The Influence of Land Conversion on Carbon Mineralization and CO_2 Emissions from Vineyards and Adjacent Oak Woodlands in the Napa Valley

Eli A. Carlisle, Kerri L. Steenwerth, David R. Smart. Department of Viticulture and Enology, University of California, One Shields Avenue, Davis CA 95616

Problem:

Oak woodlands and oak woodland grasslands in the Napa Valley have been historically converted to orchards and then to vineyards. Vineyard systems that underwent conversion 50 to 70 years ago have lost between 37.8 and 42 metric tons ha^{-1} carbon (C) from the upper 30 cm soil in comparison to adjacent oak woodlands (Carlisle and Smart, unpublished data). Substantial areas of Coastal California have undergone conversion, and the consequences of such disturbance on C flows and C cycling are completely unknown.

Objectives:

- Examine the magnitude of seasonal CO_2 fluxes from both an oak woodland-grassland and vineyards in close proximity on similar soils
- Separate these fluxes into the principle components responsible for CO_2 fluxes - root and microbial respiration.

Approach:

- **Field components**
  - Vineyard (Figure 2) and adjacent oak sites (Figure 1) located on the same soil type, a Bale (variant) gravelly loam (fine-loamy, mixed, superactive, thermic Cumulic Ultic Haploxeroll), were measured for soil CO_2 efflux using a Licor-6400 with soil chamber attachment. 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. The field sites were sampled every two weeks.
- **Laboratory component**
  - Pooled soil samples from the vineyard and oak sites were returned to the lab, sieved to 2 mm, cleared of visible roots, and placed in one quart mason jars and sealed with a lid equipped with a septa to allow headspace sampling for CO_2 concentration and $\delta^{13}C$ measurements. After sampling headspace CO_2, the mason jars were purged with zero grade air containing no CO_2 to ensure that the CO_2 and $\delta^{13}C$ data are representative of microbial activity, and not industrial or atmospheric CO_2. The jars were sampled on a weekly to monthly schedule

Figure 1: One of our undisturbed oak woodland sites, Oakville, Napa Valley California

Figure 2: One of the vineyard sites in Oakville, Napa Valley, California

Results:

Field Measurements

- Field measurements of soil CO_2 emissions have shown that the oak sites may have much greater rates of CO_2 production than the vineyard soils. The oak sites also show an increased response to precipitation events and a strong increase in CO_2 following bud break, when fine root emergence is increasing (Figure 3).
- Carbon dioxide concentration profiles from the surface down to the upper limit of the water table indicated that the vineyard and oak woodland soils probably have different effective diffusion coefficients, and we are currently examining the mechanisms responsible for this phenomenon (Figure 4). Thus, although the oak sites have higher surface CO_2 emissions rates, a critical factor concerns the quantity of dissolved inorganic C that is removed from these sites that have high water tables.
- Vineyard soil CO_2 is substantially less depleted in ^{13}C than is the oak woodland soil at shallower depths (0 – 65 cm). This observation was confirmed by examining ^{13}C evolved during long term incubations (Fig. 6). However, below 85 cm both soils show a similar $\delta^{13}C$ signature indicative of C_3 vegetation. This is true if the $4.4^0/_{00}$ enrichment due to physical discrimination of the ^{13}C isotope in diffusive transport is taken into account, and we assume that C at these deeper profiles is derived from a similar source (Figure 5).

Laboratory Incubation Measurements

- Carbon mineralization from the oak soil was 2-3 times greater than that measured from the vineyard soils. CO_2 production increased to a maximum of 0.9 mg CO_2 –C g^{-1} dry soil $hour^{-1}$ in oak woodland soils and 0.25 mg CO_2 –C g^{-1} dry soil $hour^{-1}$ in vineyard soils two weeks after initiating the incubation (Figure 6).
- The incubation $\delta^{13}C$ of CO_2 showed a clear separation between oak woodland and vineyard soils. Oak soil respiration was more depleted in ^{13}C relative to the vineyard soil (by more than 1.5‰) indicating that the vineyard soil is now mineralizing more recalcitrant C rather than CO_2 from root respiration or labile C mineralization (Figure 7).

Figure 3: Soil CO_2 efflux measurements from oak (n = 8) and vineyard (n = 6) sites located on the same Bale series clay loam. Shown are the means and standard errors of the means for these observations. Data was obtained by the use of a Licor 6400 instrument with a soil chamber attachment.

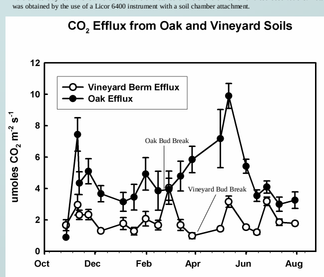


Figure 4:. Soil profile CO_2 concentrations taken from an array of depths (0, 15, 25, 45, 65, 85, 105 cm) at oak and vineyard sites located on the same Bale series gravelly loam soil type. We separated the oaks into lower oak (those located on the flood plain) and upper oak (those oaks located on a small hillside) sites after concluding that these sites might have different behavior due to variations in hillslope and depth to water table.

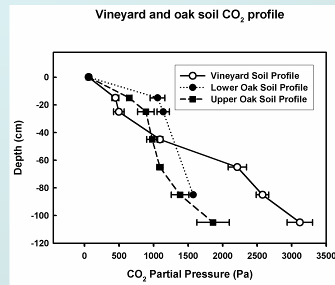


Figure 5: Soil profile $\delta^{13}C$ from soil atmosphere samples taken at 0, 15, 25, 45, 65, 85, and 105 cm depth through the use of 6 permanently established arrays of soil sampling tubes.

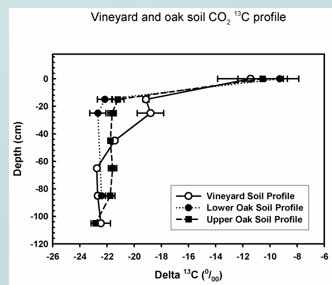


Figure 6: Laboratory incubation respiration rates as measured from headspace sampling. Shown are the means and standard errors of six observations from each soil source

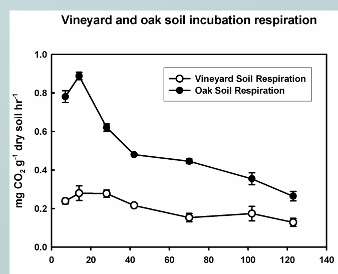
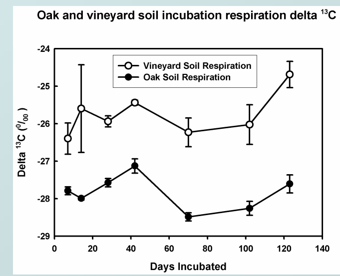


Figure 7: Laboratory incubation $\delta^{13}C$ data obtained from headspace sampling. Shown are the means and standard errors of the means (n = 6) of the different soil sources



Discussion and Future Goals:

Our results point to the real potential for perennial agricultural systems like vineyards to serve as C sinks, and help mitigate the observed increase of CO_2 concentration in the atmosphere (Pacala et al. 2000; Sperow et al. 2003). During the 2002 and 2003 seasons approximately 4.54 metric tons C ha^{-1} of above ground carbon was produced by the vineyards (leaves, cane wood and fruit). These estimates do not include new production of permanent wood. Carbon as CO_2 emitted from the vineyard soils only exceeded this value by approximately 2.0 metric tons C ha^{-1}. If we can accept estimates that fine root growth is now known to account for a larger proportion of primary production in terrestrial ecosystems than was previously thought (Gill and Jackson, 2000), the quantity of root deposited carbon becomes extremely important in the C-budgeting for these systems, and the debate concerning contributions to regional C cycling.

To help clarify these issues, future research, in addition to quantification of wood production in vineyards and oak woodlands, will need to address the quantification of fine root production and movement of inorganic and organic carbon through ground water aquifers. To that end, we have installed a suite of minirhizotron observation tubes in both the oak woodland and vineyard systems. We have been using these observation tubes to quantify root production and survivorship.

References

Gill, R.A. and R.B. Jackson 2000. *Global patterns of root turnover for terrestrial ecosystems*. New Phytologist. 147:13-32.

Pacala, S.W., et al. 2001. *Consistent land- and atmosphere-based U.S. carbon sink estimates.* Science, 292: p. 2316-2320.

Sperow, M., M. Eve and K. Paustian 2003. *Potential soil C sequestration on US agricultural soils*. Climatic Change. 57:319-339.