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Net Ecosystem Exchange responses to changes in crop management in a forage system in the Eastern Pyrenees

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Abstract. Croplands and grasslands are major land uses in Europe and provide fundamental ecosystem services, including carbon (C) cycling and storage. In general, croplands tend to be C sources while grasslands are considered as sinks, although this balance depends on local conditions and management. For instance, the role of the crop type and production intensity over the C stock has been thoroughly analyzed. However, little is known about the effect of mixed cropping, fallow and land uses rotation (cropland and grassland). Thus, we hypothesize that these practices may enhance carbon uptake and our objectives are: (1) to describe the Net Ecosystem CO_2 Exchange (NEE) temporal patterns in a mixed cropped-grazed system; (2) to assess the carbon sink/source behavior; and (3) to assess the influence of sown diversity, mixed cropping and land use rotation on NEE. The study site is Pla de Riart (42° 03' 48" N, 1° 30' 48" E, 1003 m a.s.l), a cropland which is also used for grazing between sowings. The crop is usually a forage mixture, but occasionally it is also a monoculture of forage grass species. The site is equipped with an eddy covariance flux station from the FLUXPYR network that has been recording NEE and meteorological data since 2011. In addition, above and belowground biomass samples have been taken periodically and managing practices reported by the site owner. Preliminary analysis suggests that the carbon sink behavior is directly linked to the management and that crop mixtures (legumes and grasses) might contribute to climate change mitigation, increasing CO_2 uptake, while improving ecosystem productivity, compared to monocultures.

Keywords. CO_2 – Agroecosystems – Management – Net Ecosystem Exchange.

Réponse des échanges nets des écosystèmes aux changements dans la gestion des cultures dans un système fourrager dans les Pyrénées Orientales

Résumé. *Les cultures et les prairies sont parmi les utilisations principales du territoire en Europe et elles fournissent des services écosystémiques fondamentaux, y compris le cycle et stockage du carbone (C). En général, les terres cultivées ont tendance à être des sources de C tandis que les prairies sont considérées comme des puits, bien que cet équilibre dépende des conditions locales et de la gestion. Par exemple, le rôle du type de culture et de l'intensité de la production sur le stock C a été analysé en profondeur. Cependant, on sait peu sur les effets de la culture mixte, de la jachère et de la rotation (cultures et prairies). Ainsi, notre hypothèse est que ces pratiques peuvent améliorer le stockage du carbone et nos objectifs sont : (1) de décrire les patrons temporels de l'échange net de CO_2 de l'écosystème (NEE) dans un système de culture-pâturage; (2) d'évaluer le comportement source/puit de carbone; et (3) d'évaluer l'influence de la diversité semée, des cultures mixtes et de l'utilisation des terres en rotation sur le NEE. Le site d'étude est Pla de Riart (42 ° 03 '48 "N, 1 ° 30' 48" E, 1003 m a.s.l), un terrain cultivé qui est également utilisé pour le pâturage entre les ensemencements. La culture est habituellement un mélange de fourrages, parfois une monoculture d'espèces de graminées fourragères. Le site est équipé d'une station de flux eddy covariance du réseau FLUXPYR qui enregistre le NEE et des données météorologiques depuis 2011. En outre, des échantillons de biomasse aérienne et souterraine ont été pris périodiquement et la gestion des pratiques ont été enregistrées par le propriétaire du site. L'analyse préliminaire sug-*

gère que le comportement de puits de carbone est directement lié à la gestion et que les mélanges de cultures (légumineuses et graminées) pourraient contribuer à mitiger le changement climatique, augmentant le stockage de CO_2, tout en améliorant la productivité de l'écosystème, par rapport aux monocultures.

Mots-clés. CO_2 *– Agroécosystèmes – Management – Exchange Net de l'Écosystème.*

I – Introduction

Grasslands and pastures are highly relevant in the global carbon cycle, mostly because of their capacity for soil organic carbon storage (Soussana *et al*., 2007). Soils are the biggest reservoir of carbon (C; Batjes, 1996). The preservation and accumulation of soil carbon is a relevant measure for climate change mitigation (Canadell *et al*., 2007). Generally, grasslands act most as a sink for CO_2 and can preserve very effectively soil carbon (Soussana *et al*., 2007, Schultze *et al*., 2009). However, there is high uncertainty in the total contribution of grasslands as C sinks. An important part of this uncertainty is related to the high diversity of grasslands and grassland managements, from semi-natural to intensive. Furthermore, while information about grasslands from the Alpine range is rather abundant, more information is needed about the C storage dynamics in Pyrenean grasslands. In this study, we present the results from three years of continuous measurements of microclimatology and CO_2 fluxes in an intensively managed grassland in the Eastern Pyrenees. The grassland is managed according to common practices in this region, which usually combines crop growing and grazing (Sebastià *et al*., 2011). In this particular grassland, a rotation of cereal with legume-grass forage mixtures coexists with cattle grazing during the fall. During the three years of the study, the specific crop and crop management varied, providing relevant data for assessing the effects of management on C fluxes, beyond the climatic conditions of the particular year. These results are relevant because they provide information about the effects of management on the C sinks. Practices contributing to increased C capture can lead to a net accumulation of C in soils of pastures and grasslands, thus sequestering atmospheric CO_2 (FAO 2010).

II – Materials and methods

1. Study site and experimental design

The study site is a sown forage grassland located in Pla de Riart (42° 03' 48" N, 1° 30' 48" E, Eastern Pyrenees), at 1003 m a.s.l. in the basal part of the montane altitudinal belt. Climate is Sub-Mediterranean, typical from mountain areas with Mediterranean influences. Mean annual precipitation is 750 mm and mean annual temperature around 11ºC, including the summer drought period. In 2010, an eddy covariance tower was established in the grassland. This is a specialized infrastructure that measures continuously meteorological variables (radiation, temperature, precipitation, wind speed and direction, relative humidity), soil variables (temperature, moisture), and components of the atmospheric turbulent flux to calculate CO_2, water and energy exchange at the ecosystem level.

2. Eddy covariance measurements

Eddy covariance measurements can be processed as Net ecosystem Exchange (NEE), and be compartmentalized as ecosystem production (Gross Primary Productivity, GPP) and ecosystem respiration (Reco) during a given period. Here we present results of these three variables linked to the C balance, GPP, Reco and the difference between both, NEE, during three years, from 2011 to 2013. The eddy covariance technique measures the vertical turbulent transport of energy and matter through an imaginary plane at the sensor height. It is based on the capture of measurements

at high frequency of the three components of wind speed and the scalars of interest, here CO_2 concentration, and the calculation of the covariance among those measurements. Because of the high temporal resolution, those stations are particularly adequate to analyse the temporal behaviour of atmosphere-ecosystem interactions.

3. Eddy covariance analysis

Raw data provided by the sensors were processed and flux values calculated for 30' periods. Processing was carried out with the specialized program Alteddy3.9 (Elbers *et al*., 2011). Standard algorithms were used to fill up the gaps in the data.

III – Results and discussion

The intra- and inter-annual flux dynamics in Pla de Riart were highly influenced by the management activities. Seasonally, the productive capacity of the system decreased with both harvesting and grazing, because of the reduction in vegetation. Regarding the variation among years, the carbon balance was highly dependent on the particular management of a given year (Table 1). Some years the farmer established a cereal forage crop. In this case, the field remained fallow after the summer harvest because of grazing and preparation for the next crop, which does not start accumulating biomass until the following spring. That happened in 2011 and 2012 (Table 1). On the contrary, in 2013 a forage mixture of triticale, oat and vetch was established. This sown grassland was harvested at different times throughout the year, and thus a second regrowth occurred in autumn.

Table 1. Gross Primary Productivity, ecosystem respiration and Net Ecosystem Exchange in Pla de Riart during the years 2011 to 2013. The crop cultivated each year is indicated

Year	Crop	Gross Primary Productivity (GPP, g C m^{-2})	Ecosystem Respiration (Reco, g C m^{-2})	Net Ecosystem Exchange (NEE, g C m^{-2})
2011	Barley	439	- 677	- 238
2012	Triticale	580	- 643	- 63
2013	Triticale, oat and vetch	990	- 978	12

Our results show that Pla de Riart acted in terms of the C balance as a mixed system between extensively grazed grasslands and cultivated crops. The field was close to semi-natural grasslands when a mixture was established, and in this case, the C balance was close to zero. On the contrary, it acted more similarly to a crop in terms of the C balance when monocultures of forage grasses were established, being in those situations a source of CO_2. Thus, the use of crops in monoculture brought the system to loss carbon, with an amount that depended on the productivity of the crop. The dependence of the C balance on management has already been recognized for crops (Béziat *et al*., 2009). Mountain grasslands host a high biodiversity and provide fundamental ecosystem services, including their potential role in climate change mitigation. In these systems, net ecosystem CO_2 exchange (NEE) is usually near to the equilibrium and grasslands can act as sources or sinks depending on local conditions (Gilmanov *et al*., 2010). We show that the same field can act as a source of CO_2 or be neutral, depending on the management during a particular year.

IV – Conclusions

Management factors were the most important drivers of the CO_2 flux dynamics of the sown forage grassland ecosystem of Pla de Riart, both seasonally during a given year as well as across years. The particular sown crop and the management during a given year were critical to determine the global C balance, with forage mixtures showing the most favourable C balance compared with forage grass monocultures.

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