SOIL COVER MANAGEMENT IN MEDITERRANEAN VITICULTURE

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Cover crops are used as intercrops in perennial systems such as vineyards and orchards. They are referred to by various terms: service crops, green manures or catch crops (e.g., 'cover crops for nitrate trapping' or 'CIPAN' in French). These crops are not grown for direct harvest, but rather to promote and enhance ecosystem services within the agricultural system. Although increasingly present in vineyards, cover crops require careful management, particularly in Mediterranean climates where the risk of competition with the vine is heightened. This competition can threaten both yield targets and economic viability. Therefore, cover crop management must be tailored to the specific pedoclimatic conditions, production goals and the ecosystem services sought.

SOIL COVER STRATEGIES IN VITICULTURE

Various types of soil cover are used in viticulture, mainly in the inter-row area, but also under the vine row, depending on production objectives and constraints. Four main soil cover strategies can be identified[1]:

- **Spontaneous permanent cover cropping:** Development of naturally occurring species already adapted to the plots. This strategy involves low costs (limited to cover maintenance), but no control over the species established: previous weed management may have selected invasive species that compete strongly with the vine.
- **Sown permanent cover cropping:** Long-term establishment of a mixture of selected species adapted to local conditions and with low competitiveness toward the vine. This allows better control of species composition and the ecosystem services delivered. However, sowing costs must be considered, as re-sowing may be needed periodically depending on species persistence.
- **Spontaneous temporary cover cropping:** Establishment of a spontaneous cover, offering greater flexibility in managing competition for water or nitrogen since the cover can be selectively destroyed. No sowing costs, but requires close monitoring to ensure timely intervention.
- **Sown temporary cover cropping:** Establishment for a few months of selected plant species based on the ecosystem services targeted (e.g., leguminous green manures for their potential nitrogen contribution to the soil). Sowing must be planned in advance to ensure successful emergence and biomass production. Similarly, the destruction method must be chosen carefully to maximise agronomic benefits without harming the vine.

COVER CROPS SUPPORTING THE VINE

Cover crops can provide numerous ecosystem services that benefit the vine[2], particularly in the following areas:

- **Soil physical properties and water balance:** Protection against erosion, improved soil structure (reduced compaction, better load-bearing capacity, increased porosity), enhanced water infiltration and retention, helping to reduce runoff and evaporation.
- **Soil organic matter status:** Increased organic matter content, carbon sequestration.
- **Soil chemical fertility:** Nitrogen input (depending on the C:N ratio, type of cover, biomass produced and destruction method), reduced nitrogen losses through leaching.
- **Soil biodiversity and biological activity[3]:** Increased abundance of soil fauna (earthworms, nematodes) and mycorrhizae; stimulation of microbial activity.
- **Microclimate and fungal disease regulation:** Reduced vine vigour and increased potential evapotranspiration, thereby limiting fungal development; mitigation of heat stress by reducing ground reflectance.
- **Pest regulation:** Diversification of habitats for natural enemies of pests, such as predatory mites (Phytoseiidae)[4].
- **Weed control:** Reduced germination through competition for light, water and nutrients; rapid, dense ground cover with high biomass production.

1. Pierre-Antoine Noceto, Hériché, Mathilde, Laure Gontier, Daniel Wipf, Benoît Bazerolle, et al.. Les couverts végétaux. Partie 1/2 : Une pratique agroécologique au service de la vigne. La revue des œnologues et des techniques vitivinicoles et œnologiques, 2021, 178, pp.24-26. ⟨hal-03130035⟩
2. Léo Garcia et al., Management of service crops for the provision of ecosystem services in vineyards: A review, Agriculture, Ecosystems & Environment, Volume 251, 2018, Pages 158-170, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2017.09.030
3. Karimi, B., Cahurel, J. Y., Gontier, L., Charlier, L., Chovelon, M., Mahé, H., & Ranjard, L. (2020). A meta-analysis of the ecotoxicological impact of viticultural practices on soil biodiversity. *Environmental Chemistry Letters*, 18, 1947-1966.
4. Lou Tabary, Denise Navia, Léo Garcia, Elena Kazakou, Marie-Stéphane Tixier. Diversité des acariens prédateurs dans un vignoble agroécologique méditerranéen : effet des couverts végétaux et de l'agroforesterie. VEGÉPHYL – 13ème conférence Internationale sur les ravageurs et auxiliaires en agriculture, Institut Agro Montpellier, Oct 2024, Montpellier, France. ⟨hal-04956307⟩

More broadly, cover crops also benefit the wider environment, notably through water purification and pollution mitigation, carbon sequestration, biodiversity and wildlife conservation, and enhancement of landscape aesthetics, which can be an asset for agritourism.

However, despite their many benefits, cover crops may also introduce certain disservices across nearly all the above categories. Key points of caution include strong competition for water and nitrogen, as well as a potential increase in canopy humidity, which may raise the risk of frost and fungal diseases.

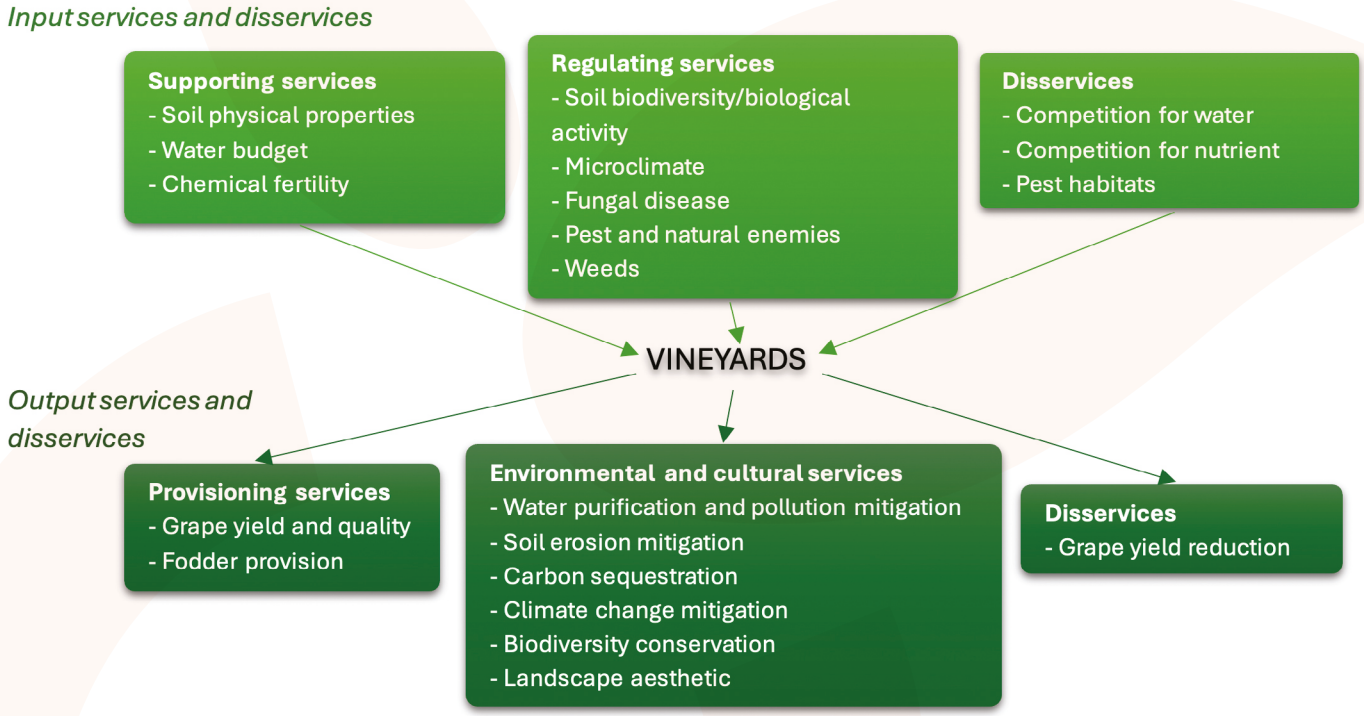

Figure 1: Ecosystem services and disservices expected from service crops in vineyards (L. Garcia et al., 2018)

TEMPORARY COVER CROPS: WHICH SPECIES TO SOW?

Figure 2: Medicago lupulina

Species selection should prioritise the primary agronomic objective and local soil and climate conditions. In Mediterranean areas, early sowing (late August to early September) is recommended to ensure good cover development. This helps reduce erosion during heavy autumn rains and prevents vine leaves from being blown away — these leaves serve as an additional source of soil nutrients.

Overseeding (increased seed rates for all species) is also advised, along with choosing a well-diversified mix (legumes, grasses, cereals, brassicas) to ensure the long-term sustainability of the cover by rotating the dominant species. Below is a selection of species recommended for Mediterranean viticulture, taken from the *Green Manure Fact Sheets*[5] by the French Vine and Wine Institute (IFV):

5. Fiches Pratiques - Engrais vert en viticulture de l'Institut Français de la Vigne et du Vin, available at: https://www.vignevin-occitanie.com/wp-content/uploads/2019/02/Fiches-engrais-verts.pdf

Charactéristics	Faba bean (*Vicia faba)*	Oat (*Avena sativa)*	Barley (*Hordeum vulgare)*	White mustard (*Sinapis alba)*
Famillly	Fabaceae (legume)	Poaceae (grass)	Poaceae (grass)	Brassicaceae (crucifer)
Average dry matter yield (t/ha)	4-6	3-6	3-6	4-5
Atmospheric nitrogen fixation	Yes	No	No	No
Potential nitrogen return for 2 t DM/ha	47 kg/ha	24 kg/ha	22 kg/ha	26 kg/ha
C:N ratio	12	18	19	17
Soil coverage	Medium to low	Good	Good	Good
Competitiveness against weeds	Low	Good to moderate	Good to moderate	Good

A study was conducted to optimise species selection to reduce runoff and limit water competition between cover crops and vines. The goal was to find the best trade-off between ground cover rate (used as an indicator of runoff and erosion control) and impact on soil water reserves (water supply/retention)[6]. Species trait analysis showed that aboveground dry matter content is correlated positively with soil water stock but negatively with ground cover rate. Additionally, several root traits significantly influence soil water retention, particularly the proportion of very fine roots, specific root length and average root diameter. Under Mediterranean conditions, *Medicago lupulina* (Fabaceae) emerged as a particularly promising species. It combines high dry matter content, shallow rooting, strong soil water retention capacity and good ground cover performance.

TEMPORARY COVER CROPS: INFLUENCE OF TERMINATION DATE AND METHOD

As previously mentioned, cover crops require precise management, with key factors being the **termination date** and **termination method**. Depending on the chosen strategy, these factors have varying impacts on both the cover crop and the vine. A recent study[7] compared two different termination dates (early termination vs. at budburst) and three termination methods (tillage, rolling, mowing). The main effects of these decisions are as follows:

- **Effects on cover crop management**

Allowing cover crops to grow until vine budburst resulted in double or triple the biomass compared to early termination. The method of termination also influenced regrowth: tillage was the most effective at eliminating covers and limiting weed pressure at flowering (a critical stage for the vine). In contrast, rolling was less effective, particularly on grasses, but generated the most surface residue, making it a good option for in situ mulching.

- **Effects on soil organic matter and microbial biomass**

After three years of monitoring, no significant change in soil organic matter was observed. Building up organic matter typically requires several years of continuous cover. Soil carbon accumulation is largely determined by the biomass produced and its characteristics (e.g., C:N ratio).

Microbial biomass, however, was significantly influenced by the timing and method of cover crop destruction: late termination (at budburst) without tillage led to higher microbial biomass levels, likely due to greater biomass return and extended root activity.

- **Effects on soil water reserves and vine water status**

Cover crops improve water infiltration and soil water storage. In this study, only the termination method significantly affected soil moisture and vine water stress. Tillage rapidly stopped cover transpiration, leading to higher water reserves and lower vine water stress compared to mowing or rolling. However, the relative effectiveness of different termination methods is still debated in the literature. The roller-crimper, for example, has been shown to enhance soil moisture conservation and reduce soil temperature compared to residue incorporation, while also reducing energy costs, an important environmental consideration in Mediterranean regions .

Lastly, year-to-year climatic variability — especially spring rainfall — has a dominant effect on soil water reserves and vine stress levels.

6. Léo Garcia, Aurelie Metay, Elena Kazakou, Jonathan Storkey, Christian Gary, et al. Optimizing the choice of service crops in vineyards to achieve both runoff mitigation and water provisioning for grapevine: a trait-based approach. Plant and Soil, 2020, 452 (1–2), pp. 87–104. 10.1007/s11104-020-04543-y. hal-02619383
7. Léo Garcia et al., Adapting service crop termination strategy in viticulture to increase soil ecosystem functions and limit competition with grapevine, European Journal of Agronomy, Volume 156, 2024, 127161, ISSN 1161-0301, https://doi.org/10.1016/j.eja.2024.127161.
8. Alonso-Ayuso, M., Gabriel, J.L., Hontoria, C., Ib´a˜nez, M.´A., Quemada, M., 2020. The cover crop termination choice to designing sustainable cropping systems. Eur. J. Agron. 114, 126000 https://doi.org/10.1016/j.eja.2020.126000.

• Effects on soil mineral nitrogen and nitrogen in grapes

Tillage-based cover termination led to much higher levels of mineral nitrogen in the soil (up to 61 kg/ha) compared to rolling and mowing (16.25 kg/ha). This can be attributed to several combined factors: accelerated mineralisation of incorporated residues and reduced competition from the destroyed cover[9]. Conversely, no-till methods allowed regrowth of the cover crop, which absorbed available nitrogen. Seasonal effects were also notable: low biomass and high C:N ratios slowed mineralisation. Nitrogen content in the grape must followed the same trend, with higher assimilable nitrogen levels in the tilled treatments, confirming a 'green manure effect'.

• Effects on vine vigour and yield

The method of cover crop termination significantly influenced vine vigour and yield. Tillage-based destruction led to greater vine vigour (higher pruning weights) and stable or even increasing yields over the three-year study period. In contrast, mowing and rolling produced lower pruning weights, which could compromise long-term sustainability in the case of repeated drought.

Observed yields (7.25 to 13.7 t/ha, depending on termination strategy)4 were acceptable for some AOPs (protected designations of origin – PDOs), but could be limiting for other types of production (PGI, table wines). Cluster number — the main yield determinant — was significantly higher in the tillage treatment, likely linked to reduced water and nitrogen stress.

MEDITERRANEAN CONTEXT: THE NEED FOR PRECISE MANAGEMENT

In Mediterranean regions, increasingly characterised by dry winters and a higher frequency of drought events due to climate change, the management of cover crops must be strategically and finely tuned to the climatic conditions of each growing season.

To best adjust the timing and method of cover crop termination, several indicators must be considered: autumn–winter rainfall balance, access to irrigation, soil depth and available water capacity and the vine's vegetative status during the previous year (signs of reduced vigour, low yield, etc.). Tillage-based termination appears to be the safest strategy to preserve vine vigour and maintain production in Mediterranean areas. However, this choice must be considered in light of production objectives and the economic value of the wines produced.

An adaptive approach seems particularly relevant. Where autumn and winter rainfall have ensured good soil water recharge, the risk of competition is limited. In such cases, it is possible to extend cover crop growth into spring to maximise biomass production and associated ecosystem services. Termination using a roller-crimper can be considered in this context. Conversely, in years marked by winter drought or a lack of irrigation, prolonged cover crop development may increase the vine's water and nutrient stress, to the detriment of its vigour and yield, especially in shallow or drought-sensitive plots. Tillage is therefore recommended for cover crop termination during dry years.

This adaptive strategy can be reinforced by choosing cover crop species that are easy to terminate mechanically, have minimal impact on soil water reserves and provide high ground cover. Finally, differentiated management at the plot level can help fine-tune the balance between soil biological activity and vine performance. Effective approaches may be, e.g., alternating practices between rows (tillage every other row, roller-crimper on the others, switching from year to year, etc.) or adjusting the level of ground cover based on intra-plot variability[5].

TO FIND OUT MORE

- Fiches engrais verts, Institut Français de la Vigne et du Vin, available to : https://www.vignevin-occitanie.com/wp-content/uploads/2019/02/Fiches-engrais-verts.pdf
- Léo Garcia et al., Management of service crops for the provision of ecosystem services in vineyards: A review, Agriculture, Ecosystems & Environment, Volume 251, 2018, Pages 158-170, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2017.09.030.
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- Léo Garcia, Aurelie Metay, Elena Kazakou, Jonathan Storkey, Christian Gary, et al.. Optimizing the choice of service crops in vineyards to achieve both runoff mitigation and water provisioning for grapevine: a trait-based approach. Plant and Soil, 2020, 452 (1-2), pp.87-104. 10.1007/s11104-020-04543-y. hal-02619383

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