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Partitioning soil CO_2 fluxes by tree-girdling in a Mediterranean (Pinus pinaster) ecosystem reveals a different response of autotrophic and heterotrophic components to environmental variables and photosynthesis under drought conditions

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The response of ecosystems to environmental factors, such as temperature and rainfall, is crucial to understand the impact of climate change on the terrestrial C cycle. Forest soil respiration represents the main pathway by which photosynthetically assimilated C is released to atmosphere; its intensity depends not only on soil environmental conditions, but also on the availability of organic substrates respired by roots and microorganisms.
Several techniques have been applied to partition the autotrophic and heterotrophic components of soil respiration in boreal and temperate forests; there is a general lack of information, on the contrary, on the dynamics of soil CO_2 efflux in Mediterranean ecosystems. The IPCC A1B scenario highlighted the importance of the Mediterranean area since it is expected to experience a temperature increase (from 2.2 °C to 5.1 °C) and a rainfall reduction ranging from –4 to –27% on annual basis.

We used the tree-girdling technique together with periodic chamber-based measurements to study the partitioning of total soil respiration (Rs) into its autotrophic (Ra) and heterotrophic (Rh) components in a 60-year old forest in Central Italy (San Rossore) dominated by Pinus pinaster. This technique has been extensively used to block the flux of photosynthates from leaves to roots, thus stopping the autotrophic root respiration in the soil.
We found that two weeks after the treatment soil respiration in the girdled plots decreased by 29% and remained stable over the period of analysis, suggesting that Rh dominates total soil respiration. The anomalous low rainfall regimen of May to October 2011 (102 mm cumulated rain) associated with average air temperatures (with a mean value of 19,6 °C over the period) gave us the opportunity to investigate the decoupled response of soil respiration to water and temperature. Time series analysis performed under this severe drought conditions showed overall low values of soil respiration with three clear peaks associated with water pulses from rain events.

Both total and partitioned fluxes were indeed significantly correlated with soil water content (Rs: R2=0,63, p<0,001; Rh: R2=0,45, p<0,01; Ra: R2=0,70, p<0,001) while the response to soil temperature was evident only for Ra (R2=0,27, p<0,05) and no significant for Rh and Rs (R2=0,11, p>0,05 and R2=0,03, p>0,05, respectively). The relationship with photosynthesis was subsequently evaluated analyzing the time-lagged correlation between daily gross primary productivity (GPP) derived from eddy covariance measurements and total and partitioned soil CO_2 efflux. The time lagged analysis showed that Ra was overall best correlated with GPP with a peak at 3 days of delay (r= 0,72, p<0,001) while Rs had a peak in the fraction of variance explained corresponding to 4 days of delay (r=0,66, p=0,001).

These findings confirm that CO_2 efflux from soil is strongly affected by environmental factors and substrates supplied by photosynthetic activity, but suggest that the effects they exert on autotrophic and heterotrophic fluxes follow different mechanisms and temporal dynamics.