Unknown | No consensus |
| Forestry | Forest farming | Expensive | Harder | No consensus | No consensus |
| | Forest grazing | No consensus | Harder | Unknown | Unknown |
| | Wood pasture | No consensus | Harder | Unknown | Unknown |

*Table 39. Southern Europe consensus on implementation, management and financial performance questions for agroforestry. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers*

| Baseline system | Type | Establishment costs | Management ease | Financial performance With subsidies | Financial performance No subsidies |
|---|---|---|---|---|---|
| Annual crops | Agrosilvopastoral | No consensus | Harder | No consensus | No consensus |
| | Alley cropping | No consensus | Harder | No consensus | No consensus |
| | Forest farming | No consensus | Harder | No consensus | Unknown |
| | Linear features | No consensus | Harder | No consensus | No consensus |
| | Intercropped orchards | No consensus | Harder | No consensus | No consensus |
| Livestock | Agrosilvopastoral | Expensive | Harder | No consensus | Unknown |
| | Alley systems | Expensive | Harder | No consensus | No consensus |
| | Forest grazing | No consensus | Harder | Unknown | Unknown |
| | Grazed orchards | Expensive | Harder | No consensus | No consensus |
| | Linear features | Expensive | Harder | No consensus | No consensus |
| | Wood pasture | Unknown | Harder | Unknown | Unknown |
| Orchards | Grazed orchards | Unknown | Harder | Unknown | Unknown |
| | Intercropped orchards | Unknown | Harder | Unknown | Unknown |
| Forestry | Forest farming | No consensus | Harder | No consensus | No consensus |
| | Forest grazing | No consensus | Harder | No consensus | Unknown |
| | Wood pasture | No consensus | Harder | More profitable | No consensus |

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

*Table 40. Consensus on implementation, management and financial performance questions for mixed farming. 'Unknown' is a combination of 'I don't know' and 'There is no evidence' answers*

| Baseline system | Type | Establishment costs | Management ease | Financial performance | |
|---|---|---|---|---|---|
| | | | | With subsidies | No subsidies |
| Annual crops | Between-farms complementarity | Expensive | Harder | No consensus | No consensus |
| | Between-farms synergy | Expensive | Harder | No consensus | No consensus |
| | Within-farm complementarity | No consensus | Harder | No consensus | No consensus |
| | Within-farm synergy | No consensus | Harder | No consensus | No consensus |
| Livestock | Between-farms complementarity | No consensus | Harder | No consensus | No consensus |
| | Between-farms synergy | No consensus | No consensus | No consensus | No consensus |
| | Within-farm complementarity | No consensus | No consensus | No consensus | No consensus |
| | Within-farm synergy | No consensus | No consensus | No consensus | No consensus |

For mixed farming types (Table 40), particularly when starting from an annual cropping baseline and introducing livestock, there was consensus that management would become harder, while establishment costs for setting up between-farm collaborations for these annual crop farms were also seen as expensive. As with the agroforestry types, there was no consensus reached on financial performance, either with or without subsidies.

### 4.3.5 Evidence base

Over 380 references were suggested by participants, and these have been allocated into the themes accordingly under the LUCIM tool. See section 5 for details.

## 4.4 Application in the LUCIM

Results from the Delphi studies feed into the Land Use Change Interactive Map in the following way:

**Land Use Change pathways for increasing resilience to climate impact drivers**

For each *Climate Region* (Northern, Western & Central, Southern) * *Baseline System* (Annual Crops, Livestock, Forestry, Orchards) * *Climate Impact Driver* (mean warming, heat extremes, cold extremes, mean precipitation, heavy precipitation, drought, and severe windstorms), the agroforestry and mixed farming types that were identified as 'Higher' resilience than the baseline are identified, based on the Delphi results, and presented.

**Resilience of each agroforestry and mixed farming type to climate impact drivers**

For each land use type, the resilience to all climate impact drivers, as concluded by the Delphi, is presented on a sunburst diagram so that users can review overall resilience.

**Key mechanisms and properties of land use types that impact resilience**

For each land use type, the themes identified through thematic content analysis that describe the key mechanisms or properties that impact resilience are identified and shown, to give users a better understanding of the drivers underpinning resilience.

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### Caveats and trade-offs

For each land use type, caveats and trade-offs identified via the Delphi are listed, to allow users to consider potential impacts of changing land use towards a more agroecological system. These include the results of the Delphi for the implementation questions (i.e. cost of establishment, ease of management and financial performance), where there was a consensus.

### Evidence base

Literature identified by participants in the Delphi is shown for each land use type, based on the resilience drivers for the type, and any papers specific to the type.

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# 5 Interactive Map

The **LUCIM - Land Use Change Interactive Map** - brings two components together: a spatial and a non-spatial.

The first component explores the spatial approach to identify target areas in Europe (see section 3) where resilient and climate-smart agroforestry and mixed farming systems could be introduced considering existing environmental pressures while providing socio-economic contexts to consider for such introduction. After combining the environmental indicators related to soil, biodiversity, water and climate change, heat maps were produced to highlight the intensity of a total of 14 environmental risks. These can be explored in the tool by looking at the different environmental pressure groups or the final target area map which combines all the indicators. Socio-economic indicators were also chosen to provide context when considering measures to encourage implementation of agroforestry and mixed farming in the target areas. These are mapped at a maximum available administrative resolution for the indicators (NUTS2 level) and can be viewed individually or as a combination of the whole set of variables related to education, economy, and demography.

The second component establishes a guided cascade of context settings and suggests future scenarios of land use/resilience strategies where different models of land use change can be evaluated as pathways towards increased resilience to climate change. In the tool, users are guided through a selection process, choosing first their climate region, then their baseline system, the climate impact driver of interest, and are then presented with the agroecological types that were identified by experts to be more resilient than the baseline for the selected climate impact driver (see section 4). For each agroecological type, resilience level for all impact drivers is shown on a radar diagram, plus a list of the key mechanisms listed by the experts (and summarised using thematic content analysis), supported by scientific references, caveats and trade-offs that should be accounted for when considering implementing such a change in land use, and finally, case studies of real life examples of agroforestry and mixed farming to provide inspiration.

## 5.1 Tool development

Technically, the tool was implemented as a JavaScript/HTML/CSS web app, solely running in the end user's browser, without collecting any information. The main libraries used were **VueJS**[3]and **Bootstrap** [4] for the web interface and the Eurostat libraries **eurostat-map.js**[5] , **gridtiler**[6], and **gridviz**[7] for the maps generation. It is running at the endpoint **https://mvarc.eu/tools/dev/agromix_lucim/** and integrated via an iframe into the AGROMIX website link **https://agromixproject.eu/tools/agromix-land-use-change-interactive-map**.

The maps are dynamically created. The grid maps have an OpenStreetMap background to facilitate localisation in the context of the map, and the grid layer is generated from CSV data tiles, presenting the number of environmental pressures per cell (see section 3). It is possible to zoom in from 25 km$^2$ to 1 km$^2$. The categorical maps, presenting the socio-economic factors, are generated from CSV data files holding NUTS2 level data. This data presents, for each of the considered variables, the value and classification class

[3] https://vuejs.org/
[4] https://getbootstrap.com/
[5] https://github.com/eurostat/eurostat-map.js
[6] https://github.com/eurostat/gridtiler
[7] https://github.com/eurostat/gridviz

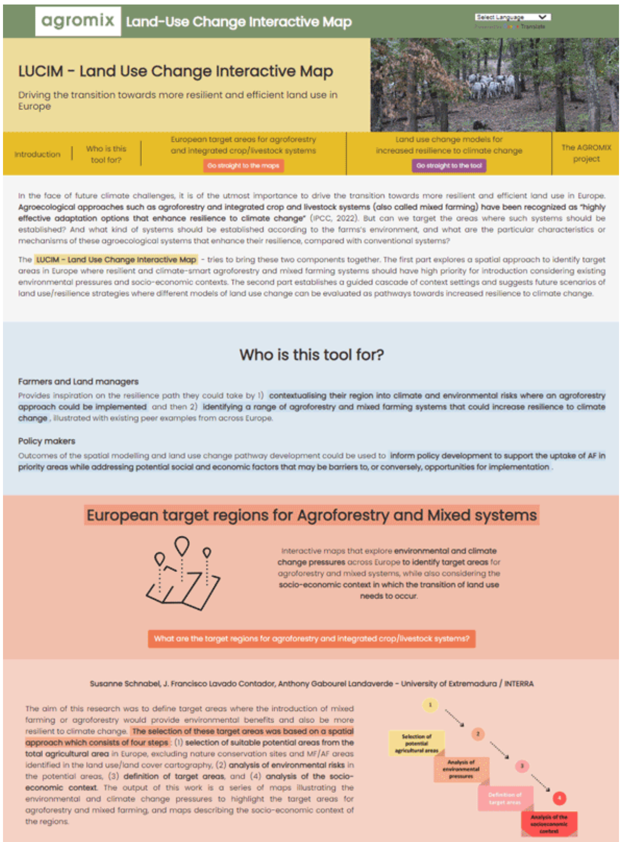
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 862993.

of each NUTS2 region. The results presented are limited to EU27, UK and CH countries. Both maps have automatic tooltips that clearly identify the region and/or the value that specific point.
The results presented for each of the land-use change pathways are also stored in CSV files. These include resilient land-use types and all the data that characterise them, the case studies list and multiple metadata regarding concepts and themes used throughout the tool.

## 5.2 User guide

The following sections show the different screens of the application.

### 5.2.1 The homepage




*Header with Google Translate widget, for **multilingual** website interaction*

*Contextual menu, with **buttons for direct access** to the maps and the tool*

*Small **introduction***

***Target users** of the tool*

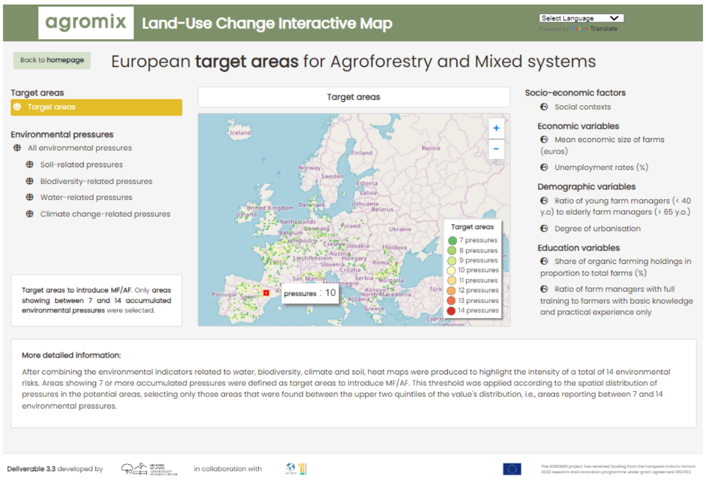
*A brief explanation on the **«European target regions for Agroforestry and Mixed systems»** section*


A brief explanation on the **«Land use change models for increased resilience to climate change»** section

Description of the **AGROMIX project** with further link to the project's page

The always-visible **authorship** of the deliverable, and **funding reference**

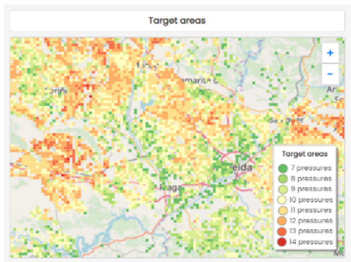
## 5.2.2 The «European target areas» section




**«Target areas»** and **«Environmental pressures»** grid map links **on the left**. **«Socio-economic factors»** categorical map links **on the right**.

Title above the map, **caption for the map on the left**, more **detailed information at the bottom**. Tooltip with **location data on click**.

The maps can be **zoom and dragged** to reach a desired location, displaying higher data resolution:



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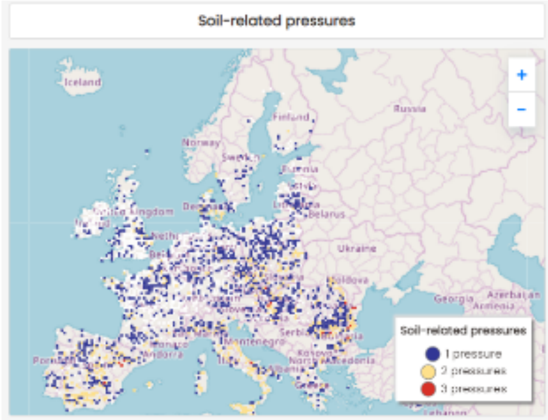
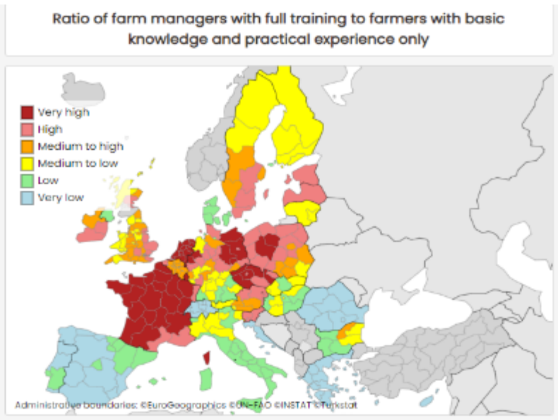
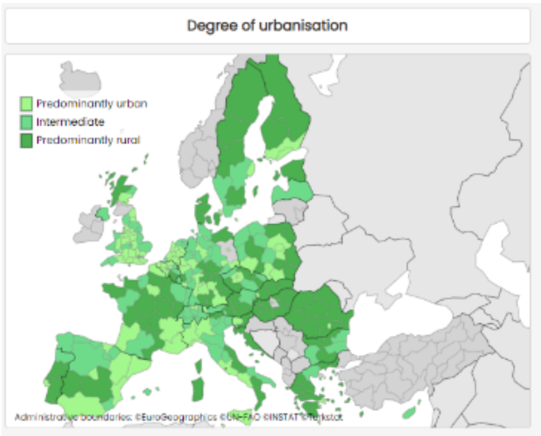
Examples of other maps available:

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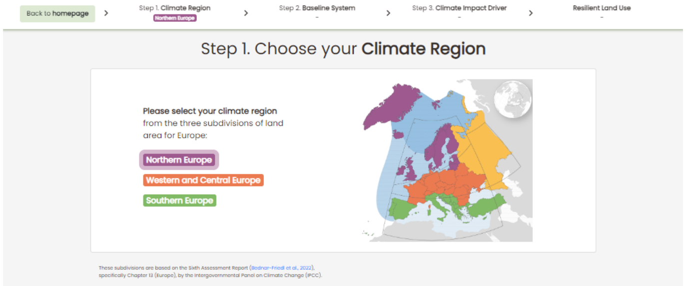
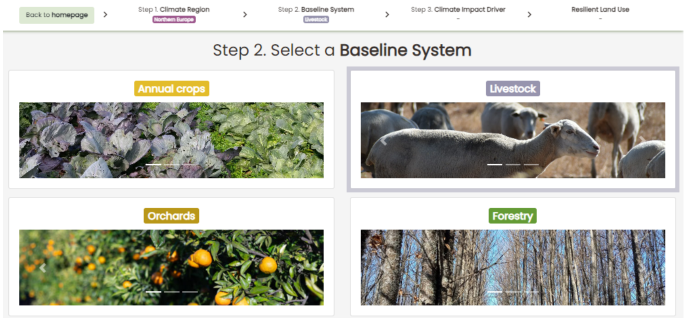
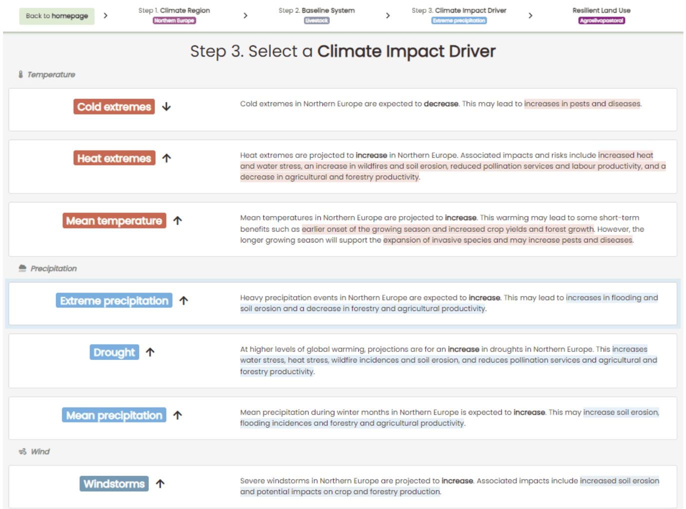
## The «Land-use change models» section



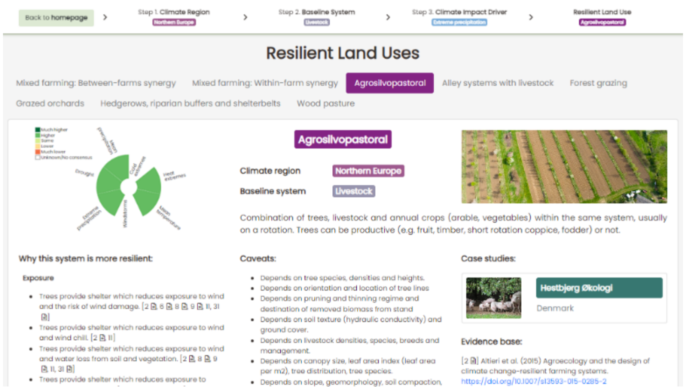

**Step 1**. Choosing between one of the **three IPCC regions**: Northern Europe, Western and Central Europe or Southern Europe




**Step 2**. Choose one of the four **baseline systems**: annual crops, livestock, orchards or forestry.




**Step 3**. Select the climate **impact driver** of interest between the seven available. Each climate impact driver has a short **description of its projected direction** of change and main consequences.




A list of the **agroecological types** that were identified by experts to be **more resilient than the baseline** for the selected region and climate impact driver is then presented. For each type, **resilience level** for all impact drivers is shown **on a radar diagram** (top left corner), plus a list of the **key mechanisms listed by the experts**, supported by **scientific references**, **caveats** and **trade-offs**.

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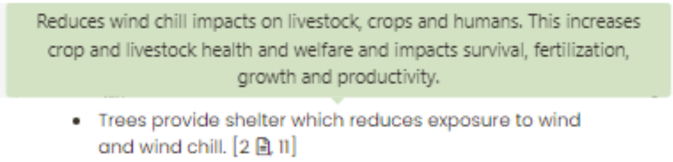
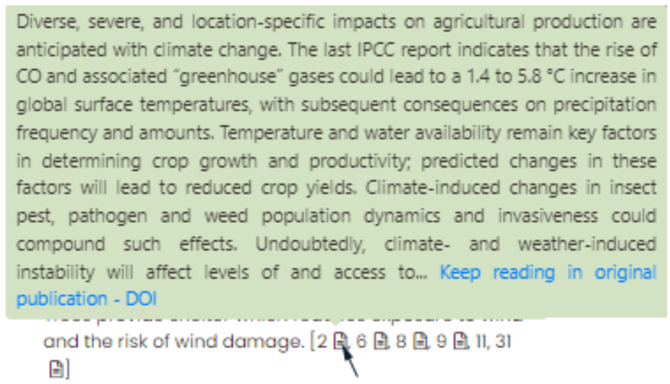
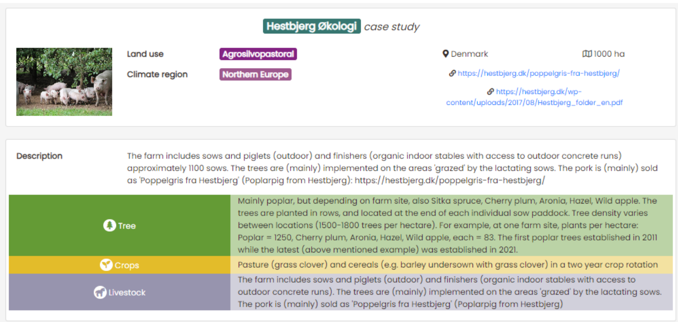



**Hovering over titles and themes** highlights their descriptions.




**Clicking** on the publication symbol opens an **excerpt of the abstract**, with a link for further reading in the **source publication with a DOI**.




For each resilient land use, there's a list of case studies of **real-life examples** of agroforestry and mixed farming to provide inspiration. Each has a **small description**, details on each of the **system components**, and **links for further exploration**.

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# 7 Annex tables and figures

*Annex 1. Extent (km$^2$) of EU countries, UK and CH, and surface area occupied by agricultural land, potential areas, MF/AF areas and protected agricultural land.*

| Country name | Country area | Agricultural land | Potential areas | MF/AF areas | Protected agricultural land |
|---|---|---|---|---|---|
| Austria | 83,945 | 30,705 | 24,138 | 2,732 | 3,835 |
| Belgium | 30,666 | 15,876 | 11,103 | 3,611 | 1,162 |
| Bulgaria | 110,994 | 58,276 | 40,062 | 5,347 | 12,866 |
| Croatia | 56,516 | 22,331 | 10,612 | 5,883 | 5,836 |
| Cyprus | 9,257 | 4,206 | 3,301 | 637 | 268 |
| Czechia | 78,873 | 42,283 | 35,817 | 3,811 | 2,655 |
| Denmark | 43,171 | 30,014 | 26,700 | 1,805 | 1,509 |
| Estonia | 45,345 | 13,579 | 10,266 | 2,572 | 741 |
| Finland | 337,523 | 26,412 | 19,195 | 6,933 | 284 |
| France | 548,942 | 309,202 | 240,005 | 41,408 | 27,789 |
| Germany | 357,661 | 189,741 | 168,304 | 451 | 20,986 |
| Greece | 131,759 | 56,371 | 33,393 | 12,228 | 10,750 |
| Hungary | 93,009 | 60,156 | 49,696 | 1,864 | 8,596 |
| Ireland | 69,940 | 44,962 | 39,448 | 3,838 | 1,676 |
| Italy | 300,650 | 143,525 | 104,769 | 24,756 | 14,000 |
| Latvia | 64,587 | 24,394 | 18,561 | 4,264 | 1,569 |
| Lithuania | 64,897 | 37,027 | 27,731 | 7,645 | 1,651 |
| Luxembourg | 2,596 | 1,271 | 995 | 1 | 274 |
| Malta | 314 | 141 | 96 | 32 | 13 |
| Netherlands | 37,380 | 21,546 | 18,335 | 2,169 | 1,042 |
| Poland | 311,941 | 175,492 | 146,907 | 8,801 | 19,784 |
| Portugal | 88,786 | 39,517 | 16,195 | 15,867 | 7,455 |
| Romania | 238,368 | 135,607 | 106,110 | 13,041 | 16,456 |
| Slovakia | 49,024 | 21,712 | 15,981 | 2,285 | 3,446 |
| Slovenia | 20,272 | 5,638 | 2,511 | 1,762 | 1,365 |
| Spain | 498,556 | 267,190 | 185,759 | 36,205 | 45,226 |
| Sweden | 449,657 | 38,028 | 32,053 | 4,248 | 1,727 |
| Switzerland | 41,286 | 14,310 | 12,849 | 1,258 | 203 |
| United Kingdom | 244,545 | 141,392 | 136,434 | 927 | 4,031 |
| **Total** | **4,410,460** | **1,970,903** | **1,537,326** | **216,380** | **217,197** |

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*Annex 2. Percentage of the area affected by annual mean temperature increase, drought frequency, aridity, and irrigation in proportion to the total potential area by country.*

| Country | Temperature | Country | Drought | Country | HPD | Country | Aridity | Country | Irrigation |
|---|---|---|---|---|---|---|---|---|---|
| Czech Rep | 100.0 | Malta | 100.0 | Luxembourg | 100.0 | Bulgaria | 75.4 | Italy | 33.7 |
| Luxembourg | 100.0 | Portugal | 99.9 | Switzerland | 99.7 | Sweden | 72.3 | Greece | 28.3 |
| Austria | 100.0 | Spain | 98.9 | Slovakia | 89.9 | Denmark | 72.3 | Romania | 23.8 |
| Belgium | 100.0 | Bulgaria | 95.2 | Austria | 88.2 | Estonia | 70.7 | Denmark | 19.4 |
| Slovakia | 100.0 | Greece | 93.4 | France | 88.1 | Finland | 68.0 | Spain | 16.9 |
| Poland | 100.0 | Cyprus | 93.0 | Latvia | 79.9 | France | 62.0 | Netherlands | 14.5 |
| Hungary | 99.9 | Italy | 67.4 | Slovenia | 74.0 | Portugal | 60.6 | Slovakia | 13.0 |
| Portugal | 99.9 | France | 60.0 | Belgium | 63.9 | Switzerland | 59.2 | Portugal | 12.5 |
| Germany | 99.9 | Romania | 59.2 | Sweden | 62.3 | Romania | 56.9 | Bulgaria | 11.7 |
| Slovenia | 99.9 | Ireland | 30.2 | Germany | 61.2 | Greece | 52.2 | Cyprus | 8.6 |
| Italy | 99.8 | UK | 29.7 | Lithuania | 60.3 | Spain | 51.6 | France | 6.4 |
| Lithuania | 99.8 | Belgium | 23.8 | Czech Rep | 59.8 | Netherlands | 48.7 | Austria | 2.6 |
| Switzerland | 99.8 | Luxembourg | 15.0 | Italy | 47.9 | UK | 47.0 | Germany | 1.6 |
| Netherlands | 99.7 | Netherlands | 10.7 | Croatia | 47.9 | Ireland | 39.7 | Hungary | 1.4 |
| Spain | 99.7 | Croatia | 6.6 | Poland | 45.4 | Latvia | 36.8 | Sweden | 1.4 |
| Cyprus | 99.2 | Germany | 4.9 | Hungary | 31.8 | Belgium | 26.1 | Switzerland | 1.0 |
| Croatia | 99.2 | Denmark | 2.1 | Denmark | 21.7 | Italy | 25.5 | Czech Rep | 0.7 |
| Bulgaria | 99.2 | Poland | 1.1 | Spain | 21.5 | Austria | 22.8 | Belgium | 0.1 |
| Greece | 98.9 | Czech Rep | 0.4 | Estonia | 9.2 | Lithuania | 21.4 | Slovenia | 0.0 |
| Romania | 98.1 | Finland | 0.2 | Netherlands | 8.4 | Luxembourg | 19.8 | Poland | 0.0 |
| Denmark | 97.9 | Slovakia | 0.2 | Greece | 6.1 | Slovenia | 17.8 | Estonia | 0.0 |
| Malta | 96.7 | Hungary | 0.1 | UK | 6.0 | Croatia | 17.2 | Finland | 0.0 |
| France | 89.4 | Latvia | 0.1 | Portugal | 4.3 | Poland | 15.6 | Croatia | 0.0 |
| Sweden | 88.2 | Switzerland | 0.0 | Bulgaria | 2.0 | Germany | 8.2 | Ireland | 0.0 |
| Latvia | 82.7 | Austria | 0.0 | Romania | 1.4 | Slovakia | 8.0 | Lithuania | 0.0 |
| UK | 78.5 | Sweden | 0.0 | Malta | 0.5 | Cyprus | 6.8 | Luxembourg | 0.0 |
| Ireland | 1.6 | Estonia | 0.0 | Ireland | 0.0 | Hungary | 3.1 | Latvia | 0.0 |
| Estonia | 1.5 | Lithuania | 0.0 | Cyprus | 0.0 | Czech Rep | 1.4 | Malta | 0.0 |
| Finland | 0.0 | Slovenia | 0.0 | Finland | 0.0 | Malta | 0.0 | UK | 0.0 |
| Q1 | 93.1 | | 0.1 | | 5.1 | | 16.4 | | 1.1 |
| Median | 99.7 | | 6.6 | | 45.4 | | 36.8 | | 7.5 |
| Q3 | 99.9 | | 63.7 | | 68.9 | | 59.9 | | 16.3 |

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

*Annex 3. Percentage of the area affected by nitrogen surplus, potential threats to soil biological functions, potential threats to soil fauna, and potential threats to soil microorganisms, in proportion to the total potential area by country.*

| Country | Nitrogen | Country | Pest control | Country | Soil biol | Country | Soil fauna | Country | Soil micro |
|---|---|---|---|---|---|---|---|---|---|
| Netherlands | 90.0 | Cyprus | 80.7 | Ireland | 75.4 | Netherlands | 84.0 | Ireland | 76.3 |
| Poland | 86.9 | Malta | 73.2 | Belgium | 64.9 | Ireland | 77.0 | Netherlands | 72.2 |
| Belgium | 80.8 | Hungary | 71.6 | Romania | 63.6 | Belgium | 69.1 | Belgium | 67.8 |
| Germany | 77.0 | Bulgaria | 68.9 | Spain | 59.4 | Germany | 59.7 | UK | 56.7 |
| Denmark | 71.3 | Romania | 65.9 | Netherlands | 57.6 | UK | 56.9 | Spain | 53.5 |
| Czech Rep | 62.4 | Ireland | 64.5 | Czech Rep | 56.7 | Denmark | 54.6 | Romania | 50.9 |
| Ireland | 50.9 | Spain | 61.6 | UK | 55.7 | Czech Rep | 54.0 | Germany | 50.3 |
| France | 44.9 | Netherlands | 60.5 | Malta | 49.6 | France | 52.5 | France | 47.8 |
| Italy | 35.7 | Slovakia | 59.9 | Hungary | 47.1 | Spain | 48.4 | Hungary | 45.7 |
| Slovenia | 34.6 | Czech Rep | 56.0 | France | 45.2 | Romania | 47.2 | Denmark | 44.7 |
| UK | 27.7 | Denmark | 54.5 | Germany | 43.6 | Slovenia | 46.9 | Malta | 43.4 |
| Luxembourg | 27.5 | Greece | 52.9 | Croatia | 42.4 | Luxembourg | 41.7 | Luxembourg | 42.4 |
| Austria | 27.0 | Poland | 50.5 | Luxembourg | 40.5 | Italy | 21.6 | Czech Rep | 42.0 |
| Croatia | 20.7 | Portugal | 50.3 | Slovenia | 32.0 | Austria | 17.5 | Slovenia | 38.8 |
| Hungary | 18.5 | Germany | 49.5 | Denmark | 31.1 | Poland | 15.4 | Italy | 23.0 |
| Greece | 14.4 | Lithuania | 47.6 | Italy | 23.2 | Greece | 11.3 | Austria | 16.3 |
| Portugal | 13.2 | UK | 44.6 | Greece | 16.6 | Hungary | 10.3 | Greece | 16.3 |
| Switzerland | 9.4 | France | 44.3 | Slovakia | 14.5 | Portugal | 10.1 | Slovakia | 14.9 |
| Cyprus | 7.8 | Italy | 44.0 | Austria | 13.8 | Finland | 7.9 | Poland | 13.4 |
| Finland | 7.6 | Croatia | 37.7 | Poland | 11.4 | Sweden | 7.3 | Portugal | 10.0 |
| Slovakia | 7.3 | Belgium | 34.2 | Finland | 8.0 | Slovakia | 3.8 | Finland | 8.9 |
| Lithuania | 6.9 | Austria | 23.3 | Portugal | 7.7 | Cyprus | 3.3 | Cyprus | 7.8 |
| Spain | 6.8 | Slovenia | 20.3 | Cyprus | 7.6 | Lithuania | 3.3 | Sweden | 6.8 |
| Estonia | 6.7 | Estonia | 20.2 | Bulgaria | 6.5 | Estonia | 3.3 | Bulgaria | 6.4 |
| Sweden | 5.6 | Sweden | 18.9 | Latvia | 5.6 | Bulgaria | 3.3 | Latvia | 6.2 |
| Romania | 2.0 | Luxembourg | 17.9 | Sweden | 5.6 | Latvia | 2.8 | Lithuania | 4.0 |
| Latvia | 1.7 | Latvia | 10.0 | Lithuania | 3.8 | Malta | 2.4 | Estonia | 3.1 |
| Bulgaria | 1.5 | Finland | 9.0 | Estonia | 2.4 | Croatia | 0.6 | Croatia | 1.1 |
| Malta | 0.0 | Switzerland | 0.8 | Switzerland | 0.8 | Switzerland | 0.3 | Switzerland | 0.1 |
| Q1 | 6.9 | | 21.8 | | 7.6 | | 3.3 | | 7.3 |
| Median | 18.5 | | 49.5 | | 31.1 | | 15.4 | | 23.0 |
| Q3 | 47.9 | | 61.1 | | 52.7 | | 53.3 | | 49.0 |

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*Annex 4. Percentage of the area affected by pollinator potential, water erosion, and wind erosion, in proportion to the total potential area by country.*

| Country | Pollinator | Country | SOC | Country | Water erosion | Country | Wind erosion |
|---|---|---|---|---|---|---|---|
| Italy | 76.2 | Bulgaria | 83.7 | Italy | 71.6 | Denmark | 40.2 |
| Spain | 74.8 | Denmark | 79.0 | Slovenia | 69.1 | Bulgaria | 18.8 |
| Bulgaria | 66.9 | Hungary | 74.8 | Austria | 64.3 | Netherlands | 13.0 |
| Portugal | 65.1 | Italy | 74.4 | Malta | 62.7 | Romania | 9.3 |
| Ireland | 62.8 | Spain | 72.9 | Luxembourg | 55.8 | Sweden | 7.3 |
| France | 60.9 | Portugal | 72.5 | Spain | 55.2 | United Kingdom | 6.6 |
| Cyprus | 59.9 | Slovakia | 70.0 | Greece | 53.3 | Greece | 3.3 |
| Romania | 59.8 | Greece | 69.5 | Slovakia | 48.0 | Czechia | 3.0 |
| Greece | 58.4 | Lithuania | 69.1 | Bulgaria | 45.0 | Slovakia | 3.0 |
| Croatia | 30.8 | Romania | 66.9 | Czechia | 42.7 | Spain | 2.8 |
| United Kingdom | 28.9 | Poland | 66.8 | Romania | 42.7 | Italy | 2.2 |
| Finland | 27.5 | Czechia | 65.6 | Portugal | 39.1 | Finland | 1.9 |
| Slovakia | 25.1 | Sweden | 46.7 | Croatia | 30.6 | Hungary | 1.7 |
| Hungary | 22.0 | Croatia | 32.3 | Cyprus | 29.4 | Estonia | 1.4 |
| Luxembourg | 18.8 | Austria | 31.5 | Belgium | 28.7 | Germany | 1.1 |
| Denmark | 16.4 | France | 30.9 | France | 28.0 | Belgium | 1.1 |
| Slovenia | 11.8 | Germany | 29.4 | Germany | 25.9 | France | 0.9 |
| Netherlands | 10.3 | Finland | 23.6 | Hungary | 24.8 | Poland | 0.5 |
| Germany | 10.3 | Estonia | 21.6 | United Kingdom | 18.9 | Austria | 0.4 |
| Belgium | 9.0 | Belgium | 10.3 | Poland | 16.6 | Ireland | 0.3 |
| Sweden | 8.2 | United Kingdom | 9.8 | Sweden | 10.9 | Lithuania | 0.1 |
| Poland | 4.7 | Latvia | 8.2 | Ireland | 8.7 | Latvia | 0.1 |
| Czechia | 4.4 | Slovenia | 5.6 | Lithuania | 5.5 | Portugal | 0.0 |
| Malta | 2.1 | Luxembourg | 1.3 | Switzerland | 5.4 | Switzerland | 0.0 |
| Switzerland | 1.5 | Netherlands | 1.2 | Latvia | 4.5 | Cyprus | 0.0 |
| Estonia | 1.2 | Switzerland | 0.5 | Estonia | 1.9 | Croatia | 0.0 |
| Lithuania | 0.2 | Ireland | 0.0 | Denmark | 1.9 | Luxembourg | 0.0 |
| Latvia | 0.2 | Cyprus | 0.0 | Finland | 1.8 | Malta | 0.0 |
| Austria | 0.0 | Malta | 0.0 | Netherlands | 0.6 | Slovenia | 0.0 |
| | 4.5 | | 6.9 | | 7.1 | | 0.5 |
| | 18.8 | | 31.5 | | 28.7 | | 1.9 |
| | 59.8 | | 69.8 | | 50.6 | | 6.6 |

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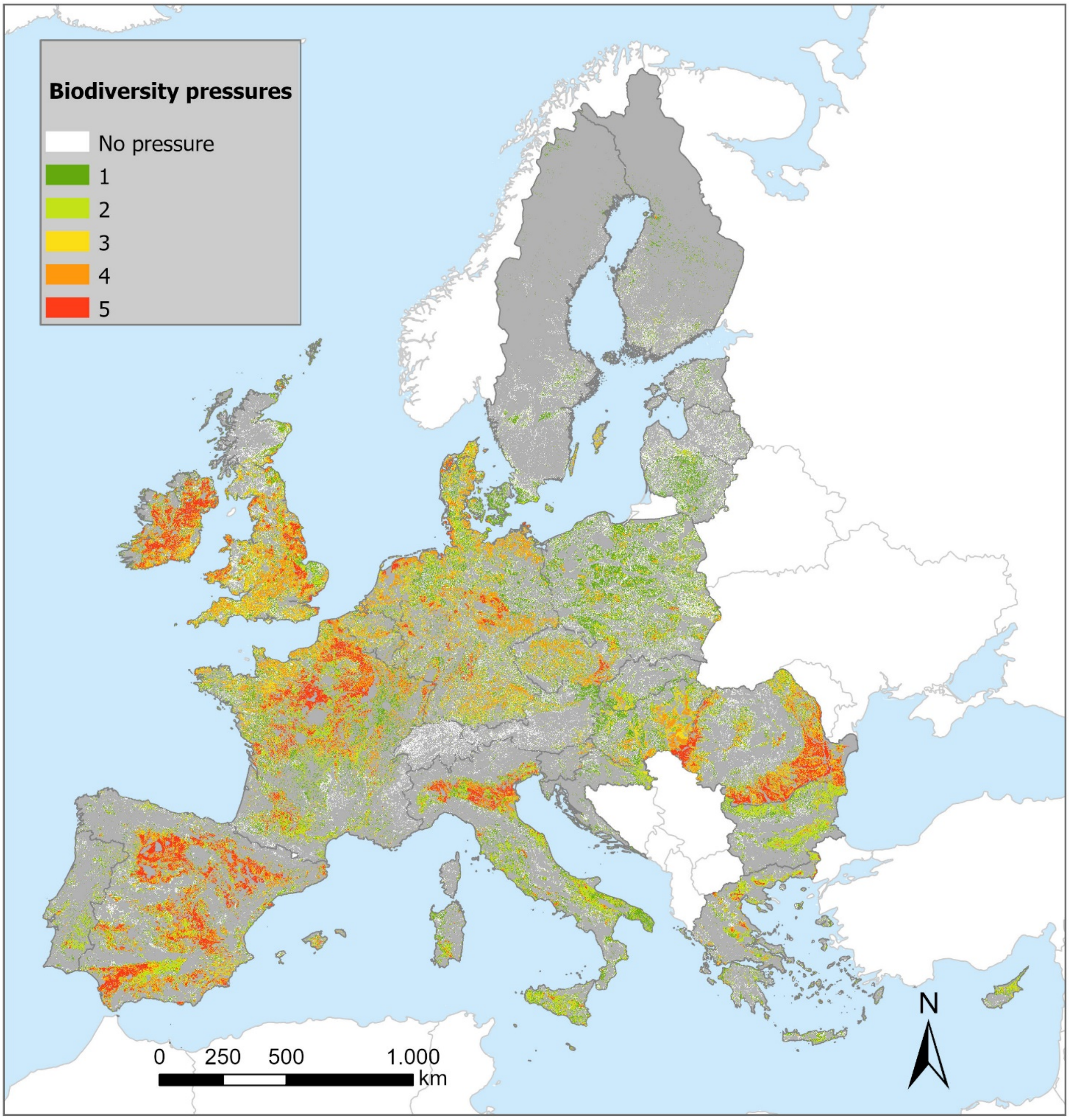
*Annex 5. Map of accumulated biodiversity-related pressures (0-5 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: pest control index, pollinator potential, potential threats to soil biological functions, potential threats to soil fauna and potential threats to soil microorganisms.*

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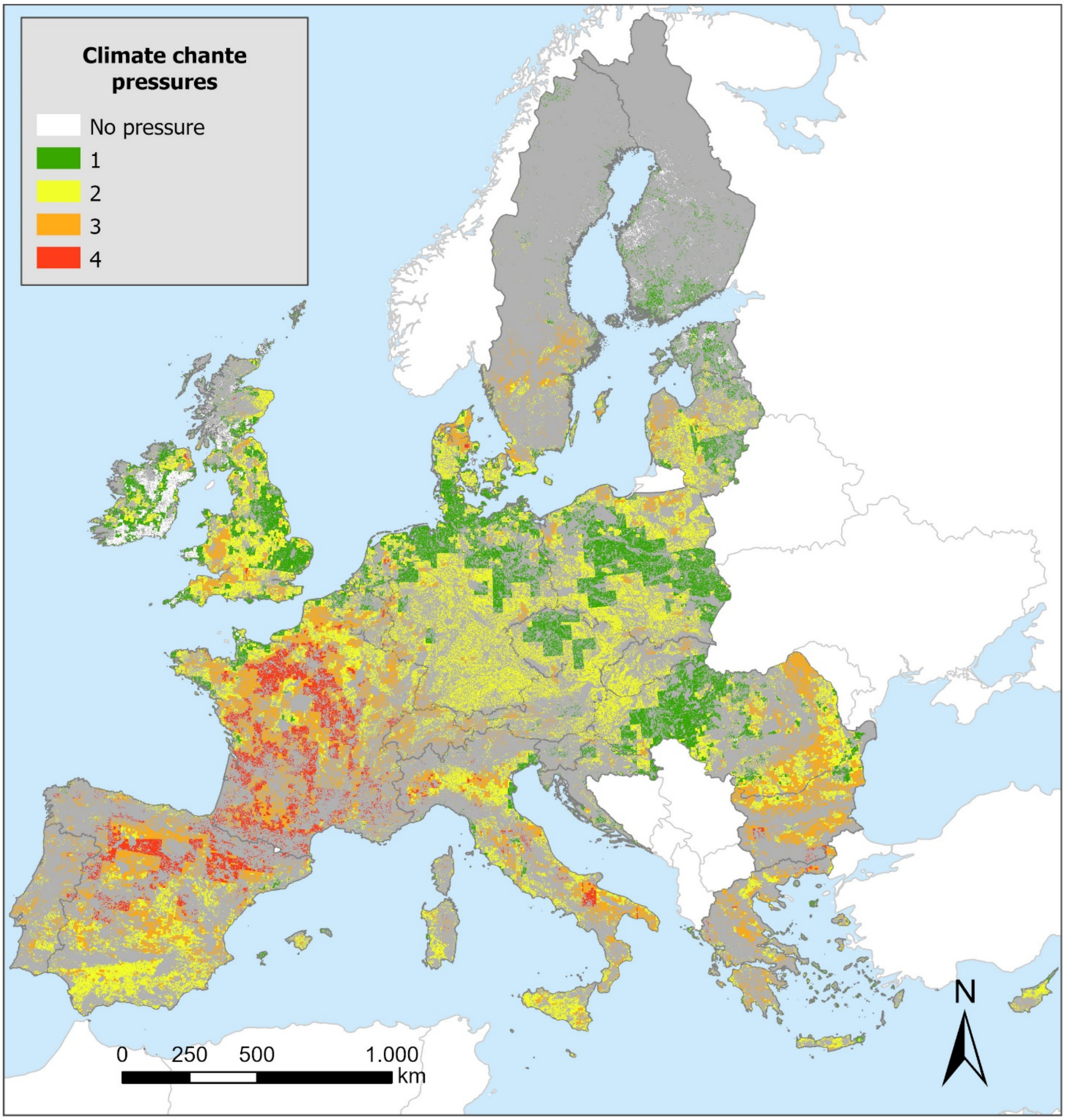
*Annex 6. Map of accumulated climate change pressures (0-4 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: annual mean temperature change, aridity index, drought frequency and heavy precipitation days.*

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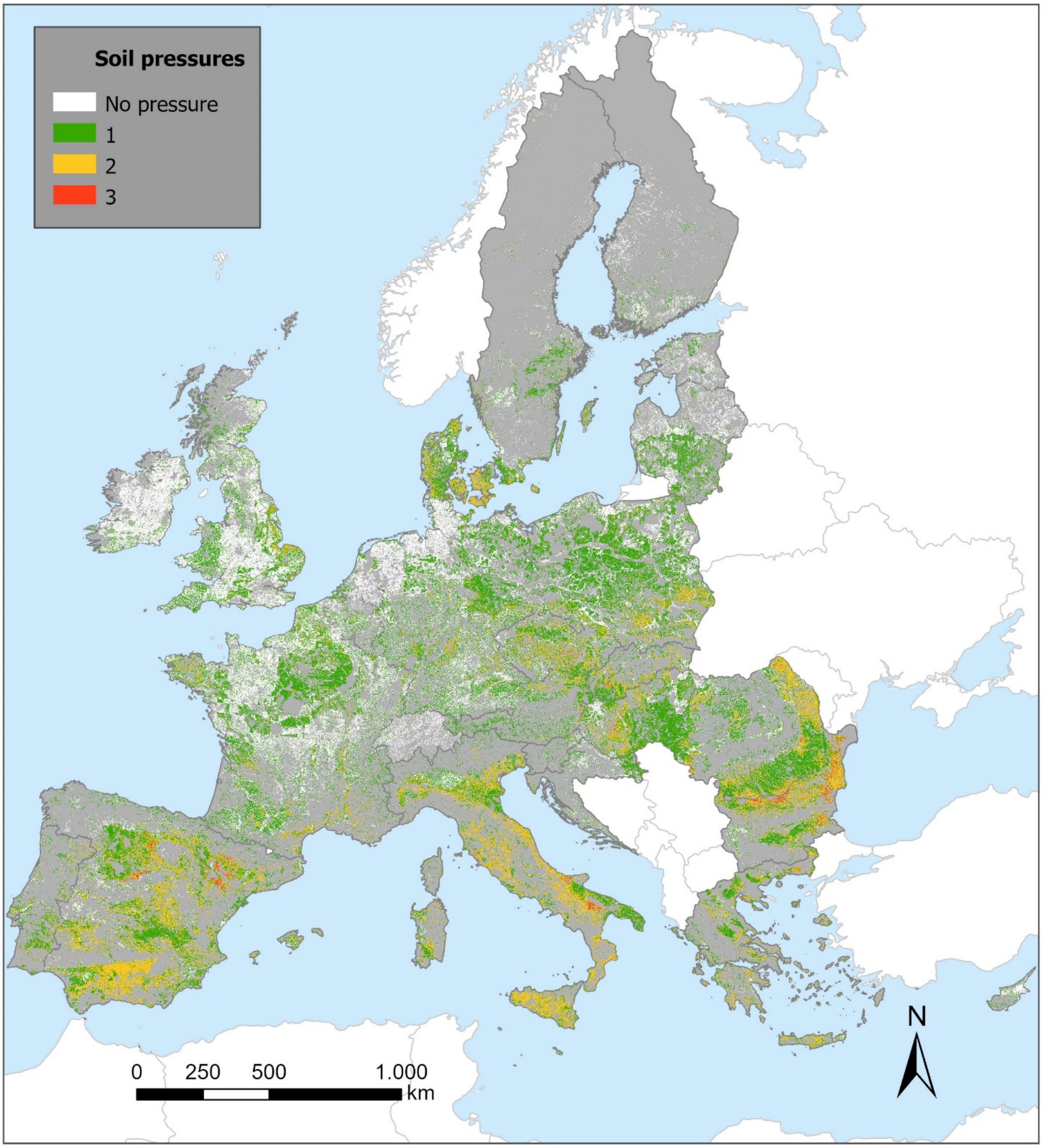
*Annex 7. Map of accumulated soil pressures (0-3 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: water erosion, wind erosion, and soil organic carbon (SOC) saturation capacity.*

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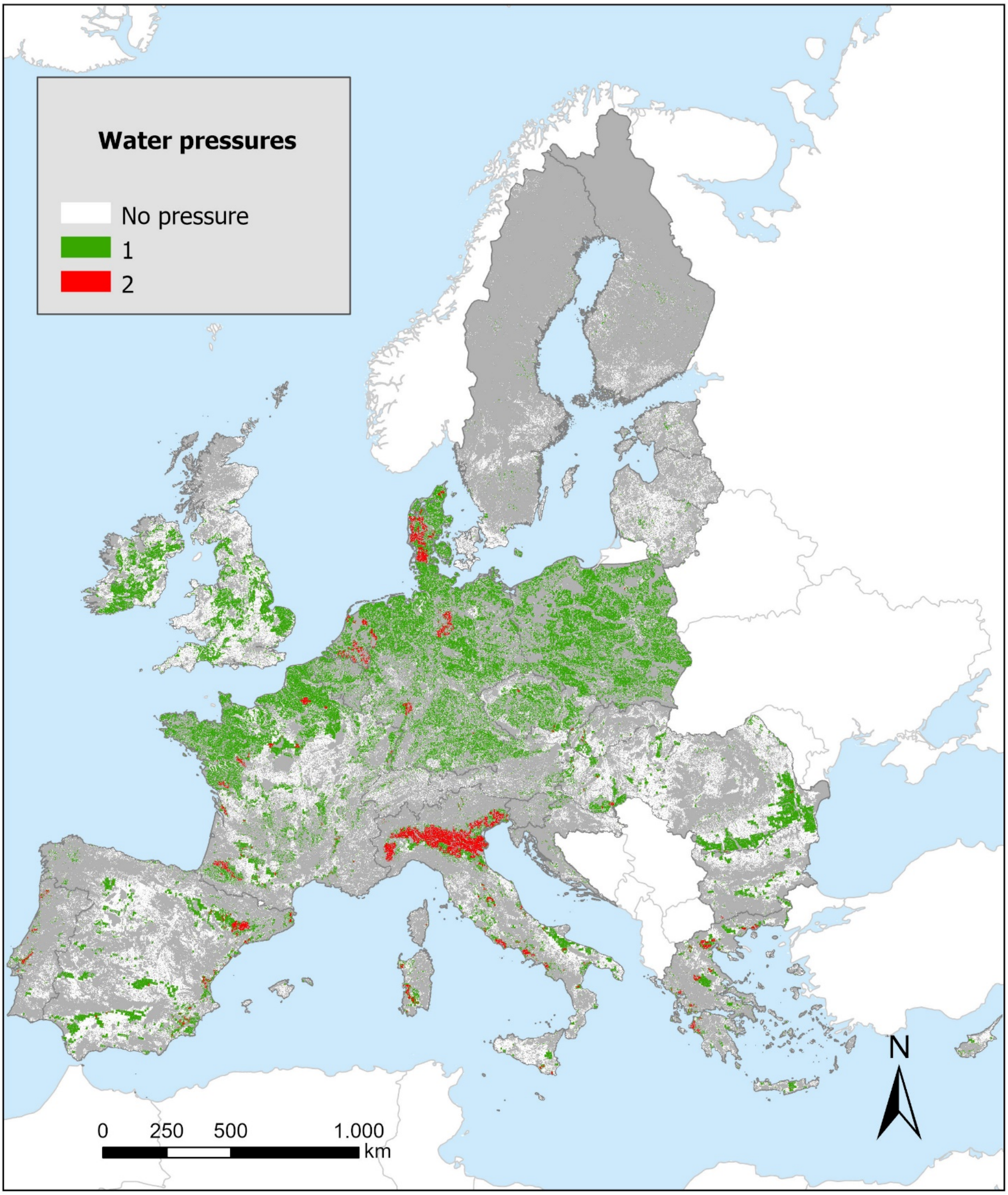
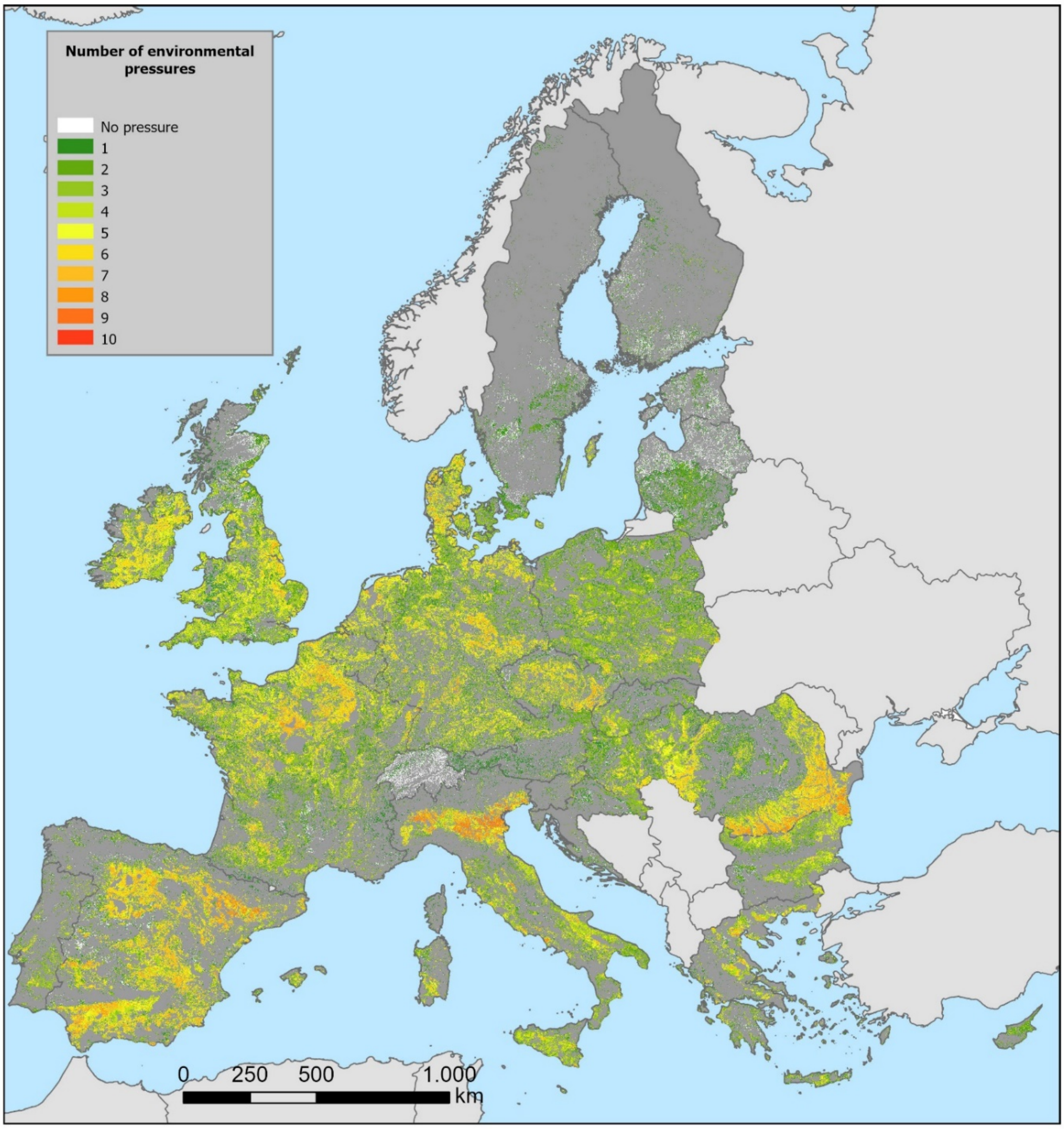
*Annex 8. Map of accumulated water pressures (0-2 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming: nitrogen surplus and percentage of irrigated areas.*




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

*Annex 9. Map of accumulated biodiversity, soil and water-related pressures (0-10 environmental pressures) in the potential agricultural area to introduce agroforestry and mixed farming. Soils: water erosion, wind erosion, and soil organic carbon (SOC) saturation capacity. Biodiversity: pest control index, pollinator potential, potential threats to soil biological functions, potential threats to soil fauna and potential threats to soil microorganisms. Water: nitrogen surplus and percentage of irrigated areas.*

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