The effects of conversion of oak woodlands to vineyards on soil carbon transformations

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There has been extensive conversion of Californian oak woodlands and oak woodland–grasslands to agricultural ecosystems consisting of woody perennials like grapevine. Deforestation of woodlands and replacement with cultivated agricultural systems and pastures has resulted in substantial release of soil C (Lal, 2002; Dahlgren et al., 2003)—an estimated 30% decrease in soil organic carbon (SOC) occurs in temperate soils within 30 years (West et al 2002) of conversion. Soil CO_2 efflux, or "soil respiration," is one of the more important components of ecosystem C budgets. Soil respiration consists of organic matter oxidation, root respiration, and rhizosphere respiration (Hanson et al., 2001). Soil respired CO_2 represents the ultimate oxidative fate of soil C, and the C lost from terrestrial ecosystems occurs mainly through soil respiration (Amundson, 2001).

In this investigation we hypothesized that conversion of oak woodlands to vineyards increases the proportion of C respired from more recalcitrant C sources in the vineyard soils relative to the oak woodland soils. At the same time, we proposed that the magnitude of soil respiration declines under cultivation of a perennial crop because long-term cultivation decreases nonrecalcitrant C in the plow layer. To accomplish these objectives, we monitored net soil CO_2 efflux, CO_2 concentration, and $\delta^{13}C$of CO_2 with depth for three oak woodland sites and three adjacent vineyard sites that were converted from oak woodlands approximately 30 yr ago. Since long-term cultural practices at the vineyard site (cultivation and tractor passes for management activities) have changed soil physical characteristics, we also examined soil physical properties that might constrain soil CO_2 efflux. All sites were located on similar soils, a Bale (variant) gravelly loam (fine-loamy, mixed, superactive, thermic Cumulic Ultic Haploxeroll). Oak woodland and adjacent vineyard were measured for soil CO_2 efflux using a Licor-6400 with soil chamber attachment. Measurements were made approximately every two weeks for 15 months between the hours of 12 and 2 pm. Soil CO_2 profile arrays consisting of 1/8 inch stainless steel tubes capped with septa were installed at 15, 25, 45, 65, 85, and 105 cm depth and sampled for CO_2 concentrations and $\delta^{13}C$ at depth. Soil temperature and gravimetric moisture were measured concurrently with the efflux. Both efflux and profile measurements were made under the oak or vineyard canopy.

Oak woodland soils had significantly higher CO_2 efflux rates than did the vineyard soils, as a result of vineyard management practices that limit the amount of organic matter input through harvest and herbicide application. Soil CO_2 concentration and $\delta^{13}C$ values showed strong differences between the two systems as well. Vineyard CO_2 concentrations were higher throughout the profile, most likely as a result of lower diffusion coefficients in the vineyard soils. The $\delta^{13}C$ values for the soils showed seasonal differences as well as differences between soils.
Oak soils were significantly more enriched in the lower depths than were the vineyard soils during the 'dry' season (Fall and Summer). However, during the 'wet' season (Winter and Spring) the $\delta^{13}C$ values were not significantly different for most of the profile. The wet season values were similar because the oak and vineyard soils were very wet and the decrease in diffusion rates due to the high water-filled pore spaces limited diffusion to such an extent that little CO_2 moved up through the profile leading to higher CO_2 concentrations and more similar $\delta^{13}C$ values. The dry season differences in CO_2 concentrations can be attributed to faster diffusion rates in the soils. The dry season $\delta^{13}C$ values were more enriched in the oak profiles as a result of vineyard conversion and management. Oak and vineyard soil microbial communities utilized different carbon sources.

This investigation has shown that the study oak woodland sites lose significantly more soil CO_2 than adjacent vineyards. Net C losses from the vineyard soils can be estimated from organic C contents (Table 2) at roughly 33 Mg per hectare since the vineyards were converted from oak woodlands 30 to 32 yr ago (Carlisle, unpublished data). Furthermore, soil physical properties that influence soil gas diffusion were altered. Cultural practices such as tillage and vineyard preparation had large impacts on SOC pools and

SOC distribution through the soil profile. Soil CO_2 concentrations and $\delta^{13}C$ values from this investigation have shown that the respiration sources in the soil profile change with season and depth, and that soil moisture content has a large influence on soil respiration $\delta^{13}C$ values. Our estimates point to the clear need to develop a more acute understanding of the contribution of belowground production in perennial cropping systems, as well as in the perennial systems from which they were converted.

References

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