CLIMED-FRUIT

Technical Article Nº 8

Improving the resilience of perennial fruit: good practices for soil conservation and carbon storage

Soil management is crucial in mitigating climate change, particularly in the vulnerable Mediterranean region, where soil degradation is a major concern. Effective soil conservation strategies encompass erosion control, fertility maintenance and preserving organic matter, physical properties and nutrients. High-quality soil enhances sustainability by reducing flood risks and supporting groundwater recharge. A key aspect of climate change mitigation is optimising soil carbon storage through 'carbon farming'. Since agriculture contributes approximately 30% of global anthropogenic emissions, increasing soil carbon content via sequestration-friendly practices presents a viable approach to offset these emissions and promote sustainable agriculture.

Farmers are adjusting their practices to cope with the challenge, but many of these solutions remain confined to specific regions or agricultural sectors. The EU-funded CLIMED-FRUIT [1] project is working to bridge this gap by collecting and sharing innovative, climate-adaptive practices from various European agricultural groups to enhance resilience and promote effective climate change adaptation and mitigation. This article presents a non-exhaustive list of experimental results from projects carried out across Europe and identified in the framework of CLIMED-FRUIT project.

Recycling farm waste and residues: a virtuous circle for soil conservation

On-farm composting

Recycling organic waste and residues through on-farm composting is a sustainable way to produce fertilisers for farm use. In this context, the Operational Group (OG) OLTREBIO [2] aimed to minimise farm inputs, recover farm waste and transfer composting process knowledge to other farmers.

Using on-farm compost tea

To improve organic production performance, the OG OLTREBIO [2] tested the effect of compost tea (CT) in a cherry orchard (Lapins variety). The CT was obtained via the aqueous extraction of on-farm compost that was placed in a strainer bag with a tight mesh and immersed in a homemade bio-extractor and incubated for five days (Fig. 1)[3]. The extraction was carried out with a ratio of 1:5 v/v (20%), and the oxygenation was obtained by activating a pump for 15 minutes every three hours [4]. Table 1 shows the main characteristics of the CT obtained. The pH values are around neutral, while the electrical conductivity (EC) was higher than 1.5 mS/cm, which suggested further dilution (1:15 v/v)[3].

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060474. This communication only reflects the author's view. The Research Executive Agency is not responsible for any use that may be made of the information provided. The authors and editors do not assume responsibility or liability for any possible factual inaccuracies or damage resulting from the application of the recommendations in this article.

Table 1. OG OLTREBIO compost tea characterisation [3]

Parameters	pH	EC (mS/cm^2)	Nitrogen (mg/L)
Water	7.2	0.45	
Compost tea (1:5 v/v)	7.4	1.72	56.7

The CT was applied in an organic cherry orchard as soil treatment (3 L/tree) and foliar treatment (250 mL/tree) at the pink bud, post-fruit setting and veraison stages.

Fig. 1. Compost tea production at the CREA-AA experimental farm: 1. preparing the bag with the compost to be extracted; 2. aqueous extraction; 3. checking electrical conductivity and pH; 4. dilutions; 5. foliar application in the cherry orchard; 6. soil application in the vineyard [3]

The foliar application of CT favoured the crop's photosynthetic activity, acting as a biostimulant rather than a soil amendment. Moreover, the application of compost tea significantly increased the fruit sugar content in cherries, Lapins variety (22.81 °Brix), compared to the control (20.63 °Brix) and contributed to improving the water condition of the plants compared to the control under severe water stress conditions (< -1.5 MPa).

Mulching

Mulch is mainly used to control weeds or maintain soil moisture. Made from different types of natural materials, it also has the side effect of improving soil health once it has deteriorated. The effect of no-till rice straw mulching on soil health parameters, including soil organic carbon (SOC), was evaluated in two citrus plantations on the Valencian coastal

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060474. This communication only reflects the author's view. The Research Executive Agency is not responsible for any use that may be made of the information provided. The authors and editors do not assume responsibility or liability for any possible factual inaccuracies or damage resulting from the application of the recommendations in this article.

plain in Spain. These plantations are jointly representative of the semi-arid hot-summer Mediterranean climate on flatlands [5]. Rice straw was cut between 5 cm and 15 cm in length and applied, and a layer 3.2± 0.4 cm high, fully covering the ground, was kept for the entire period. The straw mulch reduced soil temperature and favoured root growth fourfold, as well as soil macrofauna development. Under the straw mulch, the macroporosity was between two and 14 times higher, and the SOC mass fraction in the topsoil layer (0–20 cm) increased 10% more than in the bare soil (Fig. 2). However, the beneficial effects of straw mulching on soil health are limited after three years of treatment. It is recommended to add organic fertilisers and/or amendments alongside a surface tillage operation [5].

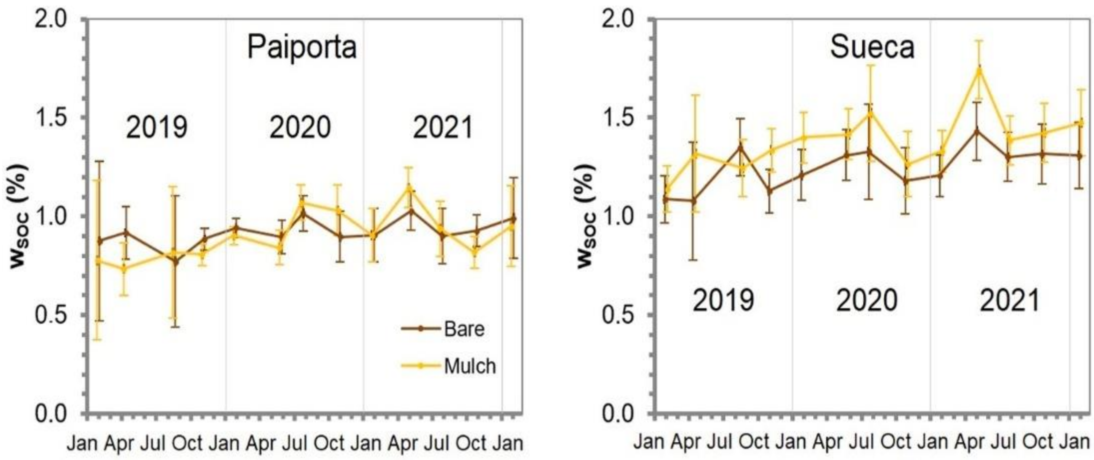

Fig. 2. Mass fraction of organic carbon in the topsoil (0–20 cm) of the orchard alleys, under straw mulch and bare, at the Paiporta and Sueca sites

Using pruning debris

Burning citrus pruning debris is now restricted due to environmental and health risks, prompting growers to adopt sustainable management. A recommended approach is shredding and spreading pruning remains, enriched with grasses or legumes, between orchard rows to recycle nutrients and enhance soil and plant quality. Covering at least 30% of the soil (50% for olives and almonds) reduces erosion, retains moisture and boosts organic matter and carbon storage. The Improvement of Soil and Plant from Enriched Pruning Remains [6] project found that this method doubled soil biological activity (Fig. 3), increased water retention and improved soil carbon sequestration (Fig. 4).

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060474. This communication only reflects the author's view. The Research Executive Agency is not responsible for any use that may be made of the information provided. The authors and editors do not assume responsibility or liability for any possible factual inaccuracies or damage resulting from the application of the recommendations in this article.

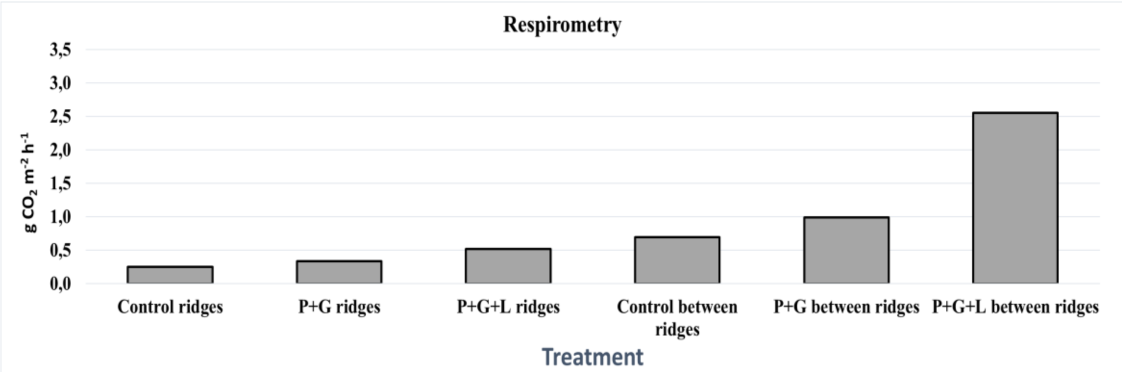

Fig. 3. The effect of applying pruning residues enriched with grasses (P+G) or grasses plus legumes (P+G+L) on soil biological activity

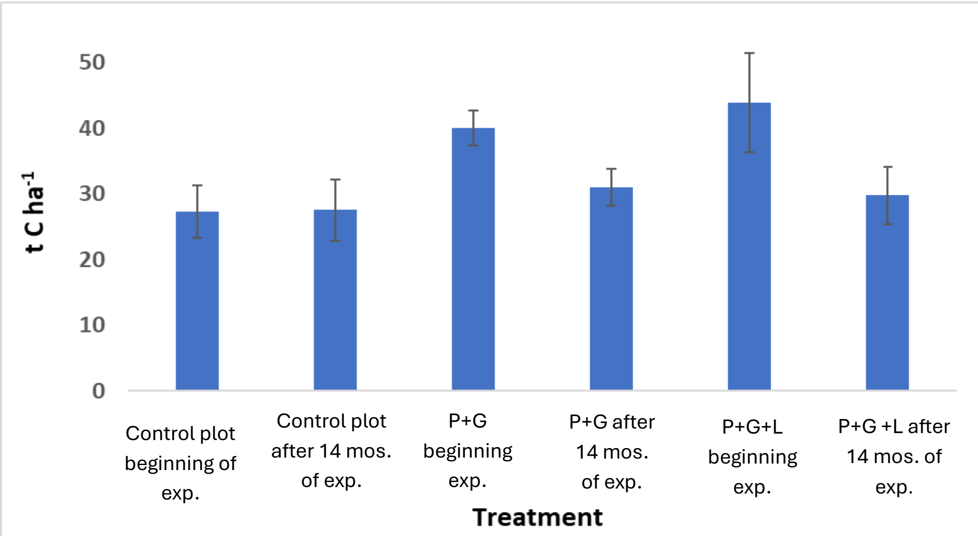

Fig. 4. The effect of applying pruning residues enriched with grasses (P+G) or grasses plus legumes (P+G+L) on soil organic carbon

Similarly, the [OG Carbocert][7] evaluated the benefits of integrating pruning debris in citrus, olive and almond orchards by spreading on the ground surface in the inter-row. The chopped or shredded debris (Fig. 5) must be small enough to prevent the formation of clods where pests may nest, to avoid hindering other operations in the orchard (treatments, sowing, etc.) and to facilitate the decomposition of the debris. Slow decomposition means carbon is introduced gradually and over a long period, and this can increase the organic carbon content in soil surface layers by 60%. In fruit orchards, the [OG Carbocert][7] evaluated a carbon sequestration potential close to 1.5 t ha^{-1} year^{-1}.

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060474. This communication only reflects the author's view. The Research Executive Agency is not responsible for any use that may be made of the information provided. The authors and editors do not assume responsibility or liability for any possible factual inaccuracies or damage resulting from the application of the recommendations in this article.

Fig. 5. Managing pruning debris cover in a citrus crop (photo: LIFE Low Carbon Feed) and shredding before application in the alley

Recycling crop by-products

Recycling almond hulls and shells (Fig. 6) as organic amendments in orchards enhances soil microbial biomass and activity, promoting soil health, nutrient cycling and carbon storage. Results of a field trial conducted in California on irrigated loam soil showed that surface-applied hull/shell amendments, 2.5 tons per hectare, significantly increased microbial biomass with bacteria and fungi compared to controls [8]. The particle sizes of the hulls ranged from 2.0–4.5 cm in length, whereas shell particles tended to be smaller, ranging from 0.3–2.5 cm, with a texture more comparable to sawdust. This organic layer supported diverse microbial communities in the upper soil layer (0–10 cm) [8] and improved soil multifunctionality and microbial activity. The amendments decomposed by 45% within a year, lowering the C:N ratio of the amendment from 53:1 to 29:1, with no negative impact on tree nitrogen status or yields.

Fig. 6. Photos of hull and shell (top) and shell (bottom) treatments in a location in Merced County during March (left), April (middle) and July (right) [9]

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060474. This communication only reflects the author's view. The Research Executive Agency is not responsible for any use that may be made of the information provided. The authors and editors do not assume responsibility or liability for any possible factual inaccuracies or damage resulting from the application of the recommendations in this article.

Soil cover crops: an ally against erosion and to promote carbon storage

The use of ground covers (native or seeded) is a recommended practice in sustainable fruit tree production, particularly in steep slope conditions, in order to control soil erosion.

The OG Carbocert [7] examined the implementation of permanent grass cover in almond orchards (Spain), to assess its impact on soil. The most effective carbon sequestration method is spontaneous cover crops, managed with cutting tools (mowers, strimmers, brush cutters) or shallow tillage, leaving plant residues on the surface. These same management types are recommended for weed control in the row and could be combined, for greater efficiency, with mulching, obtained either from mowing the cover itself (Fig. 7) or from external inputs (prioritising natural and local mulching). Grazing by sheep or goats is beneficial since it provides additional organic matter to the soil, but it should be limited to winter dormancy to avoid damage to lower branches.

Fig. 7. Spontaneous vegetation cover maintained by mowing in almond orchards (left) and sheep used for cover control in an olive grove – OG CARBOCERT [7]

Covers should have an opposite vegetative cycle to almonds to reduce water and nutrient competition, thriving from senescence to floral initiation and naturally withering post-harvest. Planned mowing encourages reseeding of desirable species while preventing unwanted ones from flowering.

'Carbon farming': maximising carbon stored throughout agricultural management

Carbon farming is the process of modifying agricultural practices to increase the amount of carbon stored in the soil. Carbon storage in soils could become a powerful tool in the fight against climate change by removing large quantities of carbon from the atmosphere and offsetting future emissions from agriculture. The European Union is actively promoting carbon farming practices to enhance soil carbon sequestration and combat climate change through funded projects. The Carbon Farming – CE project [10] standardises the monitoring of carbon sequestration in agriculture, focusing on measuring soil organic carbon (SOC) improvements through various farming methods. The Carbon farming

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060474. This communication only reflects the author's view. The Research Executive Agency is not responsible for any use that may be made of the information provided. The authors and editors do not assume responsibility or liability for any possible factual inaccuracies or damage resulting from the application of the recommendations in this article.

projects Catalogue [11] is a guideline to highlight successful carbon farming practices from projects funded under different European programmes.

Conclusion

The adoption of soil conservation practices is essential for enhancing the resilience of perennial trees and mitigating the effects of climate change, particularly in the Mediterranean region. Strategies such as compost application, on-farm composting, the use of compost tea and the integration of pruning residues and cover cropping contribute significantly to improving soil health, increasing carbon sequestration and reducing reliance on external inputs. These practices not only support the sustainable production of perennial trees but also play a crucial role in maintaining soil fertility, preventing erosion and fostering long-term environmental benefits.

Bibliography and sources

[1] CLIMED FRUIT project, https://climed-fruit.eu/

[2] OG OLTREBIO https://climed-fruit.eu/wp-content/uploads/2024/06/5.-EPA-OLTREBIO-COMPOST-TEA.pdf

[3] Compost ed estratti per la sostenibilità dei sistemi agricoli. Agrifoglio n.105. https://feder.bio/wp-content/uploads/2017/07/Compost-ed-estratti-per-la-sostenibilita-dei-sistemi-agricoli.pdf

[4] https://feder.bio/wp-content/uploads/2017/07/Poster-Oltrebio-23012023-2.pdf

[5] Visconti, F., Peiró, E., Pesce, S., Balugani, E., Baixauli, C., de Paz, J. M. (2024). Straw mulching increases soil health in the inter-row of citrus orchards from Mediterranean flat lands. European Journal of Agronomy. Elsevier BV. http://doi.org/10.1016/j.eja.2024.127115https://doi.org/10.1016/j.eja.2024.127115

[6] Improvement of Soil and Plant from Enriched Pruning Remines project: https://www.youtube.com/watch?v=mTl_-7Ghwps

[7] OG CARBOCERT https://www.en.une.org/cooperacion/carbocert

[8] Andrews, E.M., Tabassum, M., Galatis, E.G., Yao, E.H., Gaudin, A.C.M., Lazcano, C., Brown, P.H., Khalsa, S.D.S. (2024). Almond hull and shell organic matter amendments increase microbial biomass and multifunctionality in orchard soil and the undisturbed organic layer. Applied Soil Ecology, 197, 105321. https://doi.org/10.1016/j.apsoil.2024.105321

[9] Zuber, C., Doll, D., Dani Lightle, D., Crowley, R., Gaudin A. (2018). Adding Almond Hull and Shell to a Producing Almond Orchard: Feasibility and Tree Health Impacts. https://rd.almondboard.com/files/Adding Almond Hull and Shell to a Producing Almond Orchard_Feasibility and Tree Health Impacts.pdf

[10] Carbon Farming CE project https://www.interreg-central.eu/projects/carbon-farming-ce/?tab=home, https://www.interreg-central.eu/projects/carbon-farming-ce/?tab=outputs

[11] CARBON FARMING PROJECTS CATALOGUE https://acrobat.adobe.com/id/urn:aaid:sc:EU:116d525d-5e14-4064-a9b8-68a33cf36c7b

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060474. This communication only reflects the author's view. The Research Executive Agency is not responsible for any use that may be made of the information provided. The authors and editors do not assume responsibility or liability for any possible factual inaccuracies or damage resulting from the application of the recommendations in this article.