AGROFORESTRY IN VITICULTURE

Agroforestry encompasses all farming practices that combine trees (in various forms such as hedgerows, rows, groves, etc.) with crops and/or livestock, on the same plot. It is based on the complementarity between plants to promote a natural and functional balance within the farming system, through species diversification, staggered cropping and maximising interactions between different ecosystem compartments (soil, plants, animals, atmosphere)[1]. According to the international definition proposed by the World Agroforestry Center (ICRAF), agroforestry refers to the interaction between agriculture and trees, including their agricultural use: trees in fields, on farms or within agricultural landscapes, as well as farming in forests and at forest margins. It also includes tree-based cropping systems such as cocoa, coffee, rubber and oil palm. These interactions occur at various scales (field, farm, landscape) and contribute to ecosystem service provision[2]. Trees and vines have been united in a long-standing 'marriage': the first references to a 'shrubby' vine date back to the Ancient Greeks, who passed it on to the Etruscans, while it went on to become a fully established system during Roman times. Today, the wild vine Vitis vinifera sylvestris still bears witness to this, relying on the tree for its growth. There are also a few historical remnants of cultivated grapes 'married' with maples or other trees visible in the Mediterranean region.

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WHERE DOES AGROFORESTRY STAND IN RELATION TO THE CAP?

After the Second World War, agriculture intensified under the impetus of the European Commission's common agricultural policy (CAP), to the detriment of trees, which were seen as a nuisance. But over the last 20 years or so, agroforestry has been gradually gaining recognition in agricultural policies. There have been several key milestones in this development: recognition of the agricultural status of agroforestry plots (2006), more flexible rules of tree density and installation aid (2010), regulatory adjustments (2015) and new aid under the 2023–2027 CAP (eco-regime, MAEC, 'hedgerow bonus'). Today, agroforestry is fully integrated into public policy, thanks to the advocacy work of players such as the European Agroforestry Federation (EURAF). The 'hedge pact' (2023–2027) further strengthens this support by financing planting and maintenance.

WHY CONSIDER AN AGROFORESTRY SYSTEM FOR WINEGROWING?

Interesting interactions can be observed between trees and vines, impacting both the soil and climate conditions on the plot as well as certain agronomic parameters (including biodiversity balance and pest and disease prevention). Indeed, the presence of trees and hedges on the plot can be useful to influence the plot's microclimate (modifying air and energy flows), develop the plot's biodiversity, improve soil structure and 'buffer' CO_2 emissions on the plot.

WHAT IS THE INFLUENCE ON THE PLOT'S MICROCLIMATE?

To produce high-quality grapes, it is essential to control the microclimate in the vineyard. This affects the amount of available radiation (solar and infrared) and turbulent energy. The interaction of radiative and turbulent flows controls air temperature and humidity, which depend on how the system dissipates this energy. The energy is divided between sensible heat flux (which heats the atmosphere), latent heat flux (through evapotranspiration) and air/ground conduction flux (which heats or cools the ground).

Work carried out in France as part of the VITIFOREST project[3] and Juliette Grimaldi's thesis[4] has shown that:

- In terms of light capture, a deficit is observed in the vine rows located to the north of the trees, reducing the potential for photosynthesis, mitigating the harmful effects of heat peaks, but significantly increasing the duration of leaf wetting. Conversely, there is a surplus of energy, and therefore heat, in the vine rows located to the south of the trees, increasing production potential but exposing the grapes to the risk of scalding. Finally, the trees produce infrared radiation, which increases the temperature at ground level, helping to limit the impact of late spring frosts.

1. Agroforestry definition, French Agroforestry Association.
2. What is agroforestry? The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF).)
3. Emilie Bourgade, Adeline Alonso Ugaglia, Vincent Bustillo, Thierry Dufourcq, Juliette Grimaldi, et al. VITIFOREST: Evaluation of the impact of agroforestry trees in a winegrowing context. Innovations Agronomiques, 2020, 79, pp. 471-497. 10.15454/73ry-yq72.
4. Juliette Grimaldi. Impacts of agroforestry on microclimate for grape and wine production: assessment in Southern France. Life Sciences [q-bio]. Université Toulouse III Paul Sabatier (UT3 Paul Sabatier), 2018. English. ⟨NNT : ⟩.

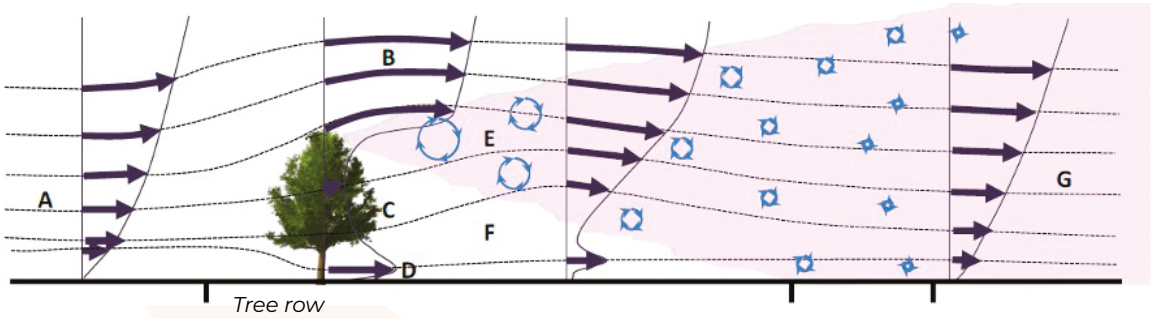

Figure 1 : Schematic representation of turbulent air flows around a lone tree (source: Grimaldi, 2018).

A: Wind profile upstream of the windbreak — *2 to 5 H*
B: Acceleration above the canopy — *3 to 10 H (if a single row of trees)*
C: Slowing of air passing through the canopy — *1.8 H (if multiple rows of trees)*
D: Acceleration below the canopy — *10 à 20 H*
E: Turbulent zone
F: Sheltered area
G: Profile restored
H: Height of the tree

- As regards interactions with the water cycle, trees can modify the presence of water or humidity in their immediate environment: they recycle deep resources and increase the relative humidity of the air by a few percentage points, allowing heat peaks to be moderated by encouraging the stomata to open and prolonging evapotranspiration flows. Trees are excellent water traps, capable of condensing the moisture contained in the air in the form of dew, but also of intercepting rainwater up to a depth of 3–5 mm.
- Turbulence fields in the plot are modified by the presence of trees. Isolated intra-plot trees increase these turbulent flows, mitigating temperature peaks and reducing the duration of leaf wetting. On the other hand, the circulation of cold air can be slowed when trees are located at the edge of a plot, particularly in a low topographical position. This can increase the risk of frost, especially in low-lying areas.

WHAT INFLUENCE DOES THIS HAVE ON SOIL STRUCTURE AND CARBON STORAGE?

Trees have an impact on soil structure by improving microbiological activity, increasing organic matter and providing numerous roots. This increases porosity and limits erosion.

In terms of carbon, a distinction must be made between the carbon fixation function (photosynthesis) and the carbon storage function (creation of a carbon stock over time). Trees' large biomass and long life mean they can fix a large quantity of carbon compared with most other plants in the agroecosystem. The carbon is then returned to the soil through their leaves, wood and roots. Soil decomposers transform this into organic matter (OM), improving fertility and fixing CO_2 in the soil. Below is an example of the storage capacity of different types of sustainably managed hedgerows (planted in southwestern France) in tonnes of CO_2 equivalent stored per km of hedgerow per year:

Table 1 : *Carbon storage in the aboveground and root biomass of a sustainably managed hedgerow by type in western France (in teqCO_2/km/year). Aboveground biomass is divided into biomass remaining on site and biomass used for wood energy. (Source: values from the Carbocage project; hedgerow illustrations from Arbre et Paysage 32, https://ap32.fr/arbres-paysages/)*

In teqCO_2/km/year	**Multi-purpose hedge** 	**Coppice hedge** 	**High hedge** 	**Shrub hedge** 
Total biomass	5.90	8.90	9.98	1.80
Root biomass	1.8	3.2	2.7	0.4
Aboveground biomass remaining on site	1.89	0	4.85	1.4
Aboveground biomass exploited (optional whether exploited)	4.41	11.40	4.85	0

WHAT INFLUENCE DOES THIS HAVE ON THE BIODIVERSITY OF THE PLOT?

In the short and medium term, the introduction of trees around the perimeter of a plot of land or within a plot of land creates a diversity of landscapes and a variability of vegetation strata, and therefore new ecological niches. Trees and all their components (branches, leaves, flowers, fruit, cracks in the trunk, roots) offer a mix of habitats, refuges, food resources, hunting, breeding and wintering areas for a wide variety of species. Organisms that are useful to the winegrower, such as mites, lacewings, certain carabid beetles, parasitoids, etc., can also benefit from these resources as part of this overall diversity.

Soil biodiversity is also affected. The combination of vines and trees promotes the mycorrhizal network, which plays an important role in the exchange of water and nutrients. Soil earthworms also have a positive impact, as shown in the VITIFOREST project, where it was demonstrated that the presence of trees has a significant impact on the distribution of earthworms, with a decreasing frequency trend observed as the distance from the tree zone increased. The presence of trees on winegrowing plots also has an impact on microbial communities, in particular by providing additional nutrient resources to soil microorganisms via the rhizosphere and tree litter.

Introducing trees into vineyards should not be considered in isolation but as part of an overall strategy combining biodiversity-friendly features (such as hedges or late mowing) and reduced inputs, to ensure effective ecological continuity.

WHAT ARE THE MAIN POINTS TO BEAR IN MIND?

Water-nitrogen competition

The potential competition between trees and vines is a real constraint that needs to be taken into account. In certain experimental plots in a Mediterranean context in the south of France, the rows of vines closest to the trees showed a drop in yield of 9% to 31% compared with the rows farther away from the trees. Differences in nitrogen nutrition were also observed, with levels up to 20% lower near the trees[5]. These results need to be interpreted and understood considering the site-specific soil and climate conditions. In fact, on plots located in southwestern France, nine years of co-planting in different arrangements revealed no difference in behaviour — either in terms of biomass production or grape quality — between vines planted in close proximity to trees (adjacent row) and those located in the middle of the plot, more than two rows away[2]. It would be useful to repeat this monitoring when the system approaches 20 years of co-cultivation with mature trees that have developed significantly.

Regardless of the case, there are various ways to prevent potential competition between trees and vines in agroforestry:

- tree management: pruning the canopy (in winter or summer) reduces shade and water consumption;
- root circling, carried out every three years, limits the spread of roots towards the vine. It may also be possible to use a pollard system;
- sowing leguminous cover crops between the rows improves fertility and limits leaching while fixing atmospheric nitrogen;
- localised fertilisation (ground or foliar) and targeted irrigation help to offset the effects of competition, particularly for rows close to trees.

Root rot

Particular vigilance is required when it comes to root rot disease. A large number of woody species can harbour the fungi responsible for this parasitism (including *Armillaria mellea*, responsible for Armillaria root rot), and the introduction of trees into winegrowing plots carries a significant risk of the disease developing over time. Oaks, peach trees and many other forest and fruit species are particularly susceptible. Root rot develops slowly but persists in the soil, causing recurrent symptom outbreaks and mortality in the same place, despite periods of fallow. There is no curative treatment available, and agroforestry may encourage its development. Some prophylactic measures to bear in mind include:

- thoroughly cleaning the plot when planting (debris, old roots);
- leaving the soil to rest for 4–5 years if replanting after uprooting;
- encouraging living, well-structured, well-drained soil;
- limiting root exchanges between the vine and nearby trees by trying to maintain a minimum distance of at least 3 m (empirical recommendation; no proof that this distance will prevent contamination between the trees and the vine).

Technical constraints linked to the development of the plot

Finally, the last point to consider concerns the layout of the agroforestry plot: several points need to be taken into account to ensure the success of the project, such as the objectives and scale of the project, the orientation of the plot, mechanisation (particularly the number of rows covered in the case of intra-plot trees), game animal problems, soil condition, etc. Furthermore, as mentioned above, the presence of trees and hedges influences the plot's microclimate, and the correct modelling of hedges plays a vital role in ensuring that they do not increase the risk of frost damage (an impermeable hedge at the bottom of a slope does not allow cold air to escape) or humidity (conducive to fungal diseases) but, on the contrary, facilitate air circulation and improve overall vineyard health.

WHAT ARE THE PREREQUISITES FOR SETTING UP AN AGROFORESTRY PLOT?

Plot layout

In terms of the type of tree formation, there are four possible types of agroforestry layout in vineyards:

- an island of trees in the plot. This should be a multi-species grove, preferably multi-strata;
- intra-parcel trees, within the rows of single or multi-species vines;
- rows of trees (either single- or multi-species) instead of one or more rows of vines;
- hedges at the edge of a plot or to divide a plot into several parts.

The final choice depends on production constraints and the winegrower's expectations: is the primary objective to limit the effect of side winds or the drift of phytosanitary products? Or to create biodiversity resources and habitats? Is the plot being developed an existing plot or one being restructured?

20 years after the first trials carried out in a Mediterranean

5. Juliette Cassagne, Agroforesterie - Les impacts sur la vigne en termes de concurrence, Vitisphère, 2014

context in the south of France and in the wake of the VITI-FOREST project, below are some recommendations to be followed wherever possible:

- favour north-south orientations to limit and balance the shading of the trees on the vines;
- leave a minimum distance of 3 metres between the line of trees and the first row of vines, ideally 4 metres;
- try to aim for a distance of 25 m to 30 m between each line of trees;
- the distances between the trees along the line will depend on the target density;
- define tree density according to local resources and vineyard needs and status. For low density, consider about 50 stems/ha, while maximum density could be considered 150 stems/ha;
- consider the space needed for mechanical equipment and tools to manoeuvre in and around the vineyard.

Choice of species

Integrating trees into winegrowing requires a site-specific selection of species to ensure the agronomic and ecological coherence of the system. It is essential to choose hardy species adapted to local soil and climate conditions and to consider the heterogeneity of the plot (soil, humidity, exposure).

Diversity, both in terms of species and genetics, must be sought to strengthen resilience and limit health risks. Depending on the winegrower's objectives, species can be chosen for their production (wood, fruit, flowering), their ecological role (shade, auxiliary biodiversity) or their compatibility with the vine (light foliage, low light competition). In the context of viticulture, it is worth noting that oaks and pines are very competitive for water and nutrients, and many fruit trees are particularly susceptible to rot. The field maple is an example of a suitable candidate for vines, as it is not very competitive or very susceptible to root rot.

Plant material must be certified in terms of health and genetics, and young plants should be favoured to encourage good recovery. If planting fruit trees, a suitable option is to plant the rootstock and to graft it on-site two years later. This allows for better and deeper rooting.

Preparing for planting

Good soil preparation is essential to ensure optimum rooting and development for the young trees that will be planted. Subsoiling, followed by surface refinement, is best carried out in autumn before the trees are planted in winter or early spring. To limit herbaceous competition and conserve soil moisture, a mulch should be laid over a 1-m2 area around the young trees. This can be done using straw, chopped wood or biodegradable film. Depending on the area, it may be useful to protect the plants from game animals with barriers / protection measures.

Tree management

Tree training is essential during the first 5–8 years to ensure their proper development. For isolated trees, trunk clearance of at least 2 m is recommended, particularly for timber production. Hedges, on the other hand, should be contained horizontally to avoid encroaching on the inter-row space and can be maintained at the same time as the vines. Depending on the species, shading can be adjusted by pruning, particularly pollarding, which limits the leaf area and encourages the creation of cavities that are useful as habitats for wildlife.

HOW MUCH DOES AN AGROFORESTRY PROJECT COST?

According to the costs listed for 2023 in France by the Réseau Haies France – AFAC Agroforesteries , a one-row hedge planted every metre would cost an average of €18.27 per linear metre, while a two-row hedge planted every 1.5 metres would cost an average of €28.91 per linear metre. You should allow 20 to 40 hours' work for 100 metres of hedge over the first 5 years[7].

The cost of planting a single tree within a plot would be €27.96 per plant. On average, 25 to 30 hours of work are needed to plant 100 trees[6].

TO FIND OUT MORE

- Institut Français de la Vigne et du Vin – Agroforestry and viticulture – Itinéraires n°28 - 2018, available at: https://www.vignevin.com/wp-content/uploads/2019/03/1811_ESOPE_IFV_Brochure_Agroforesterie_web100_DPI_VF-1.pdf
- Juliette Grimaldi. Impacts of agroforestry on microclimate for grape and wine production: assessment in Southern France. Life Sciences [q-bio]. Université Toulouse III Paul Sabatier (UT3 Paul Sabatier), 2018. English. ⟨NNT : ⟩. ⟨tel-03515990⟩, Available at: https://theses.hal.science/tel-03515990
- Delinat Consulting and Domaine Emile Grelier – Agroforestry in viticulture, a step forward towards resilience – 2022, available at: https://www.agroforesterie.fr/wp-content/uploads/2022/09/fr-agroforesterie-en-viticulture-print.pdf
- Afac-Agroforesteries – Référence coût de plantation agroforestière – 2023, available at: https://reseauhaies.fr/wp-content/uploads/2023/05/Bareme_2023_VF.pdf
- Guide technique de l'agroforesterie en viticulture en Bourgogne Franche-Comté, VITAF– 2022 project, available at: https://www.vinipole-sud-bourgogne.fr/uploads/mce/docs/Guide%20agroforesterie%20en%20viticulture%20VITAF.pdf

6. Références coût de plantation agroforestière établies par l'Afac-Agroforesteries, Avril 2023
7. https://www.vinipole-sud-bourgogne.fr/uploads/mce/docs/Guide agroforesterie en viticulture VITAF.pdf Guide technique de l'agroforesterie en viticulture en bourgogne Franche-Comté, projet VITAF, Décembre 2022

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