SUPPLEMENTARY DATA

Supplementary information. An overview of the inverse of model of Gaudin *et al.* (2017), adapted by Zhang *et al.* (2025).

The detailed methodological components of the inverse model have been presented in the two papers cited above, while this supplementary information provides a concise overview. Both studies were based on data collected under controlled experimental conditions.

1.1. Theoretical background

Total Transpirable Soil Water (TTSW) represents the amount of water a crop can extract from the soil under given environmental conditions and management practices. Conversely, the Fraction of Transpirable Soil Water (FTSW) is a ratio (between 0 and 1) quantifying the proportion of TTSW that is currently available at a given time.

TTSW integrates the interactions among soil properties (*e.g.*, depth, field capacity, lower limit of extraction), plant genetics and physiology, and atmospheric demand. Consequently, plant–climate observations provide a relevant basis for inversely estimating TTSW, as they are intrinsically linked to these processes. More specifically, the relationship between vine shoot growth indices, expressed by iG-Apex index, and TTSW is supported by theoretical and empirical studies (Pellegrino *et al*., 2005; Pichon *et al*., 2023). This relationship is particularly suitable for inverse modeling when other processes contributing to soil water dynamics, such as precipitation and soil evaporation, are minimized, thereby strengthening the coupling between soil water status and plant transpiration. Furthermore, the selected plant growth indicator must be sufficiently sensitive to soil water availability, with its response to soil moisture variations outweighing the influence of other factors such as nutrient availability or pest pressure.

1.2. Inverse model components

Gaudin *et al*. (2017) first developed an inverse model by simplifying the Soil Water Balance (SWB) equation to focus exclusively on plant transpiration during dry periods. The applicability of this methodology relies on three key conditions. First, conditions must remain dry for at least 10 days to ensure that transpiration becomes the only significant water flux. Second, the water deficit must reach a level sufficient to trigger stomatal closure in the vines. Third, external water inputs, such as capillary rise from water tables or deep soil layers, must be absent.

These conditions allow for the formulation of the inverse model shown in Equation SI.Eq.1. The basal crop coefficient (Kcb) represents the capacity of vines to extract soil water through transpiration (Doorenbos & Pruitt, 1992). Under common Mediterranean vine training systems

(*e.g.*, goblet training, vertical shoot positioning training), Kcb is assumed to remain constant during the mid-growth stage, typically ranging between 0.35 and 0.5 (Rallo *et al.*, 2021).

$$TTSW = -eta \times \frac{Kcb}{Water\ status\ slope} \qquad \text{SI.Eq.1}$$

Researchers determine the water status slope by recording a series of Predawn Leaf Water Potential (PLWP, in MPa) measurements alongside cumulative potential evapotranspiration (ET0, in mm). The accumulation of ET0 begins on the date of the first PLWP measurement. Under the specified dry conditions, the relationship between PLWP and cumulative ET0 is assumed to be linear (Roux *et al.*, 2019). This linear trend reflects the progressive decline of PLWP as climatic demand increases, and the fitted slope coefficient (MPa/mm) provides a quantitative measure of this relationship, because the higher climatic demand is, the steeper the linear trend should be (which corresponds to a faster soil water depletion rate).

Finally, the model incorporates a constant coefficient (η, 0.44) derived by Gaudin *et al.* (2017) which itself does not have any specific physical meaning. However, the value of η rests on two physiological assumptions: (1) stomatal closure occurs, when the FTSW falls below 0.4, and (2) the mathematical relationship between FTSW and PLWP follows the stable model proposed by Lebon *et al.* (2003).

Based on Equation SI.Eq.1, Zhang *et al.* (2025) adapted the inverse model by integrating iG-Apex and satellite data. In this adapted version, measured PLWP is replaced by predicted values derived from iG-Apex time series and weather data. In addition, the assumption of constant Kcb is replaced by estimating Kcb from satellite imagery. The adaptation also includes a plot-area ratio standardization to account for variability in plot size. This procedure adjusts the estimated TTSW to a common basis, expressed as a uniform number of grapevines per square meter under nominal plant density conditions.

The full formulation of the adapted inverse model is provided in SI Eq. 2.

$$TTSW = -eta \times \frac{Kcb_{satellite}}{Water\ status\ slope_{predicted}} \times \frac{Referential\ plot\ area}{Measured\ plot\ area} \qquad \text{SI.Eq.2}$$

The predictive model used to obtain predicted PLWP was developed by (Zhang *et al.*, 2024). Raw iG-Apex and weather data were transformed into predictors ($n = 30$) by an algorithm included inside the predictive model algorithm.

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