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EFFICIENT AND RESILIENT MIXED FARMING & AGROFORESTRY

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GA no:	862357
Action full title:	Multi-actor and transdisciplinary development of efficient and resilient MIXED farming and agroforestry-systems
Call/Topic:	Climate-smart and resilient farming
Type of action:	Research and Innovation action (RIA)
Starting date of action:	1 October 2020
Project duration:	53 months
Project end date:	28 February 2025
Deliverable number:	D2.4
Deliverable title:	Report on impact of innovations tested in detail on efficiency and resilience of farm systems
Document version:	Ver1
WP number:	WP2
Lead beneficiary:	05-SRUC
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Nature of deliverable:	R
Dissemination level:	PU
Delivery date from Annex 1:	M50
Actual delivery date:	29.12.2024 (M51)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862357.

Executive Summary

The aim of Task 2.4 was to field test four innovative strategies for increased integration. The innovation studies were situated in North (DK), North West (UK), Eastern (PL) and Southern Europe (PL) and utilised both research station and on-farm experiments. The four studies were:

- ***a)*** *UK –sheep grazing winter cereals for winter fodder and soil quality (network theme 1) (SRUC)*
- ***b)*** *DK – animal welfare and environmental impact of silvopastoral systems (network theme 2) (AU)*
- ***c)*** *PT – conservation agriculture in Mediterranean agro-forest-pastoral systems (network theme 2) (ISA)*
- ***d)*** *PL – impact of hedgerows on arable productivity (network theme 3) (FSK-JUCHOW)*

In the UK (a), winter grazing of cereals provided higher energy value feed than standard silage and had no significant impact on yield of the winter cereal. In Denmark (b), the willow provided a high crude protein diet to the organic pigs. Increasing the stocking density of the pigs increased both the grazing of the willow and soil nutrient loading. Regardless of the stocking rate, the willow recovered after a grazing period. In the Montado in Portugal (c), the intensification of cattle production has had a detrimental impact on both the long-term productivity and biodiversity value of ecosystem. Encouraging low input systems which include sheep is improving the sustainability of these systems. In Poland (d), the inclusion of trees along field boundaries in Poland is improving the soil biodiversity, and is increasing the soil moisture content, and reducing the soil temperature in the vicinity of the tree. This is proving to be beneficial for the productivity of the sown crop.

More detailed results from each of the innovation studies are provided in a leaflet which aims to provide accessible information for practitioners and policy makers. The leaflets complement material available on the MIXED website regarding these innovation studies.

Abbreviations

D	Deliverable
EC	European Commission
WP	Work Package
WT	Work Task

Contents

1 Background

Four innovation strategies were selected before the project started which represent different types of MiFAS as described by the 3 network themes (Theme 1. Arable crops integrated with livestock: Theme 2 Livestock and energy crops (or other fodder trees): Theme 3 Fruit/nut trees/bushes and livestock or arable crops). These were selected as they were examples of innovations that would benefit from additonal scientific data allowing guidance to be provided on the management of these systems for farmers but also their potential to deliver desirable policy benefits. These pre-existing systems were selected because the project team considered that these innovations could be refined to demonstrate how their contribution to the delivery of resilient, efficient MiFAS systems adapted to climate change could be enhanced through understanding the implications of management options. The advantage of using pre-existing systems with trees (as in 3 of the selected innovation studies) was that the trees were already established allowing measurement of systems with a certain degree of maturity rather than representative of previous land uses. These studies were situated in North (DK), North West (UK), Eastern (PL) and Southern Europe (PL) using both research station (2.4 a, b) and on/farm experiments (2.4 a, c, d).

2.4a UK –sheep grazing winter cereals for winter fodder and soil quality (network theme 1) (SRUC)

2.4b DK – animal welfare and environmental impact of silvopastoral systems (network theme 2) (AU)

2.4c PT – conservation agriculture in Mediterranean agro-forest-pastoral systems (network theme 2) (ISA)

2.4d PL – impact of hedgerows on arable productivity (network theme 3) (FSK-JUCHOW)

In the UK, sheep grazing of winter cereals was a traditional practice in the days before farms became highly specialised. In recent years, there has been renewed interest in this traditional practice by both livestock and arable farmers. From the perspective of the livestock farmer, this has been driven by the desire to mitigate the risks from extreme events. These extreme events can cause both flooding of pastures and a reduction in the yields of hay and silage due to drought conditions. In the case of the arable farmer, there is interest in both financial aspects, and the potential positive impact that the grazing of winter cereals may have on soil health. Farmers were looking for guidance on practical issues such as the forage quality of growing cereals, how long they could be grazed for and whether there were positive or negative impacts on soils.

In Denmark, organic fattening pigs have typically been fattened on indoor housing as this allows the slurry and manure to be collected. Therefore the application of the collected manure to soil is managed, minimising losses of nutrients. However, this practice does not align with organic systems where pigs should have access to the natural environment. Allowing pigs to graze grass usually resuts in the destruction of the grass, and the risk of a high pollution load. Introducing fast growing tree species into the system provides potential animal welfare benefits via providing shelter and interest for the pigs. The trees are also able to take up available nutrients added to the soil via urination and dunging. The trial was therefore established to assess the effect of allowing the pigs, managed with 2 different stocking rates, to graze on willows on animal welfare and the soil nutrient load. This has important consequences for protecting water quality which is a significant issue in Danish agriculture.

The Montado in Portugal is a traditional grazing system with cork oaks. While cork is used less for bottle stoppers than it was in the past, the cork industry is being sustained through a range of uses including insulation and flooring. In recent times, the farmers have been encouraged to intensify cattle production. This has been coupled with a decline in the number of sheep, which has reduced diversity in the pasture. The combination of increased cattle and reduced sheep numbers has led to a decline in the regeneration of natural oak, risking the unique ecosystem. The innovation practice that has been trialled is the reintroduction of sheep. The impacts of this practice on self-sufficiency and nitrogen footprint have been assessed. Diversifying the agricultural activity has the potential to reduce risk in a changing climate.

In the biodynamic farm in Poland, improving the hedgerows by establishing more trees in the hedgerows has been driven by the desire to improve the biodiversity in the landscape. Large arable areas are at significant risk from wind erosion. In addition to improving the biodiversity, trees can also provide provisioning and regulation services. The innovation trial was established to assess the impact of both old and newly established trees on soil health, moisture and temperature as well as productivity. This has been assessed by measuring these characteristics at different distances from the trees.

2 Methodology

The UK and DK teams established replicated trials to assess the effectiveness of the innovations, while PT and PL have conducted their trials on network farms. It was agreed in MS11 that the results would be presented in leaflet format, which is an accessible format for practitioners and policymakers.

3 Results

The leaflets, provided in the Annex, highlight the results and the lessons learnt from each of the case studies. They complement posters and webinars that are available on the MIXED website. Highlights are provided here:

UK –sheep grazing winter cereals for winter fodder and soil quality (network theme 1) (SRUC)

- Winter cereals are very resilient to sheep grazing
- There is little impact on the yield or crop quality of the cereal or on soil health
- The feed value of winter cereals is better than silage
- The lessons learned have already been adopted in the French network

DK – animal welfare and environmental impact of silvopastoral systems (network theme 2) (AU)

- Providing the pigs with access to an outdoor range area with willow does not negatively affect their performance
- Willow is highly palatable to pigs when foraged in spring
- Willow is resilient to grazing and recovers well
- Pig nutritional value of willow is high in protein but low in energy

PT – conservation agriculture in Mediterranean agro-forest-pastoral systems (network theme 2) (U Lisboa)

- Encouraging low-input systems that capitalize on natural resources is critical for the long-term sustainability of mixed farming systems
- Policies should consider supporting livestock systems that may be labour intensive but that are environmentally beneficial.
- Low input sheep farms play a critical role in in maintaining the Montado landscape and soil health.

- Traditional knowledge should be integrated into modern management strategies, particularly in mixed farming systems that rely on ecological processes.
- Diets high in locally available resources and low synthetic inputs can reduce the nitrogen footprint of meat production.
- Diversity provides an economic buffer against poor years, such as low livestock yields due to drought or increased feed prices.

PL – impact of hedgerows on arable productivity (network theme 3) (FSK-JUCHOW)

- The impact of trees on the provision of ecosystem services is dependent on the age of the trees, the crops planted and the agricultural management
- Trees may reduce the yield and pollination
- Trees increased the number of beneficial organisms and reduced the number of pests
- Trees lowered the temperature and increased moisture of adjacent soil
- Trees increased soil organic carbon content and biological activity

4 Annex

Leaflets for:

- UK –sheep grazing winter cereals for winter fodder and soil quality (network theme 1) (SRUC)
- DK – animal welfare and environmental impact of silvopastoral systems (network theme 2) (AU)
- PT – conservation agriculture in Mediterranean agro-forest-pastoral systems (network theme 2) (U Lisboa)
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The integration of grazing livestock into arable farming systems has positive impacts on animal, crop & soil parameters while maintaining yield

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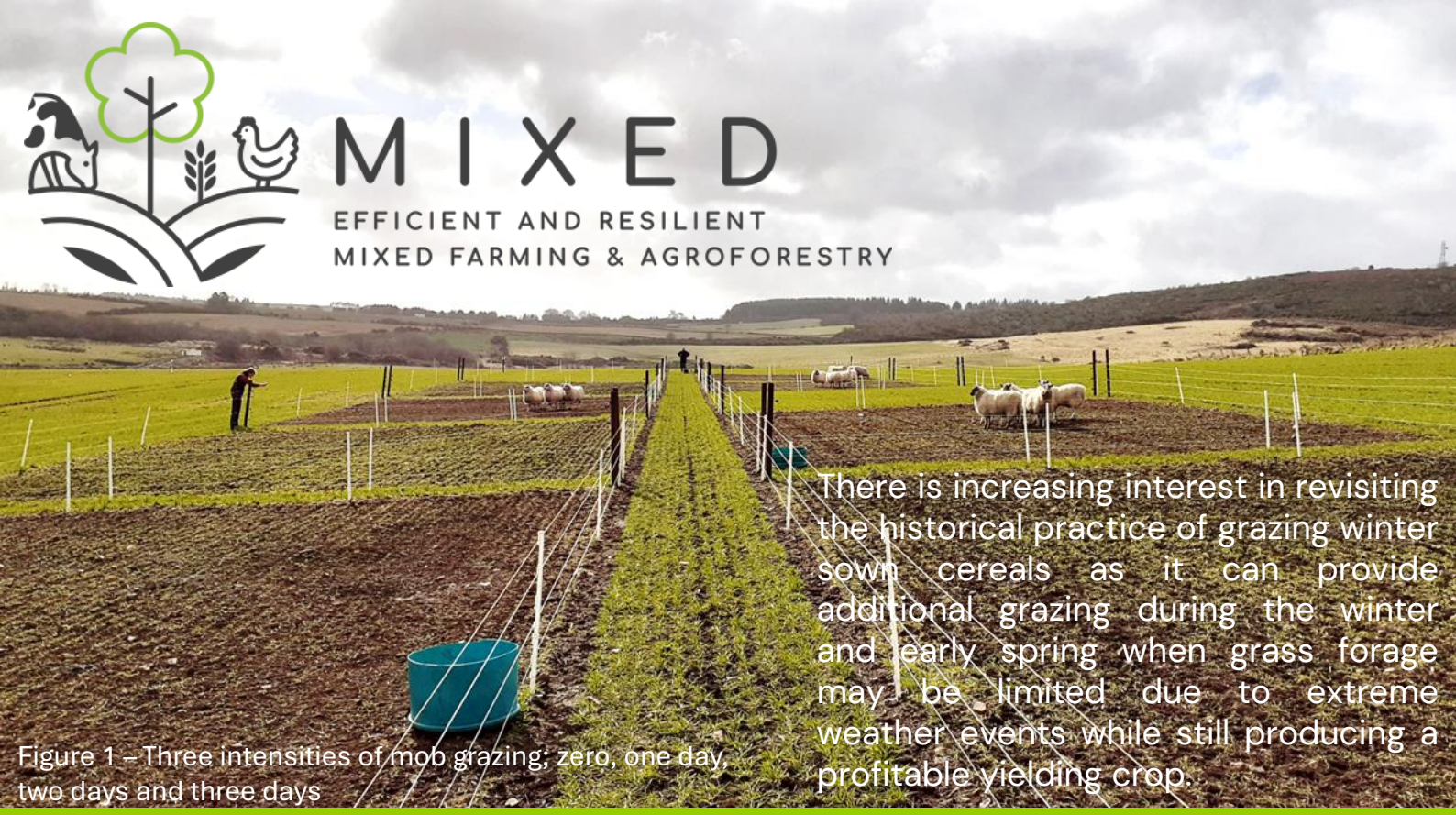

There is increasing interest in revisiting the historical practice of grazing winter sown cereals as it can provide additional grazing during the winter and early spring when grass forage may be limited due to extreme weather events while still producing a profitable yielding crop.

Figure 1 – Three intensities of mob grazing; zero, one day, two days and three days

Background

Grazing sheep on winter cereals was once common practice but has declined with the rise modern agriculture.

If successful, the practice should help fill the winter feed gap, building resilience against more extreme weather events and the associated lack of forage / fodder.

Trials in northeast Scotland over three years, with ungrazed and grazed sites, tested the impact of grazing on winter cereals across a range of crop and soil quality measures.

Methodology

Forage biomass and feeding value were assessed every few weeks from November until early May and the live weight gain of lambs was modelled.

Disease and weed pressure were assessed during the season as well as soil quality indicators using Visual Evaluation of Soil Structure (VESS) and counts of earthworms as a proxy.

At harvest, plots were yielded with a combine harvester and grain quality and soil quality indicators assessed.

We hypothesised that the grazing of winter cereals can provide a valuable winter feed source for ruminants, as well as maintain acceptable grain & straw yields, while maintaining soil "health".

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"What lessons can we learn from our innovation study which helps us to improve the efficiency and resilience of mixed farming systems in Europe?"

Figure 2 – Same site as Figure 1 but several months later with no viable differences in crop growth

Analysis of the feed value and modelled live weight gains of sheep showed equivalent if not better results than from a high-quality silage.

Winter cereals seem very resilient to sheep grazing & recover well whether "mob" grazed **or** extensively grazed as long as grazing takes place prior to stem extension. There is also evidence for a reduction in severity of crop disease early in the season.

No significant reduction in crop yield at harvest. An early sowing date / early grazing (pre-Christmas) and a typical sowing date / later grazing (e.g. March) all seem to work equally well. Potential to check very "forward" crops – e.g. due to mild winter.

Evidence of increased earthworm abundance and no detriment to soil structure.

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The lessons learned here in northeast Scotland are already being put in to practice in other countries (e.g. France)

The main take home messages:

- **Winter cereals have a very good feed value profile**

Analysis of feed value showed results equal to or better than high-quality silage, with D-values over 90% and metabolisable energy (ME) exceeding 14 MJ kg^{-1} DM. In comparison, average silage has D-values around 70%, with good quality silage offering an ME of 11.5 MJ kg^{-1} DM.

Arable farmers already getting enquiries about grazing opportunities for sheep flocks.

Winter cereals seem very resilient to sheep grazing & recover well

- **Little impact on yield or agronomic / crop quality / soil quality factors**
  - Whether "mob" grazed like in plot experiments **or** extensively grazed like on network farms
    - Early sowing date / early grazing (pre-Christmas) and typical sowing date / later grazing (e.g. March) all seem to work equally well
  - Potential to check very "forward" crops – e.g. due to mild winter
  - Few negatives, but a number of positives
    - Indication of improved worm counts / reduced cereal disease (pre-stem extension)
    - Grazing income

Integrating fattening pigs and willow

Exploring a novel summer concept for organic pigs in Denmark

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862357

AARHUS UNIVERSITY

Background

Nearly all organic fattening pigs are raised in indoor housing systems with outdoor concrete runs. This system enables the collection of manure for use in the arable crop rotation. However, it does not align with the organic principle of naturalness, as the pigs have no access to pasture. Producing fattening pigs on pasture poses challenges for nitrogen (N) cycling as the pigs destroy the vegetation increasing the risk of N leaching.

Willow is expected to be more robust to pig activity compared to pasture. Thus, introducing a willow-planted area will enhance the naturalness and environmental stimulation for the pigs and reduce risk of N leaching compared to pasture-based systems.

Trials in Denmark with fattening pigs in a willow-system, tested the impact on pigs' growth rate, soil N load and willow regrowth.

Methodology

Rows of the willow clone Torhild *((Salix schwerinii × S. viminalis) × S. viminalis)* were established in 2019. The first batch of pigs gained access in 2021. The willow were coppiced in February to ensure fresh shoots and sprouts for the spring.

Feeding strategy (2021). Fattening pigs were introduced at approx. 92 kg in June, (200m^2 willow area/pig). They were in groups of eight pigs and either fed according to the norm or 70% of the norm.

Animal density (2022-2023). Fattening pigs were introduced at approx. 30 kg in May. They were in groups of either 4 or 8 (100 m^2 or 50 m^2 per produced pig).

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When introduced in May the pigs had a high intake of willow. Analysis of the willow leaves and branches shows a relatively high crude protein content (Crude protein 20 % of dry matter).

The stocking density did affect the available biomass, as the pigs continually pruned the willow throughout the production period (< 250 kg dry matter/ha for 50 m^2/pig and > 1500 kg/ha for 100 m^2/pig, measured in July after the pig production period)

The stocking density affected the soil nutrient load. Samples taken after the production period, show that providing 50m^2 willow area/pig gave a soil inorganic N load (0-100 cm) of more than 2.5x the load compared to the lower stocking density (100m^2/pig).

The willow was robust against the pig activity and had strong regrowth after the pig production periods.

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The system was a combined system with indoor straw bedded area and a willow range.

In the range the pigs found fresh shoots and leaves highly palatable, they used the shade of the willows, and they got the benefit of the naturalness to root deep in the soil.

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Increasing Montado's mixedness by combining cattle and sheep can offer multiple benefits.

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LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA

Background

- The rise of cattle intensification incentives in the past has led to a decline in natural oaks regeneration within Montado ecosystems. Also contributing to a reduction in sheep production tendency.
- Sheep grazing increases vegetation heterogeneity and diversity compared to cattle grazing in Mediterranean dry grasslands.
- Integrating sheep with cattle can supports Montado sustainability, socially, environmentally and economically.

Methodology

Farmers participated in detailed surveys on Montado inputs and outputs.
The farm's annual resource management was evaluated using emergy analysis, while a nitrogen footprint was calculated for livestock feed management.
Through these approaches self-sufficiency and the enviromental load of the farms were studied to evaluate the whole sustainability under scenarios of low pasture yield.

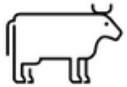
Maintaining the farm's balance between feed production and animal yield is becoming a challenge when facing climate change influencing the rain seasons and increasing drought over the hotter months.

“What lessons can we learn from our innovation study which helps us to improve the efficiency and resilience of mixed farming systems in Europe?”

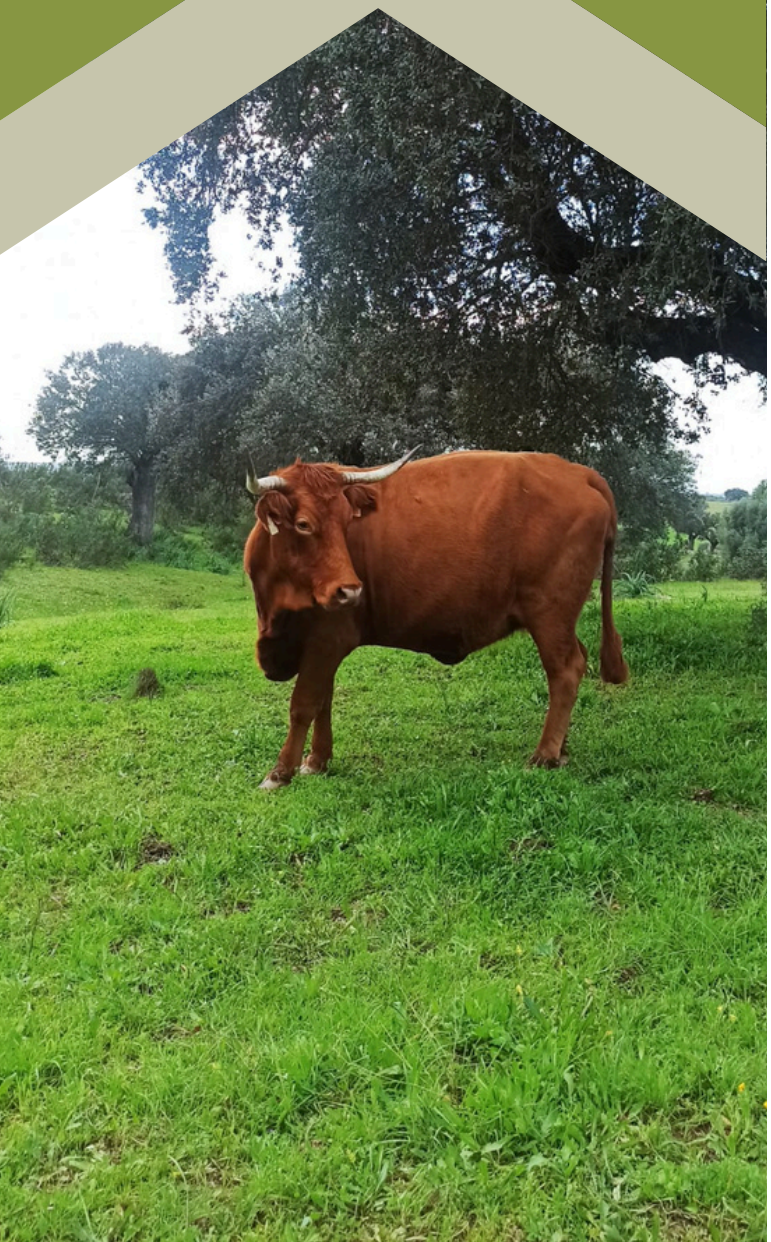
Encouraging low-input systems that capitalize on natural resources is critical for the long-term sustainability of mixed farming systems.

Traditional knowledge should be integrated into modern management strategies, particularly in mixed farming systems that rely heavily on ecological processes.

Diversity provides an economic buffer against poor years, such as low livestock yields due to drought or increased feed prices.



Diets high in locally available resources and low in synthetic inputs can reduce the nitrogen footprint of meat production.



Take Home Messages

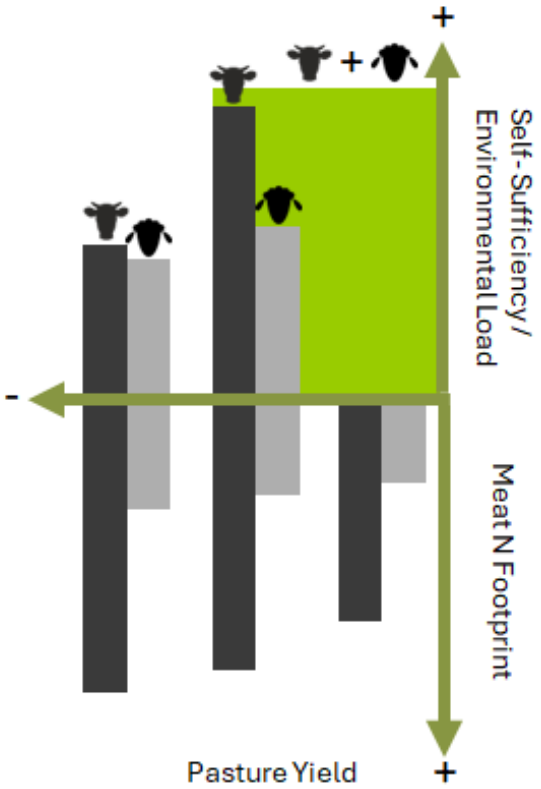
Sheep farming, more labor-intensive and reliant on purchases compared to cattle, is experiencing a decline in market demand.

Despite this, sheep farming is a low-impact practice that helps maintain soil health and the overall landscape.

In times of reduced pasture yield, sheep pose lower risk as they require less feed. Cattle, on the other hand, pose a higher risk during low yield periods, as farmers must either purchase concentrates, import fodder, or oversell livestock, which can lead to financial strain or lower market prices.

Reliance on external feed increases, especially in cattle, livestock's Nitrogen Footprint.

Results



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862357

Ecosystem services provided by trees in organic-biodynamic farming

IUNG Institute of Soil Science and Plant Cultivation

JUCHOWO Projekt Wiejski

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862357

Background

Hedgerows has been proven as a practice that contributes to strengthening of environmental services in agriculture.

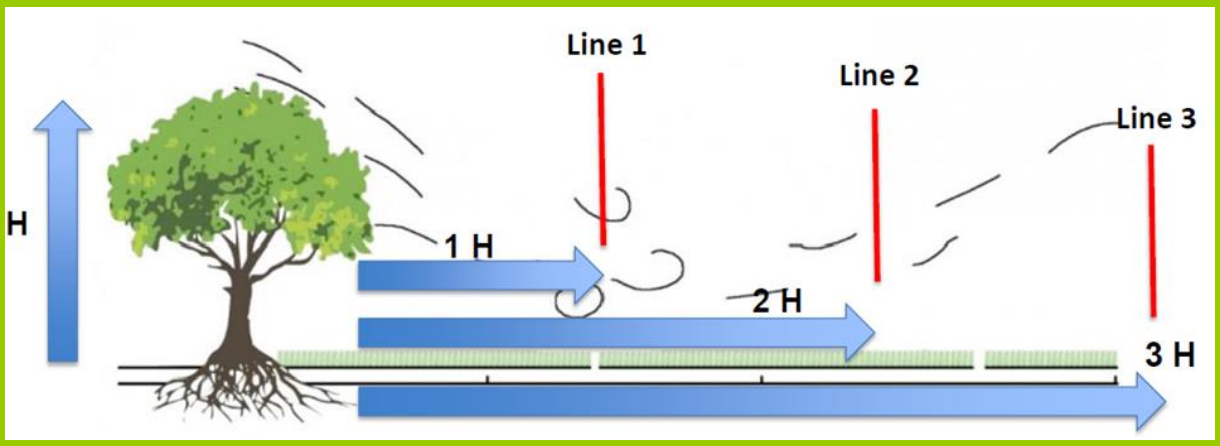
However, the effect of hedgerows may be different for provisioning and regulation services.

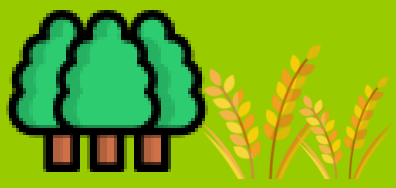
This work attempts to evaluate the effect of trees on crop yields, pollination potential, natural plant protection and climate regulation in organic arable agroecosystems.

Methodology

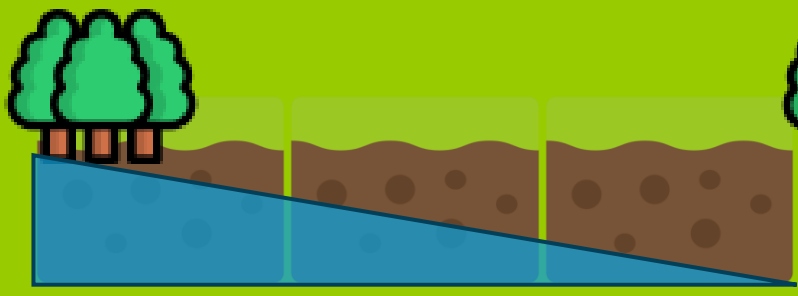
We assessed the potential of different ecosystem services, such as climate change mitigation, crop biological protection and pollination.

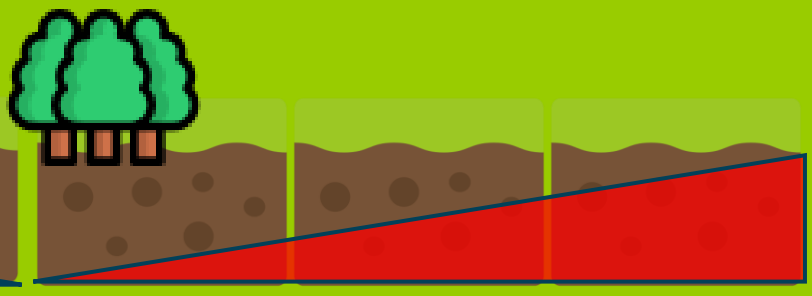
To collect data for indicators, samples and measurements were taken at three different distances from the trees. The distance at which measurements were taken was a multiple of tree height. In the case of young trees, it was 5m, 10m and 15m. In the case of old trees, it was 10m, 20m and 30m.





We found that crop yields were on average higher in the vicinity of trees, especially in case of young ones, however it depended on the species grown. For example, lupin and buckwheat grown near old trees yielded less than cereals.





Soil moisture is a good indicator of climate change mitigation that can be delivered by maintaining or planting trees in open areas. In our study at the closest distance from trees (5-10 m), soil moisture was 14%, at the next distance (10-20 m) 12% and only 10% at the furthest distance (20-30 m). This suggests that trees create suitable conditions for water storage in the soil.

Soil temperature is another indicator of adaptation to climate change. At the first and second distance from the trees, the temperature was almost 1°C lower than at the furthest distance from the trees (20-30m). Old trees, in particular, have a major impact on keeping soil cool.

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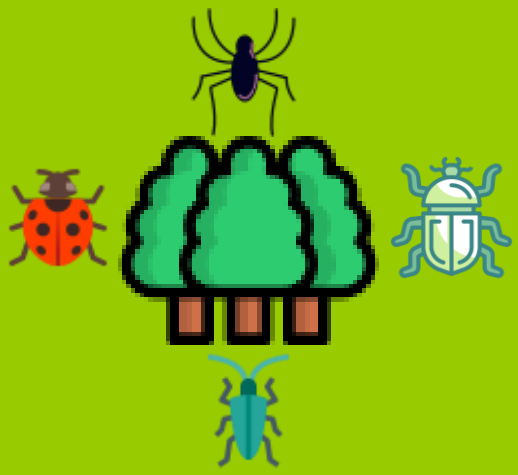
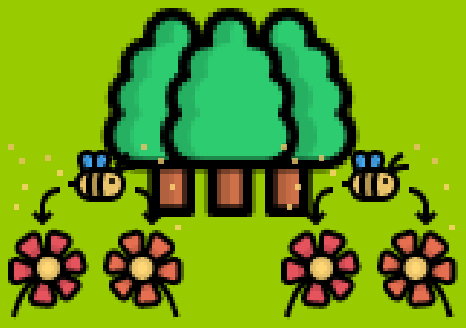


The large number of natural enemies of pests near trees created good conditions for increasing natural plant protection. Several groups of predators such as ladybugs, spiders, carabids and minute pirate bugs were more numerous near the trees than in more distant locations.

The presence of trees influenced the reduction of pests such as aphids, thrips, leaf beetles, weevils, leaf bugs and gall midges. This is due to the formation of a good habitat for their enemies. However, some diseases and pests may be linked with the presence of trees.



The presence of trees had a positive impact on ecosystem services related to pollination. More pollinators were found near young trees than old ones, however, it depended on the plants cultivated. Also, the larvae of some pollinators are natural enemies of pests.

In the vicinity of the trees, greater microbial activity was found affecting the improvement of soil quality. The number of bacteria was 22% higher. Dehydrogenase activity was 135% higher, acid phosphatase 112% higher and alkaline phosphatase 48% higher. Soil carbon content was higher by 37% and nitrogen content by 12%.

The main take home messages:

- **No significant reduction in crop yields**
- **Conservation of soil moisture**
- **Temperature reduction**
- **Reduction in the number of pests**
- **Increased presence of pollinators and beneficial organisms**
- **Increased microbial activity and improved soil quality**