Change in carbon balance of a dry calcareous grassland caused by spontaneous afforestation

Ferlan M.[1,2], Eler K.[1], Alberti G.[3], Vodnik D.[1], Peressotti A.[3], Miglietta F.[4], Simončič P.[2] and Batič F.[1]
[1] *University of Ljubljana, Biotechnical faculty, Ljubljana, Slovenia*
[2] *Slovenian Forestry Institute, Ljubljana, Slovenia*
[3] *DISA - University of Udine, Italy*
[4] *CNR-IBIMET – Firenze, Italy*
Corresponding author: mitja.ferlan@gozdis.si

Abstract

Changes in land use represent one of the most important components of global environmental change. An experimental site has been established in the Slovenian Karst (Submediterranean climate region) with the aim to investigate the effects of land use change on ecosystem carbon cycling. Paired eddy flux measurement design was used in order to assess net ecosystem exchange (NEE) of two ecosystems: extensively used dry grassland and abandoned grassland invaded by woody plants. The use of two eddy towers allowed us to detect the influence of land use change on C fluxes. In this work we present one year of measurements with the emphasis on distinct responses of NEE of both ecosystems to short term effects such as rain pulses.

Keywords: calcareous grassland, eddy covariance, NEE, woody plant encroachment.

Introduction

The proliferation of woody plants in grasslands has the potential to profoundly influence hydrology, biogeochemistry, biodiversity, and future land use options in the affected areas. Many studies propose that it can lead to carbon storage in these ecosystems, but there are also reports (Jackson *et al.*, 2002) that woody plant encroachment into grasslands has resulted in ecosystem carbon loss. There are limited reports on net ecosystem exchange (NEE) in transitional areas where there is plant conversion from grasslands to woodlands (e.g. Scott *et al.* 2006) which indicate the potential for increased carbon sequestration. However, in dry regions this potential is very dependent on precipitation patterns (Potts *et al.* 2006). The aim of our study was to estimate the net CO_2 exchange for extensively used dry calcareous grassland in a Submediterranean climate region that is invaded by woody plants.

Materials and methods

In August 2008 micrometeorological and meteorological measurements were applied over two sites located at Podgorski kras plateau in South West Slovenia (45°33' N, 13°55' E, 400-430 m a.s.l.). Rendzina soil developed on the paleogenic limestone bedrock prevails. Soil depth is very uneven ranging from 0 cm (rocky outcrops) to several decimeters in soil pockets between rocks. The area was subjected to widespread land-use changes in the last decades. The previously (over)grazed pastures were largely abandoned and are being slowly overgrown by shrubs and trees. Within the study area two study sites were chosen on the basis of current and historic land use. The grassland site has been used more or less permanently as a low intensity pasture in the last decades. The succession site which is abandoned for at least three decades is covered by small trees and shrubs occupying 40% of the surface. The average height of the tree layer, which is mostly represented by *Quercus*

pubescens, is 7 m. Above-ground woody biomass is around 100 m^3 ha^{-1}. The slope of the sites does not exceed 3 degrees.
Eddy covariance systems and other meteorological measurements were installed on both research sites. The instruments were installed at 15 m and 2 m height at the succession and grassland site, respectively. The applied methodology for eddy covariance flux data evaluation followed the Euroflux protocol with the Webb Pearman Leuning correction.

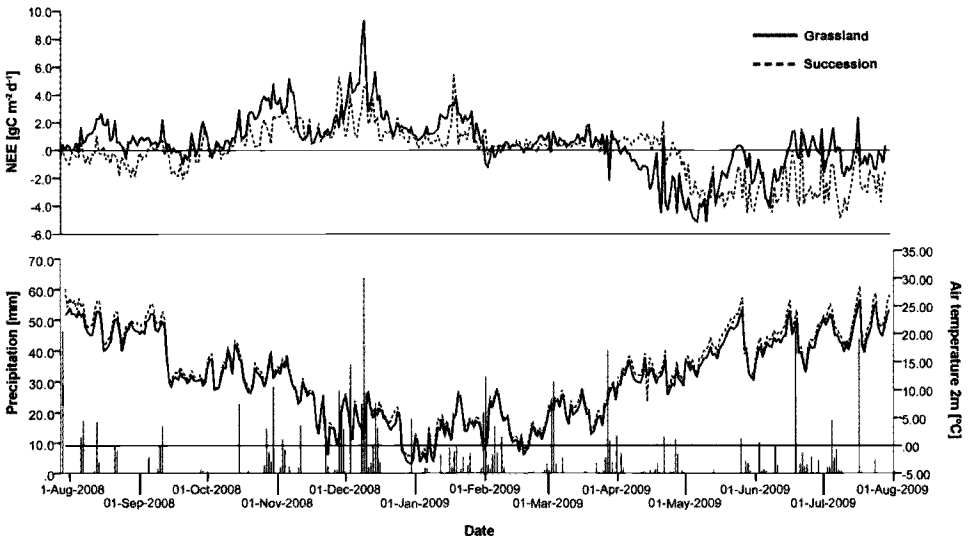

Figure 1: Daily values of eddy covariance based net ecosystem exchange, precipitation and air temperature for grassland and succession ecosystem for the period August 2008 – August 2009.

Results and discussion

In the first year of carbon exchange measurements (1 August 2008 – 1 August 2009) the grassland was a net carbon source, emitting 195 g m^{-2} C and the succession site was a weak carbon sink sequestering of -63 g m^{-2} C. Despite the difficulty of inference from one year of measurements, the GPP of the investigated ecosystems were quite low, indicating generally low productivity of the investigated ecosystems. However, paired measurements allow us to compare the responses of both ecosystems to some environmental factors. There is apparently an almost one-month lag of the succession site before it becomes a net sink for carbon. The onset of negative NEE on the succession site matches the burst of leaves of the trees. Since both sites are similar in composition of their herbaceous layer, in phenological development of its main species and in peak biomass (244±60 g of dry mass m^{-2} on grassland vs. 227±80 g m^{-2} on the succession site), it can be concluded that the shifts of the C balance are mainly governed by the activity of forest fragments. There is no indication of higher losses of carbon on the succession site in the period before the start of the vegetation period, which might theoretically decrease the net sink capacity of the ecosystem. Evidently the grassland was a net sink for carbon for a brief period of time. After roughly 4 months the daily carbon balance was again positive, indicating the specific phenology of grassland species which is a well known adaptation to frequent summer droughts in Mediterranean ecosystems. The succession site remained a net sink for much of the summer, which is again mostly attributed to the invaded trees and shrubs and to a lesser degree to more green herbaceous vegetation under

the trees. Carbon fixation of forest fragments ceased in mid October 2009. In the winter period, when gross primary production (GPP) is absent or negligible, the grassland site had larger carbon losses than the succession site. There is no clear explanation for this phenomenon since the grassland site had much less dead plant biomass prone to decomposition and smaller living plant biomass performing respiration. Additionally, there is a difference in the response of both ecosystems to drought and high temperature. In the grassland there was an apparent halt of GPP at the end of May 2009 (in the period of the most intensive growth) which is attributed to a short drought episode with high temperatures. The response of the succession site to these conditions is not perceivable, indicating generally a larger buffer capacity of the succession site to drought stress.

There was a strong and instantaneous increase in CO_2 emissions during rainfall events. The increase is especially profound in autumn and winter period and less so in spring, suggesting that the availability of fresh litter might contribute significantly. It is not clear yet if this increase is solely the effect of increased litter decomposition and soil respiration as suggested by Inglima *et al.* (2009) or whether water induced displacement of CO_2 enriched soil air.

Conclusions

We observed that woody plant encroachment can significantly shift the C-balance of the ecosystem. Despite undefined contributions of limestone weathering and the fact that eddy covariance measurements could be influenced by spatial heterogeneity of the karstic ecosystem, we estimate that the yearly difference of NEE between the grassland and invaded sites can be largely attributed to the length of the growth season. This study also suggests some possible benefits of silvopastoral systems in semi-arid climates, where scattered trees and shrubs may decrease the sensitivity to environmental perturbation and increase ecosystem carbon sequestration.

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