



## Quantifying and qualifying terroir: Empirical evidence linking climate, vineyards, and people across scales

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Climate affects the geographic range, yield, price, and biochemical composition of winegrapes. At the regional scale, historical climate and yield data were successfully used to develop simple models of crop yields using two or three monthly climate parameters for twelve major California crops, including winegrapes. These crop models were used to project the impact of future climate change on crop yields, showing that greater warming would increasingly push highly suitable areas for viticulture outside of their current range. Correlating temperature with price for Pinot noir throughout its growing range in California demonstrated higher prices for grapes grown in cooler climates, whereas prices dropped off rapidly above a ripening temperature threshold, indicating the vulnerability of grape price to climate change. At the vineyard scale, a three-year field study of eleven Pinot noir vineyards in California's North Coast showed that warm temperatures early in the growing season were correlated with increased phenolic compounds (anthocyanins and tannins), which likely benefits wine quality, but warmer periods later in the ripening process appeared to offset these effects. At the microclimate scale, high light intensities were measured on Pinot noir fruit in vertically shoot positioned vineyards, indicating a potential for changing canopy management to provide more optimal ripening conditions.

Vineyards are highly managed, and there are many opportunities for viticulturists to shape the micro- and meso-climate that vines experience, thereby influencing the biophysical drivers of terroir through their site selection and vineyard planting and farming choices. An analysis of the precision agriculture and management strategies used by winegrowers in California and Australia showed that growers tend to rely more on short-term farming actions for adapting to environmental stresses; these may have considerable potential to enhance adaptive capacity, and are easier to undertake than the longer-term site and planting adaptations often cited in the literature as climate adaptations for viticulture. I use the framework of ecosystem services, or the benefits that people receive from nature, to characterize terroir as an example of a cultural ecosystem service, where regional identity contributes to well-being in both financial and social terms. This potential is being examined in a new case study in the rapidly growing wine industry in southern England. Finally, through ranking exercises conducted with growers and winemakers, ten distinct dimensions of wine quality were revealed, which were categorized to form a typology of wine quality that can be used to design and communicate research into the nature of and elements contributing to wine quality, including terroir.