CLIMED-FRUIT

Technical Article Nº 7

Improving vineyard resilience: 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 significant concern. Effective soil conservation strategies encompass erosion control, fertility maintenance and the preservation of 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 the agro-food system 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

Using on-farm compost

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] recover farm waste through the composting process. The first phase of the process involved preparing the piles after crushing and mixing the raw materials (Fig. 1), i.e., crop residues mixed with grass cuttings. The pile was then covered with a sheet, and oxygenation was ensured by the aeration system, which was activated at regular intervals (ten minutes every two hours in the first two weeks). The temperature was measured continuously (up to 50–70°C), while the humidity was checked weekly (40–70%). To allow the homogenisation and fermentation of the materials, the pile was turned weekly twice in the first two weeks and once until the end of the process.

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Fig. 1. On-farm composting at the CREA-AA experimental farm: 1. collection of farm waste; 2. shredding and mixing; 3. preparing and oxygenating the pile; 4. checking the temperature and humidity; 5. storing the mature compost; 6. application in the field [3]

The mature compost was applied for three years as fertiliser in organic table grape vineyards in doses of 2.1 tons/ha, which reduced the inputs and fuel used by the farm by 70% and 10%, respectively.

Using pruning debris

The OG Carbocert [4] evaluated the benefits of integrating pruning debris in vineyards by spreading it on the ground surface in the inter-row. The chopped or shredded debris must be small enough to prevent the formation of clods where pests may nest, to avoid hindering other operations in the orchard/vineyard (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%. When these practices are combined with mulching, this increase reaches 73%.

Comparison of different amendments in soil carbon storage

The OAD MO project [5] has conducted experiments on the application of organic matter in viticultural soils, including green waste compost, commercial compost, pomace compost and cover crops. The results show that organic amendments improve soil carbon content and organic matter content, although significant differences between the different types of organic matter tested are rare due to the slow evolution of soil carbon levels and the heterogeneity of carbon distribution.

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The data was used to parameterise and validate the [AMG model for viticulture](), which calculates changes in organic carbon stock over the long term. A prototype simulation tool was developed to provide a decision support tool for farmers. Three scenarios were analysed of a Languedoc vineyard with the stony alluvial soil typical of Costières de Nîmes:

- Reference scenario: mechanical weeding of all inter-rows and input of green waste compost (25 tons every four years, 36% MO, ISMO 60)
- Scenario 1: temporary cover crop in all inter-rows, application of 25 tons of green waste compost every four years (36% MO, ISMO 65) and pruning debris left on the soil
- Scenario 2: mechanical weeding and pruning debris
- Scenario 3: pruning debris and temporary cover crops in every alley

This simulation showed that the soil carbon provided by the organic amendment (green waste compost) is much higher than that provided by the grass cover (around five times higher) (Fig. 2). The AMG model predicted an increase in soil carbon stock of 2 t ha-1 after around 15 years of temporary grass cover application. In addition, the application of organic amendment could significantly increase soil carbon stock by 10 and 15 t C/ha by 2050.

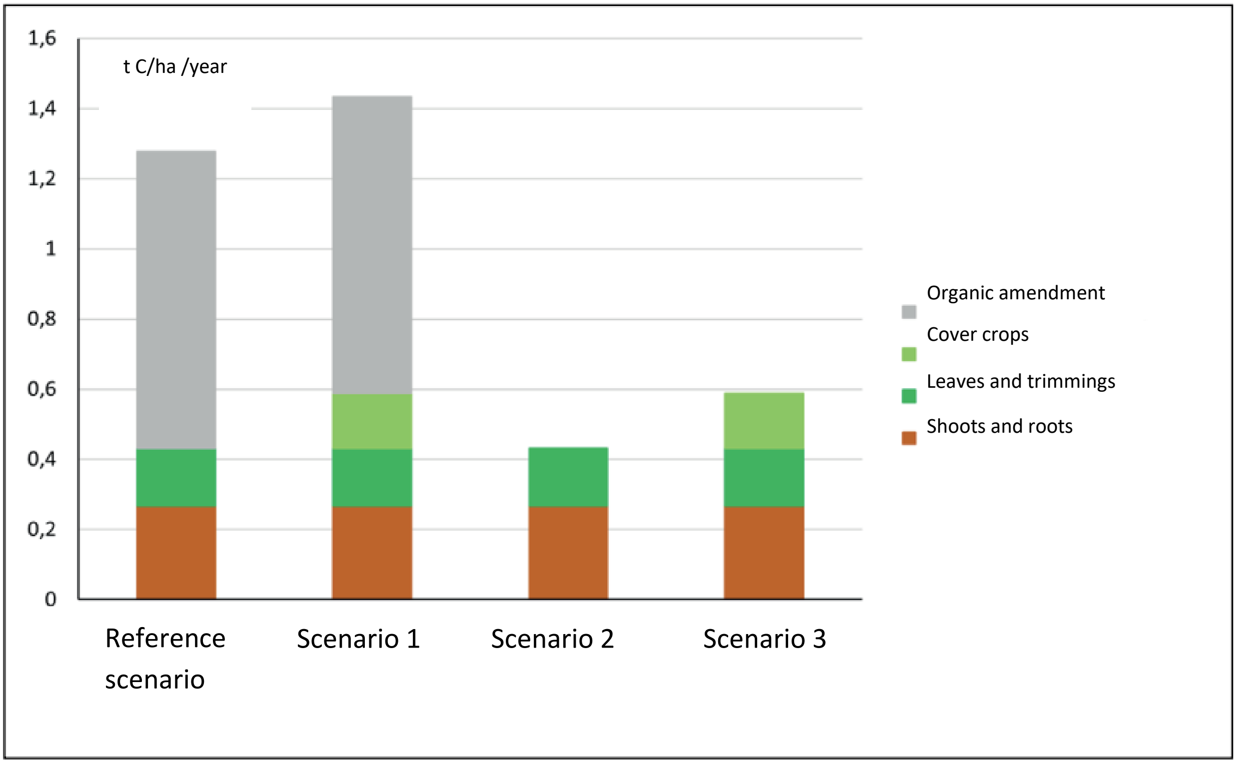

Fig. 2. Results of simulation using the OAD MO in the Languedoc vineyard study case [6]

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Cover crops: an ally against erosion and to promote carbon storage

Ground covers

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

The OG IOCONCIV [7] studied the use of a self-reseeding cover crop under a vine row in Tuscany, Italy (Fig. 3). The permanent cover was *Trifolium subterraneum ssp. brachycalicinum* for its self-seeding capacity, allowing different cycles for 3–4 years. The *brachycalicinum* subspecies has evolved to tolerate dry soils and is better suited to sub-alkaline, silty clay loam soils. The clover biomass serves as a living mulch in autumn, winter and spring, transitioning to a dead mulch in summer, with the effect of minimising competition with grapevines for water and nutrients and reducing drought stress due to the soil coverage during the summer. At the end of summer, the spontaneous germination of clover seeds initiates a new biological cycle under the rows, offering benefits such as suppressing weed emergence and improving soil fertility.

Fig. 3. Photos A and B' show the subclover at its maximum vegetative stage, while C shows the subclover after it has died, continuing to cover the soil as dead mulch [8]

Green manure

Green manure is a cover crop that produces biomass and is returned to the soil to improve its fertility and structure if water and nutrient competition are kept under control. The date, type of termination and choice of species are important factors for the proper implementation of this practice. Green manure can influence the supply of nitrogen to the crop, thus limiting the use of inputs [9].

During an experiment carried out in a vineyard in France, it was measured that approximately 62% of the carbon in terminated green manure biomass was mineralised, while the remainder was classified as 'stable' carbon, as indicated by the organic matter stability index (OMSI) [10]. The closer the OMSI value is to 100%, the more it indicates that the carbon provided by the green manure will remain in the soil for an extended period. Calculations have been conducted to determine the theoretical carbon storage capacity of green manures. For instance, green manure of 4 tons dry matter ha^{-1} (sown in all the inter-rows), represents 1,600 kg C ha^{-1}, i.e., 608 kg of stable carbon per ha (OMSI 38%). In the case of green manure sown in alternate rows, the potential carbon storage is 200 kg/ha,

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i.e., 50 kg C/t DM. This carbon storage varies little depending on the green manure species used as they all have the same organic matter stability index [10].

In the Mediterranean context, sowing green manure as early as possible at the end of the summer (late August/early September) will ensure that the seedlings are well-developed during heavy rainfall in autumn, to reduce erosion and prevent vine leaves from getting blown away (they are a source of nutrients for the soil). Over-dosing seedlings (for all species) is also advisable in Mediterranean conditions, as well as choosing a well-diversified mix (legumes, grasses, brassicas) to ensure the sustainability of the cover with rotation of the dominant species.

Agroforestry and hedges: creating carbon sinks in and around plots

Trees and hedges play a crucial role in shaping soil fertility and carbon storage since they act as carbon sinks by absorbing atmospheric CO_2 through photosynthesis and storing it in their biomass (wood, roots, leaves) and the soil through root systems and organic matter. Hedgerows can also reduce runoff and thus organic matter loss through soil erosion. Based on a literature review [11], hedgerows contribute to additional carbon storage of 750 kg C/ha^{-1} per hedge year^{-1}. However, it is generally difficult to establish a hedgerow due to a lack of space once the vineyard or orchard is in place and due to water and nutrient competition. In such cases, it is advisable to implement smaller shrub hedges along the boundaries of the plot. Carbon storage associated with planting hedges around vine plots can be estimated using a carbon footprint calculator, GES&VIT tool [12] developed by IFV.

'Carbon farming': maximising the 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 projects Catalogue [13] is a guideline highlighting successful carbon farming practices from projects funded under different European programmes.

Carbon Farming Med – Euroregion [14] aims to help farmers develop a sustainable and resilient Mediterranean agricultural system while encouraging their entry into the carbon market to obtain another source of income. This objective will be achieved by optimising regenerative agricultural practices in a Mediterranean context and providing the necessary tools to facilitate the adoption of carbon credits in the market. The Carbon Farming – CE project [15] standardises the monitoring of carbon sequestration in agriculture, focusing on measuring soil organic carbon (SOC) improvements through various farming methods. The partnership adapts and tests various techniques and business models and develops a monitoring tool for transnational, standardised carbon sequestration. LIFE VitiCaSe [16] is

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a project dedicated to carbon farming in viticulture, characterised by a series of agricultural and soil management practices aimed at increasing the capacity of the wine-growing ecosystem to capture and retain atmospheric carbon.

Conclusion

Adopting soil conservation practices is essential for enhancing vineyard resilience and mitigating the effects of climate change, particularly in the Mediterranean region. Strategies such as the application of compost, on-farm composting, the use of compost tea, integration of pruning residues, cover cropping and agroforestry significantly improve soil health, increase carbon sequestration and reduce reliance on external inputs. These practices not only support sustainable viticulture but also play a crucial role in maintaining soil fertility, preventing erosion and fostering long-term environmental benefits.

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