7.2. Exchanges of CO_2 and water vapour at the ecosystem scale

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Abstract

The monitoring of the exchanges of CO2 and water vapour helps provide an understanding of ecosystem functioning at different temporal scales. Results found across an elevational/bioclimatic gradient show the relevance of bioclimatic factors in the balance of the two and indicate the usefulness of long-term monitoring of CO_2 exchanges and water vapour as indicators of ecosystem functioning. Specifically, this study provides information on how Mediterranean ecosystems respond to climate change. This study also provides relevant information to optimise post-fire human action to favour ecosystem regeneration.

Aims and methodology

CO_2 exchanges provide ecosystem information concerning its behaviour as a source or sink of CO_2, enabling the discrimination of different phenological periods. In the growth period, the ecosystem assimilates more CO_2 than it emits, primarily due to greater vegetative development. However, there are other periods in which emissions predominate, mainly due to the senescence of vegetation together with accelerated degradation processes of organic matter and lower soil-water content, favouring the ventilation of CO_2 accumulated in soil pores [6,7].

The variations in the periods of CO_2 assimilation and emissions noted in different ecosystems are influenced by biotic factors such as vegetation and microorganisms; abiotic ones such as temperature and soil water content and anthropogenic ones, particularly perturbations caused by fires. Therefore, ecosystems situated in different bioclimate belts with certain conditions of vegetation types, soil, mean temperature, and precipitation, behave in dissimilar ways, showing different periods of fixation and emissions.

The aim of this work is to quantify and characterise the exchange of CO_2 and water vapour in Mediterranean ecosystems. For this purpose, ecosystems were studied on an elevational gradient with different bioclimatic conditions (precipitation and temperature; Figure 1). In an effort to understand the effect of the post-fire treatments, studies were also performed about CO_2 exchanges and evapotranspiration in two plots of burnt ecosystems with different management of the burnt wood (logging and non-intervention). These studies were conducted using *Eddy Covariance* towers able to record the assimilation and emission of CO_2 by the ecosystem and its evapotranspiration [8].

Results

Carbon balance under different bioclimatic conditions.

The results found in the three ecosystems studied for the hydrological year 2007/2008 show an increase in the assimilation period with elevation (Figure 2), which was associated with a net increase in carbon assimilation (Figure 3).

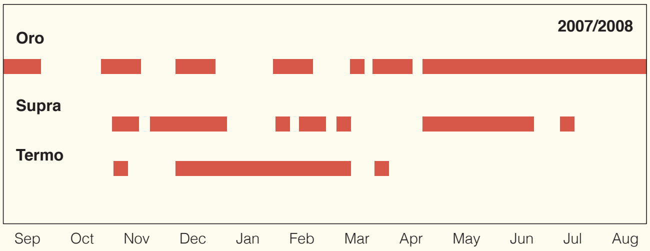
The most arid ecosytem, the thermomediterranean belt located in the Cabo de Gata-Níjar Natural Park, acted as a CO_2 source, emitting more CO_2 by respiration and soil ventilation than annually fixed by plants. As precipitation augments, despite the fall in temperature, the balance changes.

The ecosystem of the supramediterranean belt situated in the Sierra de Gádor acts practically in a neutral way, emitting slightly more than it fixes, while the ecosystem of the oromediterranean belt in the Sierra Nevada National Park serves as a CO_2 sink.

Figure 1

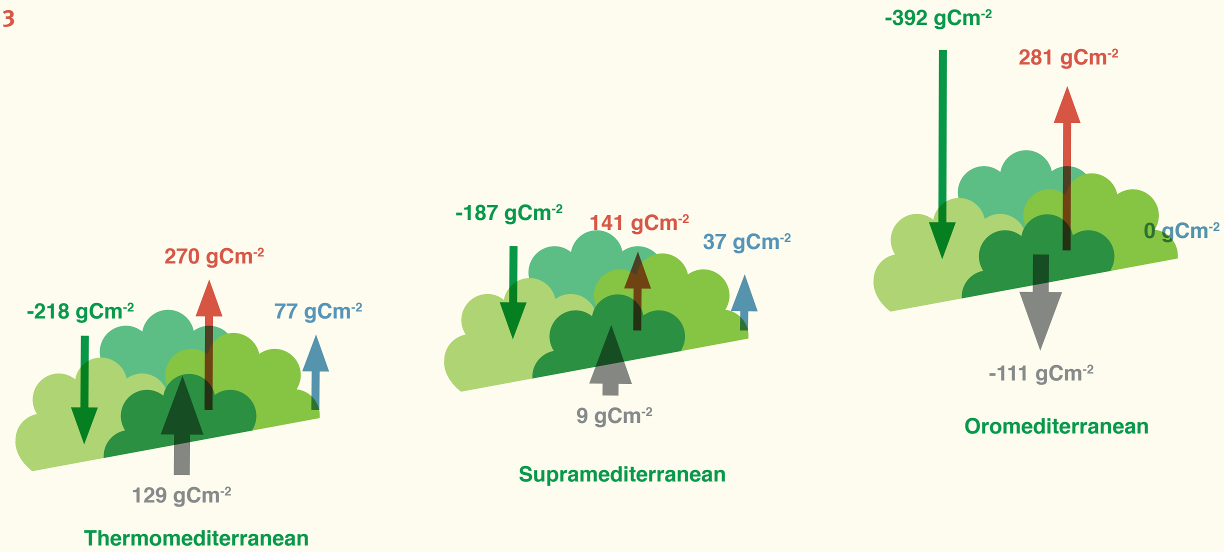
Images of the three study sites of this work. Left to right: thermomediterranean belt (Cabo de Gata-Nijar National Park), supramediterranean belt (Sierra de Gádor), oromediterranean belt (Sierra Nevada National Park).

Figure 2



Assimilation periods of three ecosystems of Mediterranean shrublands located in thermo-, supra-, and oromediterranean bioclimatic belts. These assimilation periods were defined as weeks with a net balance of carbon assimilation.

Figure 3



Carbon assimilated by photosynthesis (green arrow) emitted by respiration (red arrow) or by processes of soil ventilation (blue arrow) and total net exchange (grey arrow) in the hydrological year 2007/2008 by three ecosystems of Mediterranean shrubland located in the thermo-, supra-, and oromediterranean bioclimatic belts. The negative sign of the total net exchange denotes carbon fixation by the ecosystem.

Effect of post-fire treatment on the carbon balance

The different ways of managing burnt wood after a fire have direct impacts on the CO_2 and water balances of the ecosystem. In the area affected by the fire of 2005 on the hillside of Lanjarón, within Sierra Nevada National Park, 2 plots were established with different approaches to manage of burnt wood. One was called "No Intervention", where no action was taken after the fire and the burnt trees remained standing. The other was called "Removal", where the trunks were removed and the branches chipped. Three years after the fire, the "Removal" treatment acted as a CO_2 source, while the "No Intervention" treatment served as a sink registering a greater rate of evapotranspiration due to greater plant regeneration (Figure 4).

Discussion and conclusions

Mediterranean ecosystems show great variability in the net annual exchange of carbon, from acting as sources of approximately 120 g cm^{-2} (thermomediterranean) to serving as sinks of equal magnitude (oromediterranean). The ecosystem located in the thermomediterranean belt shows a continuous growth season during the winter when water availability and temperatures allow net carbon assimilation. During the rest of the year, before the lack of water and the high temperatures, the adaptive mechanisms of the plants are activated, such as the stomatal closure, resulting in a decline in assimilation, without photosynthesis recovering during the sporadic precipitation events as occurs in other ecosystems. In the supramediterranean ecosystem, an increase in precipitation and a decrease in temperatures translate as discontinuous growth periods that extend almost all year long, except for the hottest and driest summer months and part of the coldest months. In the oromediterranean ecosystem, the assimilation occurs almost during the entire year except for the months when the ground is covered by snow. This increase in growth periods and net carbon assimilation with elevation could be related to different behaviour of photosynthesis and respiration processes in relation to temperature. Although a fall in temperatures causes a loss in photosynthetic efficiency, this limits even more the respiration processes of the soil, and therefore even in the coldest periods, with low biological activity, the carbon assimilation predominates [9].

Finally, with regard to the post-fire treatments, several arguments could explain the net carbon assimilation in the "No Intervention" plot as opposed to the "Removal" plot three years after the fire [10]:

1) "No intervention approach" improves soil fertility. The burnt wood of the trees and the woody remains represent an enormous reserve of nutrients left *in situ* to be progressively incorporated into the soil.

2) "No intervention approach" improves microclimatic conditions. The effect of the burnt trees and limbs alter the micrometeorology, facilitating plant regeneration.

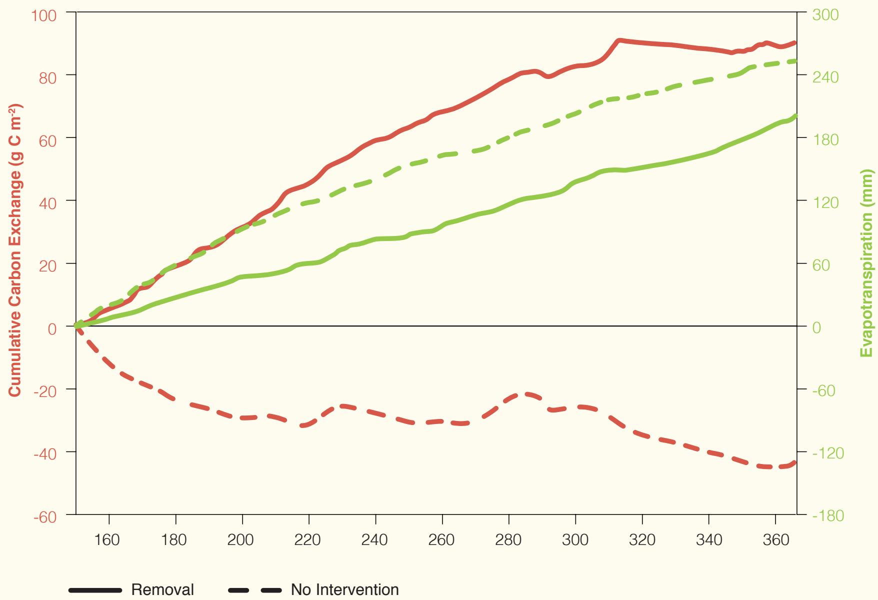
3) Wood removal negatively affects regeneration, damaging the seed bank and seedlings thereby reducing plant density.

4) The presence of trunks and branches reduces herbivory.

5) The dead material reduces erosion, minimizing runoff.

6) The site attracts seed dispersal by birds.

Figure 4



Quantity of carbon emitted to the atmosphere (g C m^{-2}) and evapotranspiration (mm) in the post-fire treatments of "No Intervention" (dashed line) and "Removal" (solid line) from June to December.