Geophysical Research Abstracts,
Vol. 11, EGU2009-10702-3, 2009
EGU General Assembly 2009

Fire recurrence effects on aboveground plant and soil carbon stocks in Mediterranean shrublands with Aleppo pine

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Changes in fire regime due to intensification of human influence during the last decades led to changes in vegetation structure and composition, productivity and carbon sink strength of Mediterranean shrublands and forests. It is anticipated that further climate warming and lower precipitation will enhance fire frequency, having consequences for the carbon budget and carbon storage in Mediterranean ecosystems. The purpose of this study was to determine whether fire recurrence modifies aboveground plant and soil carbon stocks, soil organic carbon content and total soil nitrogen content in shrublands with Aleppo pine on the Garraf Massif in Catalonia (Spain). Stands differing in fire frequency (1, 2 and 3 fires since 1957) were examined 13 years after the stand-replacing fire of 1994 and compared with control stands which were free of fire since 1957. Recurrent fires led to a decrease in total ecosystem carbon stocks. Control sites stored 12203 g m^{-2}C which was 3.5, 5.0 and 5.5 times more than sites that burned 1, 2 and 3 times respectively. Carbon stored in the aboveground biomass exceeded soil carbon stocks in control plots, while soils were the dominant carbon pool in burned plots. An increasing fire frequency from 1 to 2 fires decreased total soil carbon stock. Control soils stored 3551 g m^{-2}C, of which 70 % was recovered over 13 years in once burned soils and approximately 50 % in soils that had 2 or 3 fires. The soil litter (LF) layer carbon stock decreased with increasing fire frequency from 1 to 2 fires, whereas humus (H) layer and upper mineral soil carbon stocks did not change consistently with fire frequency. Fire decreased the organic carbon content in LF and H horizons, however no significant effect of fire frequency was found. Increasing fire frequency from 1 to 2 fires caused a decrease in the organic carbon content in the upper mineral soil. Total soil N content and C/N ratios were not significantly impacted by fire frequency. Recurrent fires had the greatest impact on aboveground plant carbon stocks. Aboveground plants in control plots amounted to 8652 g m^{-2}C, of which 93 % was stored in trees, while carbon storage in the most frequently burned sites was only 509 g m^{-2}C. Shrub carbon varied barely between fire frequencies, corroborating the high resilience of resprouting shrub species to fire recurrence. The most striking result was the immense decrease in Aleppo pine carbon stock which varied between 7770 g m^{-2}in control plots and 25.6 g m^{-2}in 3-fires plots. Differences between control and burned plots are principally explained by the age of the plots. The decrease in Aleppo pine carbon stock within burned plots was not associated with a growth reduction, but was due to a decrease in stem density. The results indeed indicate that the recruitment of Aleppo pine on more frequently burned plots is obstructed due to cumulative effects of short fire return-intervals ($<$15 years), impeding self recruitment of the species. These findings combined with prior results suggest a dichotomy in carbon storage. When pine recruitment is successful with sufficiently long fire-return intervals, garrigue-Aleppo pine mixed stands may attain up to 15600 g m^{-2}C. However with poor pine recruitment due to short fire-return intervals a maximum of $\sim$ 6000 g m^{-2}C would be stored in systems that resemble native garrigues of the area. This highlights that the potential of the current system to store large amounts of carbon depends on the successful recruitment of Aleppo pine.

Keywords: *Aleppo pine, garrigue, fire recurrence, fire-return interval, secondary succession, carbon storage, ecosystem carbon stock*