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# Review finds vineyard climate research is concentrated in irrigated Mediterranean sites

The survey of 92 studies said that bias leaves major gaps in evidence on water use and carbon storage in other climates.

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A review published Oct. 12 in the journal OENO One found that research on how vineyards exchange water and carbon with the atmosphere is still heavily tilted toward irrigated systems in hot, dry regions, leaving major gaps in the data needed to judge

how vineyards in other climates use water and store carbon.

The paper, written by Julien Giraudo, Julien Crétat, Mathieu Thevenot, George Burba, and Olivier Mathieu, examined 92 peer-reviewed studies published between 2000 and early 2025. Together, those papers covered 47 vineyards and 25 years of measurements made with the eddy-covariance method, a micrometeorological technique that uses instruments above the canopy to measure exchanges of water vapor and carbon dioxide between the land surface and the air.

The authors said viticulture faces two linked pressures under climate change: using water more efficiently and understanding whether vineyards can help remove some atmospheric CO2. Their review found that the evidence base is much stronger for water than for carbon. About 81% of the studies in the sample focused on evapotranspiration, or ET, the combined loss of water from soil evaporation and plant transpiration. Another 13% focused on net ecosystem exchange, or NEE, a measure of whether an ecosystem is taking up more carbon than it releases. About 5% examined water use efficiency, which links biomass production to water consumed.

Most of the water-focused work came from irrigated vineyards in arid and Mediterranean regions, including a strong concentration of studies tied to California’s GRAPEX project and other hot, dry winegrowing areas. Across those studies, climate was a major driver of yearly variation in both ET and NEE, especially global radiation and vapor pressure deficit, which reflects how strongly the atmosphere draws moisture from plants and soil.

The review found that transpiration accounted for most of vineyard ET, with contributions ranging from 56% to 86% in the studies that partitioned the flux. That matters for growers because the more precisely they can track ET, the more accurately they can estimate vine water demand and adjust irrigation to limit water stress. For wine producers, that could affect both water costs and grape quality as hotter summers and scarcer water put more pressure on vineyard management.

At the same time, the authors said the literature includes important uncertainties. Many studies used flux-station measurements to test alternative instruments or to calibrate water-balance models, but heat advection from nearby land is common in vineyard

regions and can distort ET estimates for some of those methods. That means tools validated in one site may not transfer cleanly to another if surrounding terrain, management, or climate differ.

The picture is thinner for carbon. The review said most NEE studies were carried out in Italy, and only five sites were identified as having complete annual NEE measurements. Across those sites, the average annual balance was -135.7 g of carbon per square meter, a result that points to Mediterranean vineyards acting as moderate carbon sinks. But the authors stressed that this does not settle the question of how much carbon vineyards really retain, because lateral carbon flows, including harvested grapes removed from the field, must be counted to estimate the true carbon balance.

That caution is especially relevant as wine businesses face growing pressure to document their environmental footprint. The available evidence may support better field-scale decisions, but it does not yet justify broad carbon claims for vineyards across all regions. The review warns, in effect, against extending carbon-balance results from a small group of mainly Italian and Mediterranean sites to the wider wine sector without more representative measurements.

The study also found that vineyards remain poorly represented in the global flux-monitoring system. More than 2,100 eddy-covariance locations exist worldwide across different ecosystems, the authors wrote, but only three vineyard sites are currently part of major open-access networks: one in ICOS, one in FLUXNET, and one in AmeriFlux. That limits the ability of researchers and growers to compare vineyards with forests, grasslands, croplands, and other agricultural systems on a common basis.

Geography is a central problem in the current literature. The monthly carbon dataset assembled for the review was 88% Italian, and most of those observations came from humid subtropical or Mediterranean climates. By contrast, vineyards outside those settings, including high-density plantings in northern Europe, were much less studied despite their economic weight and established reputation in the wine market. The authors also noted that warm-climate grape varieties were overrepresented in the published record.

Water use efficiency, a topic that could help connect irrigation and carbon questions, remains a small part of the field. The review found that studies on WUE used different methods, making direct comparisons difficult. The authors called for a standardized approach so researchers can better identify the biophysical drivers of both water and carbon fluxes in vineyards.

The paper’s broader message is that climate adaptation and climate mitigation in vineyards cannot be separated. Better ET measurements may help growers reduce water use and target irrigation more closely. But understanding whether vineyards help absorb carbon will require more complete annual measurements, more accounting for carbon removed at harvest, and more data from vineyards beyond the irrigated Mediterranean systems that dominate the literature today. The authors said the field needs a dedicated vineyard flux network spanning different soils, climates, and management systems to clarify how viticultural practices affect both water consumption and carbon uptake.