



AGROMIX brings together farmers, researchers and policymakers to explore agroecological solutions for more resilient land use in Europe, developing tools to implement these practices.

agromixproject.eu



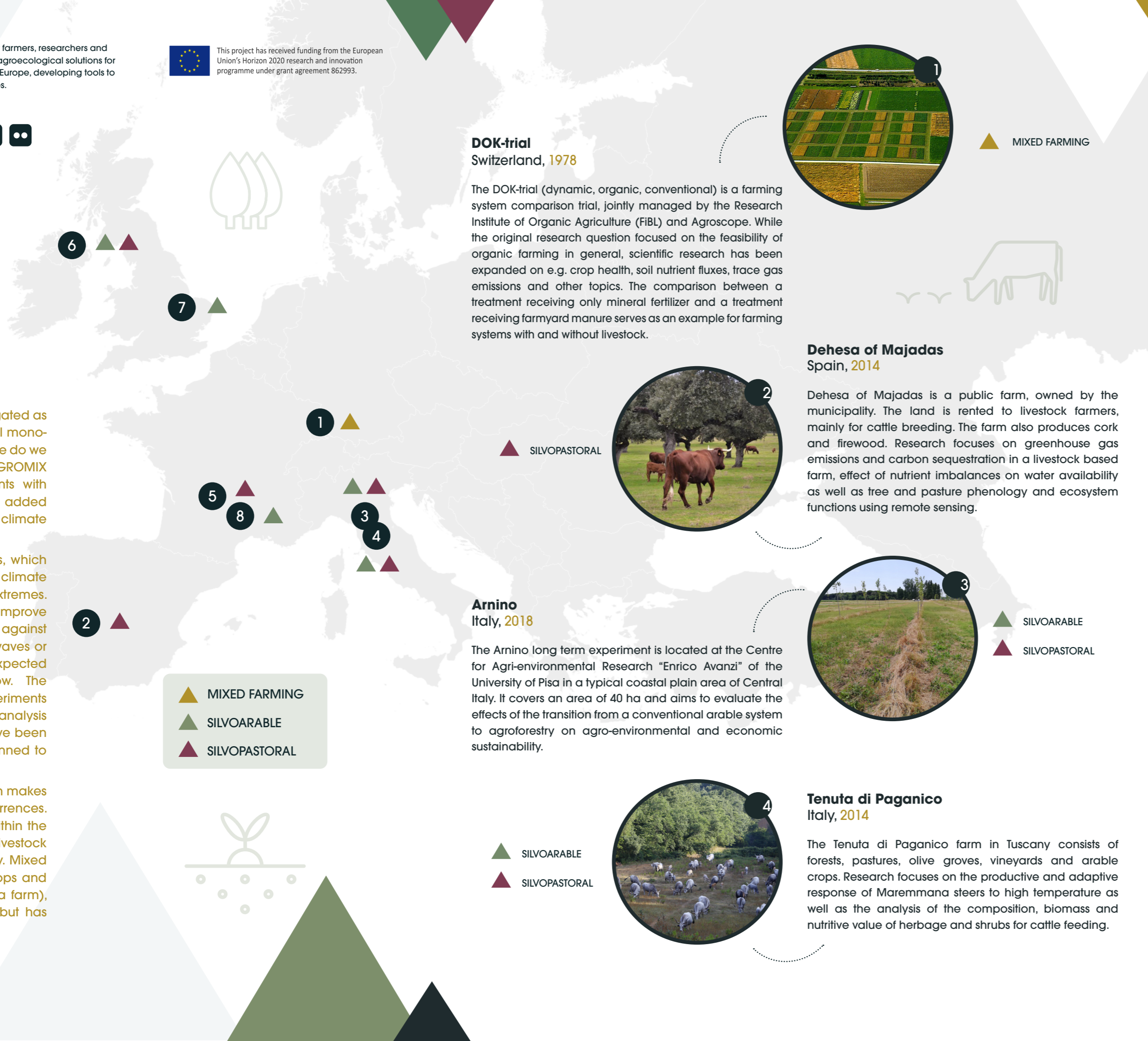
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 862993.

Scientific testing of agroforestry and mixed farming

Mixed farming and agroforestry are propagated as climate resilient alternatives to conventional monocropping. But what scientific knowledge-base do we actually have? The EU Horizon 2020 project AGROMIX identified eight long-term field experiments with replicated designs, that allow testing the added value of mixed farming and agroforestry for climate resilience.

Agriculture needs to meet many demands, which increasingly becomes challenging under climate change and more frequent weather extremes. Agroforestry and mixed farming potentially improve the resilience of agricultural production against weather extremes such as late frost, heat waves or droughts. Yet, the empirical bases for those expected resilience benefits is surprisingly narrow. The AGROMIX project brings together eight experiments that meet scientific standards for statistical analysis (replicated trials with controls) and that have been running over several years and/or are planned to continue.

Agroforestry has many different faces, which makes it difficult to find a definition that fits all occurrences. Generally, the inclusion of woody plants within the production of crops ("silvoarable") or livestock ("silvopastoral") is regarded as agroforestry. Mixed farming means the production of both, crops and livestock at the same productive unit (i.e. a farm), a practice that was typical for centuries, but has decreased in the last decades.



- MIXED FARMING
- SILVOARABLE
- SILVOPASTORAL

DOK-trial Switzerland, 1978

The DOK-trial (dynamic, organic, conventional) is a farming system comparison trial, jointly managed by the Research Institute of Organic Agriculture (FiBL) and Agroscope. While the original research question focused on the feasibility of organic farming in general, scientific research has been expanded on e.g. crop health, soil nutrient fluxes, trace gas emissions and other topics. The comparison between a treatment receiving only mineral fertilizer and a treatment receiving farmyard manure serves as an example for farming systems with and without livestock.



MIXED FARMING

Dehesa of Majadas Spain, 2014

Dehesa of Majadas is a public farm, owned by the municipality. The land is rented to livestock farmers, mainly for cattle breeding. The farm also produces cork and firewood. Research focuses on greenhouse gas emissions and carbon sequestration in a livestock based farm, effect of nutrient imbalances on water availability as well as tree and pasture phenology and ecosystem functions using remote sensing.



SILVOPASTORAL

Arnino Italy, 2018

The Arnino long term experiment is located at the Centre for Agri-environmental Research "Enrico Avanzi" of the University of Pisa in a typical coastal plain area of Central Italy. It covers an area of 40 ha and aims to evaluate the effects of the transition from a conventional arable system to agroforestry on agro-environmental and economic sustainability.



SILVOARABLE
 SILVOPASTORAL

Tenuta di Paganico Italy, 2014

The Tenuta di Paganico farm in Tuscany consists of forests, pastures, olive groves, vineyards and arable crops. Research focuses on the productive and adaptive response of Maremmana steers to high temperature as well as the analysis of the composition, biomass and nutritive value of herbage and shrubs for cattle feeding.



SILVOARABLE
 SILVOPASTORAL

Lamartine agroforestry site France, 1989

The research site was established in 1989. Back then, research questions covered the production of timber as additional income for farmers. Since then, research has shifted on studies to limit heat stress of sheep during summer in an agroforestry system.



SILVOPASTORAL

Wakelyns United Kingdom, 1992

Wakelyns agroforestry farm was established in 1992 by Professor Martin Wolfe and since 2019 has been run by his sons, David and Toby. The farm has been a long-term study site for research by the Organic Research Centre. Key research areas include bioenergy production, tree-crop interactions and total productivity, functional biodiversity, and sustainability.



SILVOARABLE
 SILVOPASTORAL

Agroforestry Research Platform AFBI Loughgall, United Kingdom, 1989

Two field trials managed by AFBI at its Loughgall research station are used in this project. Previous work focused on the comparison between grassland, agroforestry and woodland systems.



SILVOARABLE

Restinclières Agroforestry Platform France, 1995

The domain of Restinclières is a public estate, owned by the "Conseil Départemental de l'Hérault". The land is rented to two farmers, one who produces cereals, the other one vine. The owner manages the trees. Research focuses on the impact of trees on the crop production and on the sustainability and resilience of agroforestry systems.



SILVOARABLE

Contact
klaus.jarosch@agroscope.admin.ch

- 1 Agroscope, Switzerland
- 2 University of Extremadura, Spain
- 3 4 University of Pisa, Italy
- 5 8 INRAE, France
- 6 Agrifood and Biosciences Institute, United Kingdom
- 7 Organic Research Centre, United Kingdom

- Authors:**
- | | |
|---------------------|-----------------------|
| Klaus Jarosch (1) | Gerardo Moreno (2) |
| Daniele Antichi (3) | Rodrigo Olave (6) |
| Mickaël Bernard (5) | Alice Ripamonti (3) |
| Lydie Dufour (8) | Victor Rolo (2) |
| Henny Lowth (7) | Will Simonson (7) |
| Alberto Mantino (3) | Lorenzo Tramacere (3) |
| Jochen Mayer (1) | Collin Tosh (7) |
| Marcello Mele (3) | Felix Herzog (1) |



AGROMIX brings together farmers, researchers and policymakers to explore agroecological solutions for more resilient land use in Europe, developing tools to implement these practices.

agromixproject.eu



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

Long-term climate resilience experiments with silvoarable agroforestry systems in Europe: Lessons learned

The inclusion of woody plants into the arable cropping systems can have multiple positive effects such as an increased biodiversity, the protection of crops from weather extremes and/or the more efficient use of resources. Resource use is characterized by the competition between crops and trees for water, sunlight and nutrients. Field experiments provide the opportunity to study those effects directly in the field, before they are employed in large scale. However, patience is required, since effects can only be observed once the trees reach a certain age. Here we present three long-term field trials that provide information on productivity and environmental benefits of silvoarable agroforestry at different time scales.



▲ MIXED FARMING
▲ SILVOARABLE
▲ SILVOPASTORAL

3

ARNINO
Italy, 2018

Aim
To compare an agro-silvo-pastoral and a silvo-arable system based on alley cropping with, respectively, an agro-pastoral and an arable system in terms of crop yield, soil fertility, carbon sequestration, weed biodiversity and economic efficiency.

Statements
"We are happy to have established such an experiment because it could be a break-through innovation in our area, dominated by specialised systems. At the same time, it is challenging for us due to acreage (40 ha), wildlife competition, long-term horizon, lack of specific and multidisciplinary expertise."

Key findings

- The trial was only recently established, and to date only preliminary observations are available.
- Crop, weed and soil parameters are being collected at increasing distances from the tree rows.

References:

- Antichi, D., Mazzoncini, M., Tramacere, L. G., Sbrana, M., Barberi, P., Moonen, A. M., Carlesi, S., Mantino, A., Ragagnini, G., and Mele, M. (2019). Agroforestry systems for adaptation to and mitigation of climate change: Effects on soil fertility. *Agrochimica*, Special Issue 2019, 139-144.
- Mele, M., Mantino, A., Antichi, D., Mazzoncini, M., Ragagnini, G., Cappucci, A., Serra, A., Pelleri, F., Chiarabaglio, P., Mezzalana, G., and Bonari, E. (2019). Agroforestry system for mitigation and adaptation to climate change: Effects on animal welfare and productivity. *Agrochimica*, Special Issue 2019, 91-98.

Contact
Daniele Antichi: daniele.antichi@unipi.it

7

Wakelyns
United Kingdom, 1992

Aim
To provide scientific evidence and practical demonstration that alternative ways of food production are not only possible but advantageous.

Statements
"We are proud of our long-standing association with this experiment because it has pioneered the concept of resilience through diversity and is now helping to catalyse widescale adoption of agroforestry in the UK."
"Building on the existing legacy of research findings, experimental work under Agromix is now seeking to understand how to measure climate change resilience and model the adaptation potential of different scenarios of farm management practice in the future."

Key findings

- Crop diversity: synergies between agricultural productivity and ecosystem services can be optimised through enhanced species diversity, including diverse fertility-building leys and integration of herbaceous and tree crops.
- Biomass for decentralised energy production and soil improvement: biomass production from short rotation coppice, in-field trees and hedgerow management can meet domestic heating needs in a sustainable and cost-efficient way and also improve soils when added as ramial woodchip.

References:

- Smith et al 2021: Making hedgerows pay their way: the economics of harvesting field boundary hedges for bioenergy. *Agroforestry Systems*.
- Three approaches to calculating the LER of a diverse silvoarable system in the UK. Westaway et al 2021 *Aspects of Applied Biology* 146.

Contact
Colin Tosh: colin.t@organicresearchcentre.com

8

Restinclières Agroforestry Platform
France, 1995

Aim
Restinclières was the first ever silvoarable experiment in France with control treatments (monocropping, forestry) that allow a true assessment of the feasibility and productivity of alley-cropping agroforestry.

Statements
"I am proud of our experiment because it is a showcase of agroforestry for numerous researchers, students, farmers, advisors and reporters"
"If we could establish the experiment again, we would widen the alleys and choose a better location for the forestry controls by taking into account the depth of soil and water table."

Key findings

- With deciduous walnut trees, winter crop yield is not much impacted until the ratio between the height of trees and the width of the alley reaches 0.8.
- Tree roots are deeper in our agroforestry fields than in forestry control.
- Trees protect vineyard from frost or severe heat.

References:

- Dufour L., Dupraz C., Talbot G., Metay A., 2013.- Assessing light competition for cereal production in temperate agroforestry systems using experimentation and crop modeling. *J. Agr. Crop Sci.* 199 (3):157-227.
- Blanchet G., Barkaoui K., Bradley M., Dupraz C., Gosme M., 2021.- Interactions between Drought and Shade on the Productivity of Winter Pea Grown in a 25 year old Walnut based Alley Cropping System. *J. Agr. Crop Sci.*

Contact
klaus.jarosch@agroscope.admin.ch

Website:
colin.t@organicresearchcentre.com

1 Agroscope, Switzerland
2 University of Extremadura, Spain
3 **4** University of Pisa, Italy
5 **8** INRAE, France
6 Agrifood and Biosciences Institute, United Kingdom
7 Organic Research Centre, United Kingdom

References:

- Dufour L., Dupraz C., Talbot G., Metay A., 2013.- Assessing light competition for cereal production in temperate agroforestry systems using experimentation and crop modeling. *J. Agr. Crop Sci.* 199 (3):157-227.
- Blanchet G., Barkaoui K., Bradley M., Dupraz C., Gosme M., 2021.- Interactions between Drought and Shade on the Productivity of Winter Pea Grown in a 25 year old Walnut based Alley Cropping System. *J. Agr. Crop Sci.*

Contact:
[Lydie Dufour: lydie.dufour@inrae.fr](mailto:Lydie.Dufour@inrae.fr)

Authors:

Klaus Jarosch (1)	Gerardo Moreno (2)
Daniele Antichi (3)	Rodrigo Olave (6)
Mickaël Bernard (5)	Alice Ripamonti (3)
Lydie Dufour (8)	Victor Rolo (2)
Henny Lowth (7)	Will Simonson (7)
Alberto Mantino (3)	Lorenzo Tramacere (3)
Jochen Mayer (1)	Colin Tosh (7)
Marcello Mele (3)	Felix Herzog (1)

Long-term climate resilience experiments with silvoarable agroforestry systems in Europe: Lessons learned

The inclusion of woody plants such as trees or bushes in pastures have a long tradition. The vegetation is characteristic for distinct landscape and has multiple positive effects on plant and animal biodiversity since, for example, insects and birds find food and places to rest. Also, the grazing livestock can benefit from the presence of trees, since they can serve for as wind breaks or provide shadow and fodder. Here we present different long term trials that aim to determine the effect of silvopastoral systems on livestock such as sheep or cattle.



Dehesa of Majadas Spain, 2014

Aim

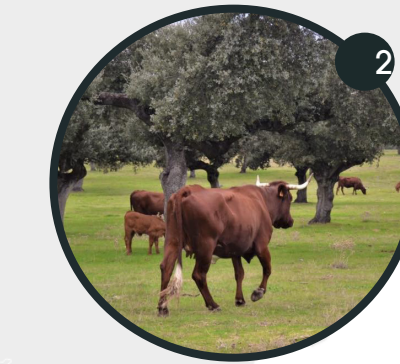
To investigate the functioning of silvopastures extensively grazed with an emphasis on quantifying the contribution of trees to pasture production and quality, soil carbon sequestration and biodiversity of the whole system (compare to open treeless pastures), and management schemes for the adaptation and mitigation of climate change.

Statements

"We have a long trajectory studying the functioning of Iberian dehesas as model of traditional agroforestry, testing alternative management practices to face the multiple ecological and economic challenges that threaten the persistence of this and other traditional agroforestry systems"

Key findings

- Trees and shrubs are sources of forage resources that help to overcome seasonal limitations of grass understory growth in dehesas. Shrub understory favors tree recruitment and regeneration ensuring the stability (long persistence) of the system.
- Trees provide refuge and fodder for many species, creating ecological niches for a wide range of organisms. As a result, dehesas are frequently more biodiverse than adjacent forests and open pastures.
- Trees reinforce the carbon sequestration capacity grazing systems, allowing for offsetting the greenhouse gas emissions associated with livestock rearing.
- Trees can favor pasture production through the improvement of soil physical and chemical fertility, but trees and pasture also compete for soil water and light; tree density and management practices must be designed to optimize overstory-understory interactions and outcomes.
- A combined pasture production, tree regeneration and growth, fruit production and livestock production and welfare assessment is needed to design sustainable management schemes.



▲ SILVOPASTORAL



Gerardo Moreno



Victor Rolo

References:

- Moreno G et al. 2018. Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services. *Agroforestry Systems* 92(4), 877-891.
- El-Madany TS, G Moreno et al (2018). Drivers of spatio-temporal variability of carbon dioxide and energy fluxes in a Mediterranean savanna ecosystem. *Agricultural and Forest Meteorology* 262, 258-278.
- Rolo V, Moreno G. 2019. Shrub encroachment and climate change increase the exposure to drought of Mediterranean wood-pastures. *Science of the Total Environment* 660, 550-558
- Rolo V, Moreno G et al. 2020. Challenges and innovations for improving the sustainability of European agroforestry systems of high nature and cultural value: stakeholder perspectives. *Sustainability Science* 15, 1301-1315.

Contact:

[Website](#)

Gerardo Moreno: gmoreno@unex.es

Tenuta di Paganico Italy, 2014

Aim

The main objective of the experiment is to evaluate the effect of heat stress on beef cattle welfare and productivity according to the presence or not of trees on pasture (silvopastoral system vs. open pasture system).

Statements

"We are proud of our experiment because it can contribute to better understand the thermal comfort effect of the agroforestry systems on livestock in the Mediterranean area and to contrast the effect of climatic change on livestock production"

"If we could establish the experiment again, we would adopt smart collars instead of visual observation, in order to monitor more accurately individual animal behavior in response to heat stress".

Key findings

- During the spring season, silvopastoral treatment did not seem to provide any benefit to cattle in terms of animal welfare, due to the lack of thermal stress and the abundance of herbage biomass in the open pasture. The average daily gain was higher in open pasture group compared to silvopastoral.
- During the summer period, the heat stress resulted in a sharp decrease of average daily gain for cattle in the open pasture, whereas cattle in the silvopastoral group maintained the same value of average daily gain for large part of the hot season.
- The average heat load values of animals were significantly higher and above the danger threshold for animals of the open pasture group during the whole hot season, resulting in a worsening of animal welfare condition, if compared to cattle in silvopastoral group.

References:

- Alice Ripamonti, Giovanni Pecchlioni, Francesco Annecchini, Laura Casarosa, Alessio del Tongo, Jacopo Goracci, Marcello Mele, Alberto Mantino. 2022. Herbage intake, nutritive value and cattle productivity within silvopasture and open pasture systems: a case-study in a Mediterranean livestock farm. EURAF2022 conference.
- Alice Ripamonti, Giovanni Pecchlioni, Francesco Annecchini, Laura Casarosa, Alessio del Tongo, Jacopo Goracci, Marcello Mele, Alberto Mantino. 2022. Grazing management reduced cattle growth but limited pasture depletion in a Mediterranean agrosilvopastoral system. The 5th World Congress on Agroforestry 2022

Contact:

[Website](#)

Marcello Mele: marcello.mele@unipi.it

▲ SILVOARABLE
▲ SILVOPASTORAL



Marcello Mele

Alice Ripamonti

▲ SILVOPASTORAL



Mickaël Bernard

Lamarine agroforestry site France, 1989

Aim

The objective of this study is to know if trees could be a way of adaptation to climate change by measuring precisely the benefits of their presence in the grasslands and the consequences on biomass production (quantity and quality) and on animals' internal temperature and behavior.

Statements

"I am proud of our experimentation because we were able to develop a methodology to continuously measure the animals' behavior on pasture. If we could establish the experiment again, we would replicate these systems in different French soil and climate conditions to further study silvopastoral systems."

Key findings

- In our pedoclimatic context (the French mid-mountain), our first results show that agroforestry systems can play a positive role in climate change adaptation by providing a more favorable microclimate for animals and grass. Sheep can modulate their behavior by seeking shade, by shifting or reducing the duration of their intake, allowing them to better regulate their internal temperature and thus improve their welfare under stressful conditions.
- For grassland, the presence of trees can impact biomass production when the density is high (more than 100 trees/hectare) but compensate by a better capacity to valorize grass with a slowed phenological development, a more stable quality resulting in a better flexibility of use of the grasslands.

References:

Camille Béral, Donato Andueza, Cécile Giane, Mickaël Bernard, Fabien Lagre, et al.. PARASOL: AGROFORESTERIE EN SYSTÈME D'ÉLEVAGE OVIN - Étude de son potentiel dans le cadre de l'adaptation au changement climatique. *Agrooif*; Inra; Idele; UnilSalle. 2018. fffal-02932381f 158p.

Contact:

[Website](#)

Mickaël Bernard: mickaël.bernard@inrae.fr

Agroforestry Research Platform AFBI Loughgall, United Kingdom, 1989

Aim

To investigate agro-forestry systems with an emphasis on quantifying the impact of management practices on ecosystem functioning and climate change mitigation strategies including greenhouse gas dynamics and global warming potential as well as ecosystem service provision.

Statements

"I am proud of our long term experiment because is the oldest facility in the UK and recognized for its research and much needed to improve climate projections and increase resilience of our farming systems."

Key findings

- The Agri-Food and Biosciences Institute (AFBI) has been involved in agroforestry research since 1989, initially as part of UK and EU networks investigating the effects of tree density on sheep production, pasture production and ecosystem services delivery. AFBI research has shown that trees can be successfully integrated and grown in pasture. Trees grown in pasture can extend the grazing season, so improving grass utilisation. They also help grazing resilience during extreme rainfall, increase biodiversity and carbon sequestration and provide renewable fuel.
- Other environmental benefits demonstrated in AFBI research include reduced wind and temperature stress on animals, root differentiation, improved soil structure and less leaching of nutrients. Economic predictions are positive. These come from farmer surveys, recommendation in the Sustainable Agricultural Land Management Strategy and inclusion in the current Environmental Farming Scheme. Uptake on commercial farms across UK has shown that agroforestry is a realistic land-use option that delivers key objectives in managed landscapes.

Contact

klaus.jarosch@agroscope.admin.ch

- 1 Agroscope, Switzerland
- 2 University of Extremadura, Spain
- 3 4 University of Pisa, Italy
- 5 8 INRAE, France
- 6 Agrifood and Biosciences Institute, United Kingdom
- 7 Organic Research Centre, United Kingdom

Authors:

- Klaus Jarosch (1)
- Daniele Antichi (3)
- Mickaël Bernard (5)
- Lydie Dufour (8)
- Henny Lowth (7)
- Alberto Mantino (3)
- Jochen Mayer (1)
- Marcello Mele (3)
- Gerardo Moreno (2)
- Rodrigo Olave (6)
- Alice Ripamonti (3)
- Victor Rolo (2)
- Will Simonson (7)
- Lorenzo Tramacere (3)
- Colin Tosh (7)
- Felix Herzog (1)

References:

- Fornara, D., Olave, R., Burgess, P., Delmer, A., Upson, M., McAdam, J (2018). Land use change and soil carbon pools: evidence from a long term silvopastoral experiment. *Agroforestry Systems*. (92) 4: 1035-1046.
- McAdam, J. H., Sibbald, A. R., Teklehaimanot, Z., Eason, W. R. (2007). Developing silvopastoral systems and their effects on diversity of fauna. *Agroforestry Systems*. 70(1):81-89
- Website link: Farm Woodland & Agroforestry projects | Agri-Food and Biosciences Institute

Contact:

[AFBI website](#)
Rodrigo Olave: rodrigo.olave@afbini.gov.uk



Long-term climate resilience experiments of mixed farming systems: Lessons learned

The capacity of farms to produce food and their resilience against external impacts is very much dependent on fertile soils. To maintain a high soil fertility, the nutrients that are removed by crop harvest have to be replenished, which nowadays often takes place with mineral fertilizers. In modern agriculture there is a trend to disconnect crop production from animal production. This causes severe trade-offs for the environment, leading to a high demand of synthetic fertilizers for crop production, and a surplus of animal manure on farms that specialize on livestock production. Mixed farming, i.e. the combination of both crop and livestock within the same farm, has the benefit that the recycling of nutrients within the farm is facilitated. In the AGROMIX project, we use a unique long-term field trial to compare the effect of mixed-farming with conventional farming.



▲ MIXED FARMING
 ▫ SILVOARABLE
 ▲ SILVOPASTORAL



▲ MIXED FARMING



Jochen Mayer

DOK-trial Switzerland, 1978

Aim

The original aim of the DOK trial was to study the effect of different farming systems (organic farming, mixed farming, conventional farming) on crop performance, soil properties and other ecosystem services. Today, the trial serves as an experimental platform for basic as well as applied research topics, including soil biodiversity, greenhouse gas emissions, nutrient dynamics and farming system sustainability.

In Agromix we compare mixed farming treatments that are fertilized with slurry to conventional farming, where mineral fertilizers are used.

Statements

"The DOK-trial provides the unique opportunity to study different farming systems since more than 40 years."

Key findings

- Mixed and non-mixed farming systems have similar crop yield over 42 years.
- Mixed farming systems keep a high soil quality, while it is reduced under non-mixed farming.
- High soil quality and soil biota requires comparatively high livestock density which causes trade-offs to other goals such as food security and reduced greenhouse gas emissions.

References:

- Hartmann, M., Frey, B., Mayer, J., Mäder, P., & Widmer, F. (2015). Distinct soil microbial diversity under long-term organic and conventional farming. *The ISME Journal*, 9(5), 1177-1194.
- Leifeld, J., Reiser, R., & Oberholzer, H. R. (2009). Consequences of conventional versus organic farming on soil carbon: Results from a 27 year field experiment. *Agronomy Journal*, 101(5), 1204-1218.
- Mäder P, Fliessbach A, Dubois D, Gunst L, Fried P, Niggli U. Soil fertility and biodiversity in organic farming. *Science*. 2002; 296:1694-7.
- Mayer, J., Gunst, L., Mäder, P., Samson, M. F., Carcea, M., Narducci, V., & Dubois, D. (2015). Productivity, quality and sustainability of winter wheat under long-term conventional and organic management in Switzerland. *European Journal of Agronomy*, 65, 27-39.

Contact

Website
 Jochen Mayer: jochen.mayer@agroscope.admin.ch

Contact

klaus.jarosch@agroscope.admin.ch

- ① Agroscope, Switzerland
- ② University of Extremadura, Spain
- ③ ④ University of Pisa, Italy
- ⑤ ⑧ INRAE, France
- ⑥ Agrifood and Biosciences Institute, United Kingdom
- ⑦ Organic Research Centre, United Kingdom

Authors:

- | | |
|---------------------|-----------------------|
| Klaus Jarosch (1) | Gerardo Moreno (2) |
| Daniele Antichi (3) | Rodrigo Olave (6) |
| Mickaël Bernard (5) | Alice Ripamonti (3) |
| Lydie Dufour (8) | Victor Rolo (2) |
| Henny Lowth (7) | Will Simonson (7) |
| Alberto Mantino (3) | Lorenzo Tramacere (3) |
| Jochen Mayer (1) | Colin Tosh (7) |
| Marcello Mele (3) | Felix Herzog (1) |