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# Impact of training system, soil management, and soil water holding capacity on vine water status in the Cognac production area under climate change

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With climate change, the risk of water deficits in vineyards is tending to increase, which may impact both yield and grape quality. In this study, the Lebon *et al.* (2003)[1] soil water balance model was applied to assess the impact of training systems, soil water holding capacity (SWHC), and soil management practices on vine water status in the Cognac production area from 1962 to 2021. This research quantifies if and how water deficits can be effectively managed by modifying vine training systems and soil management practices in a wine-producing region using simulation tools. Such tools can guide research and provide actionable levers for wine producers to adapt their production system to climate change.

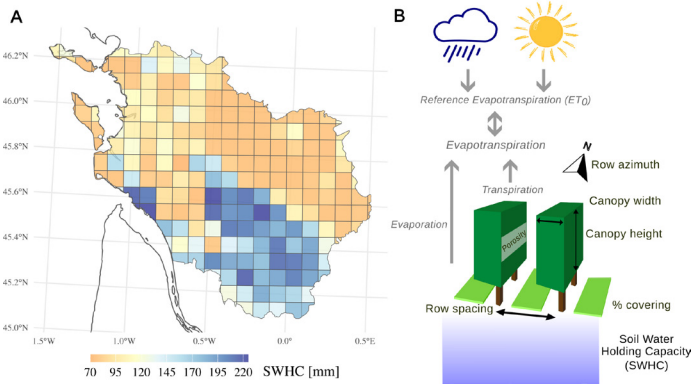



**FIGURE 1.** A) Average soil water holding capacity across the Cognac region, mapped on an 8 km grid used for the simulations (matching the resolution of the climate dataset). B) Simplified diagram illustrating the canopy geometry parameters considered by the Lebon model in the water balance simulation.

## Methodology

A climate dataset with an 8 km grid resolution (SAFRAN database; daily rainfall and temperature) from 1962 to 2021, combined with the average SWHC estimated at the same resolution from existing French national synthetic maps (Figure 1A), was used as input for the Lebon model. This grapevine water balance model includes parameters of canopy geometry (e.g., height, width, porosity, row spacing, and orientation; Figure 1B). In addition, a cover crop transpiration module accounted for grass cover configurations (0 %, 35 %, 70 %), while phenology and sugar ripeness models were used to apply the output of the model (estimated water deficit) to sensitive periods of the grapevine cycle based on phenophases (flowering - maturity), rather than on calendar dates.

To evaluate the model's sensitivity and response to varying SWHCs and viticultural practices (e.g., soil cover management and training systems), input parameters of canopy geometry were set across a range reflecting the regional practices. From this analysis, three parameter combinations representing canopy development and soil management were selected to simulate cropping systems with typically low, medium, and high water deficits. These combinations were subsequently used for regional-scale simulations.

## Results

### Temporal evolution

A significant increase in modelled water deficit was observed over the 60 year study period, particularly in the north-western part of Cognac region, affecting 23 % of the area. At the regional scale, this increase is associated with a warmer period from flowering to maturity (an average increase of +1.8°C at the regional scale), a shorter duration of this period (an average decrease of 8.5 days), and a slight decrease in cumulative precipitation. However, the decrease in precipitation was not significant for most of the region and can be partly explained by the shorter flowering-maturity period.

### Effect of soil water holding capacity

A linear mixed-effect model (LMM)[1] was used to assess the contribution of training system parameters to the simulation of water deficit. The model explained 57 % of the total variance. SWHC is the predominant factor influencing grapevine water status, explaining 82 % of the variance on the simulated severe water deficit days, followed by grass cover (9.2 %) and canopy width (6.3 %). Canopy height, row spacing, and azimuth had less impact (<1 % of variance), while canopy porosity had negligible effect (<0.05 %).

### Training system and soil management

The parameters linked to the training system and soil management practices also play a role, and by selecting scenarios that reduce vine transpiration it is possible to significantly reduce the number of water deficit days (Figure 2).
Over the 1992-2021 period, the average number of days with severe water deficit increased at the regional scale by an average of 12 days (Figure 2B) for the median scenario, and by 23 days (Figure 2C) for the scenario with a high exposed leaf area and grass cover, relative to the scenario with reduced exposed leaf area (Figure 2A). Spatial variability remained strongly influenced by SWHC, with soils having high water reserves (>200 mm) showing no significant

[1] LMM is a statistical model that describes the relationship between a response variable and some of the covariates that are measured or observed along with the response.


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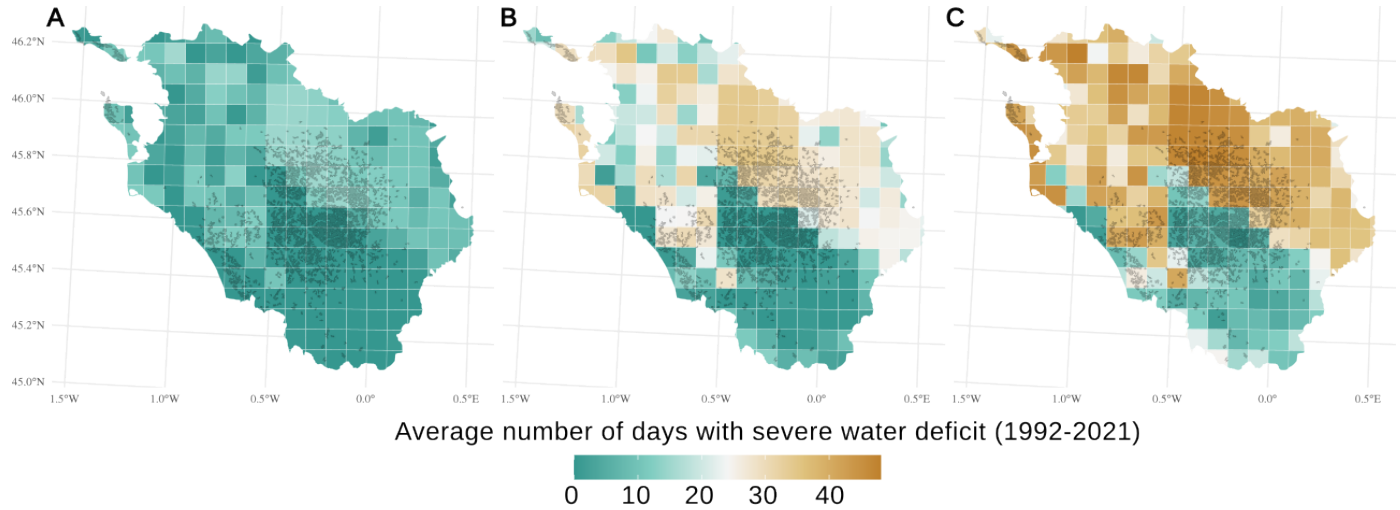



**FIGURE 2.** Average number of days with severe water deficit simulated from flowering to maturity in three scenarios: A) reduced exposed leaf area (canopy height = 0.9 m, width = 0.5 m, porosity = 20 %, row spacing = 3 m, orientation = E-W) with 0 % grass cover; B) commonly used training system in the region (canopy height = 1.2 m, width = 0.7 m, porosity = 12 %, row spacing = 2.7 m, orientation = N-S) with 35 % grass cover; C) larger exposed leaf area (canopy height = 1.5 m, width = 1 m, row spacing = 2.5 m, orientation = N-S) with 75 % grass cover.

increase in water deficit, even under growing conditions with high exposed leaf area and grass cover (Figure 2C).

## Discussion, limitations, and avenues for future research

The model's accuracy depends on input data, particularly SWHC estimates and grass cover effects. SWHC is primarily determined by inherent soil characteristics, such as texture and the percentage of coarse elements, which are beyond the grower's control. However, it also depends on vine rooting depth, which can be modified by the producer through appropriate pre-planting soil preparation or the use of vigorous rootstocks.

The percentage of grass cover is the easiest adaptable parameter among those studied. Growers can adjust it from year to year, and even within a single season, depending on the climatic conditions of the vintage, making its effect on grapevine water deficit highly modulable. This modelling exercise did not take into account such management practices, nor the choice of grass cover species and their desiccation, all of which can significantly influence soil evaporation and cover crop evapotranspiration and, as a result, the level of grapevine water deficit.

The canopy dimensions, governing the radiation interception, strongly influence the transpiration rate of the vine. Among the different parameter values tested, the canopy width has the greatest effect. Trimming the vines to make narrower rows reduces transpiration, but it exposes the grapes to more sunlight due to reduced shade, which is not desirable for this type of distilled wine production. Hence, the management of the row width in a warmer and drier climate is a trade-off between the reduction of vine transpiration and the protection of grapes from direct sunlight.

To increase the robustness of the results, the model outputs should be validated using measured plant-based indicators of vine water status, such as $\delta^{13}C$ or water potentials[2]. This study is based on 8 km gridded climate data and national synthetic maps estimating SWHC, which do not take into account the effects of fine-scale topographic niches and microclimatic variations, nor variations in vine rooting depth. Ongoing work aims to validate these modelling tools at the scale of the Cognac region, refine the spatial resolution of the simulations, and improve the characterisation of SWHC at parcel scale, in order to provide more accurate predictions of vine water status.

While this study focused on the Cognac region, its results can be extended to other regions, as they provide a framework for assessing regional variations in vine water status as induced by local soil and climate conditions, as well as their evolution over time. It also provides a means of assessing the impact of potential levers to alleviate water deficits under climate change scenarios, which can be easily duplicated in other wine production areas exposed to increasing water deficits. ■

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***Sources :*** *Sourced from the research article: 'Impact of training system, soil management and soil water holding capacity on vine water status in a changing climate over 60 years in the Cognac production area' (OENO One, 2024).*

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