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Does transhumant sheep system provide ecosystem services for climate change adaptation in Mediterranean environment?

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Abstract. Since adaptation to climate changes has become a major challenge for the scientific communities, provisioning Ecosystem Services as Climate Regulation are growing in research interest. Greenhouse gasses are widely considered drivers of climate change and it has been demonstrated how different agro-ecosystems can influence the climate by either taking or realising greenhouse gases. Land use change does affect the soil C pool and many authors showed how the conversion of permanent vegetation (forests or grasslands) to cultivated crops led to a loss of soil C. On the contrary, many researches highlighted how croplands re-converted in grasslands ensure a soil C increment. Central Italy cropping system is characterised by rainfed winter cereals in rotation with preparative crops in the hilly areas and with high value crops (mainly, horticultural crops or vegetables) in the river valleys. Within this system, the presence of transhumant sheep farms allowed the conversion of annual crops in long lasting alfalfa grasslands (up to 10 years) grazed by flocks during the winter period. In this paper, we compared two conventional crop fields with a five-years lasting alfalfa grassland analysing heterotrophic soil respiration effluxes and soil C stock. Results suggest that transhumant system is able to increase the soil C sequestration.

Keywords. Soil Carbon Pool/flux – Mediterranean – Grazing *vs* cropping systems – Ecosystem services.

Le système de moutons transhumants est-il capable de fournir les services écosystémiques pour l'adaptation au changement climatique dans les systèmes de culture méditerranéens ?

Résumé. *Depuis que l'adaptation aux changements climatiques est devenue un enjeu majeur pour les communautés scientifiques, les services écosystémiques d'approvisionnement comme la "régulation climatique" sont de plus en plus importants aux yeux de la Recherche. Les gaz à effet de serre sont largement considérés comme des facteurs de changement climatique et il a été démontré comment les différents écosystèmes peuvent influencer le climat par l'effet de serre dite "prise ou libérée". L'utilisation des terres affecte la couche carbonique du sol et de nombreux auteurs ont montré comment la conversion de la végétation permanente (forêts ou prairies) vers des champs cultivés, a conduit à une perte de C du sol. De nombreuses recherches ont mis en évidence la façon dont les terres agricoles reconverties en prairies assuraient un incrément de carbone du sol. Le système de culture de l'Italie centrale est caractérisé par les céréales d'hiver pluviales en rotation avec des cultures de préparation dans les zones montagneuses et les cultures à haute valeur (principalement, les cultures horticoles ou de légumes) dans les vallées fluviales. Dans ce système, la présence d'élevages de moutons transhumants a permis la conversion de cultures annuelles, en champs de luzerne durables (jusqu'à 10 ans), broutés par les troupeaux pendant la période d'hiver. Dans cet article, nous avons comparé deux champs de culture classique avec une prairie de luzerne (en place depuis 5 ans), pour analyser la respiration du sol et son efflux de carbone. Les résultats suggèrent que le système transhumant est en mesure d'augmenter le stock de C dans le sol.*

Mots-clés. *Pool/flux de carbone dans le sol – Méditerranée – Pâturage* vs *systèmes de culture – Services écosystémiques.*

I – Introduction

Many scientific evidences demonstrate how climate change (CC) is altering the function of ecosystems (Nelson *et al*., 2013) especially in the Mediterranean basin which became one of the most threaten areas of the world (Bangash *et al*., 2013). Therefore, adaptation to CC has become one of the most compelling issues that must be faced by stakeholders (scientists, policy makers and farmers). Regulating Ecosystem Services are the benefits that people obtain from the regulation of ecosystem processes, including mitigation climate change effects (MA, 2003). Soil respiration is one of the main terrestrial contributors to CO_2 fluxes in the global carbon cycle (Gong *et al*., 2014). Site-specific management practices affect C losses by soil respiration and, in turn, the soil C budget (Batjes, 1999). Therefore, agro-ecosystems play a crucial role concerning climate regulation as well as their management affect soil C processes. Central Italy cropping system is characterised by rainfed winter cereals in rotation with preparative crops in the hilly areas and with high value crops (mainly, horticultural crops or vegetables) in the river valleys. Within this system, the presence of transhumant sheep farms allowed the conversion of annual crops in long lasting alfalfa fields (up to 10 years) grazed by flocks during the winter period. In this work we test the hypothesis that land use and management based on transhumant can generate ecosystem services in terms of soil C sequestration. Therefore objectives in this paper are to evaluate the grassland management effects on (i) chemical-physical properties of soil; (ii) seasonal dynamics of soil respiration; and (iii) amount of soil C losses.

II – Materials and methods

The study area is located in Marche Region, central Italy (43°22'24.9" N; 13°35'23.4"E) and it is representative of the plain area cropping system composed by a mixture of high values annual crops (vegetable crops, winter cereals etc.) The climate is Mediterranean with an average annual precipitation of 769 mm and a mean annual temperature of 13.7°C. In November 2014 we identified three adjoined fields: two intensively cultivated (INT A and INT B) and one used as a pasture by a transhumant sheep farm (TRH). Rather than envisage a plot scale experimental design we adopted a system analysis approach identifying representative fields with comparable soil and climate characteristics. Similar studies have been carried out studying one representative site for each land use rather than try to replicate it across the ecosystem (e.g. Almagro *et al*., 2009). Heterotrophic Soil respiration (HSR) efflux was measured in situ using a portable, closed chamber, soil respiration system (EGM-4 with SRC-1, PP-Systems, Hitchin, UK) with a measurement time of 120 s. In November 2015 three PVC collars per field (10 cm inner diameter and 10 cm long, with perforated walls in the first 5 cm) were inserted into the soil to a depth of 9 cm. Soil was isolated with a PVC cylinder (40 cm diameter, 40 cm high) opened at both ends, following the method described by Alberti *et al*. (2010). During each CO_2 efflux measurement, the SRC-1 chamber was fitted to a collar. Measurements started in January 2015 and ended in September 2015. Soil T°C and Soil Water Content (SWC) were measured at each plot at the same time of CO_2 efflux measurement using, respectively, a build-in T°C probe EMG-4 and a FieldScout TDR 100 Soil Moisture Meter. SWC and T°C were measured, respectively, in the top 20 cm of soil and at 10 cm depth. Soil analysis have been carried out to define the management effects of the two systems produced on the soil characteristics. The past fields management have been assessed by interviews. Linear and non linear regression analysis have been performed in order to investigate HSR dependence on soil T°C and SWC. Differences in HSR within date of measurement have been verified with one way ANOVA.

III – Results and discussion

The crop rotation of the two intensive fields is in line with the ordinary management of the area where the main crops are vegetables and winter cereals. Within these fields, alfalfa generally lasted 2 years as cover crop for soil improvement purposes and has an extremely low economic value. Despite this, transhumant management maintains alfalfa as temporary grassland used by sheep flocks during winter and mowed 2/3 times during summer (Fig. 1).

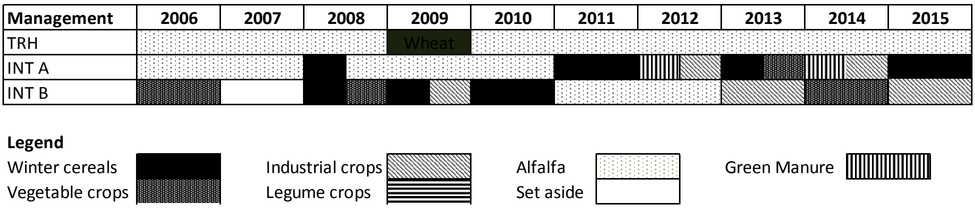

Fig. 1. Use of soil from 2006 in the three fields of the study area.

The comparison of soil analysis of the three fields (mean ± standard error) showed a similar texture (sand 19% ± 2.35; silt 46% ± 0.18; clay 34% ± 2.49), pH (8.3 ± 0.05), field Capacity (29.3% ± 0.76) and wilting point (20.4% ± 0.54). ANOVA on soil analysis shows significant differences among the managements with a larger C loss on INT A and INT B. Moreover, TRH shows a higher amount of soil N, NO_3- and a higher C/N ratio.

Table 1. Chemical-physical properties (mean ± standard error) of the soils obtained from three soils samples for each field at a 30 cm depth. Statistical significance has been assessed with LSD test ("a"=p<0.05; "A"=p<0.01)

Management	TOC (g/kg)	TEC (g/kg)	NO_3- (mg/kg)	Total N (g/kg)	C/N
TRH	13.60 ± 0.46^A	7.24 ± 0.12^A	8.37 ± 0.15^a	1.38 ± 0.04^a	9.43 ± 0.24^a
INT A	11.17 ± 0.07^B	6.16 ± 0.03^B	7.33 ± 0.37^b	1.22 ± 0.02^{ab}	8.73 ± 0.07^{ab}
INT B	11.50 ± 0.15^B	6.66 ± 0.03^C	5.63 ± 0.48^c	1.27 ± 0.02^b	8.70 ± 0.06^b

TOC: Total Organic Carbon (Springer-Klee method); TEC: Extractable Organic Carbon (According to DM 13/09/1999); NO_3- (According to DM 13/09/1999); Total N (Kjeldahl Method).

Exponential and linear regression analysis were performed to test respectively the relationships between (i) HSR and T°C (HSR= $a\ e^{b\ x}$) and (ii) HSR and SWC (HSR = $a + bx$) (Ray *et al*., 2002). When the SWC was lower than 21.5% the regression analysis shows significance between HSR and SWC in TRH and INT A ($p<0.05$) (Tab. 2).

Table2. Regression parameters of HSR= a $e^{b\ x}$ (where x is T°C) and HSR = a + bx (where x is SWC) (*p<0.05; **p<0.01)

Management	HSR f(x)	SWC < 21.5%					SWC < 21.5%				
		a	b	R^2	p	DF	a	b	R^2	p	DF
TRH	SWC	0.14	-0.18	0.57	*	8	0	1.32	0.00		8
	T°C	0.39	0.05	0.07			0.63	0.05	0.78	**	
INT A	SWC	0.12	-0.08	0.42	*	8	-0.08	3.08	0.07		8
	T°C	0.14	0.09	0.17			0.44	0.06	0.70	**	
INT B	SWC	0.02	0.88	0.05		8	0.05	0.08	0.03		8
	T°C	0.58	0.03	0.28			0.53	0.04	0.30		

As observed by Rey *et al*. (2002) soil respiration dynamics within soil use show a temporal variability imputable to SWC and T°C dynamics. ANOVA of HSR within date of measurement shows significant differences ($p<0.05$) in 1st April; 26th May, 25th June, 26th August and 23rd October, and for $p<0.01$ in 4th March, 3rd July and 24th September (Fig. 2).

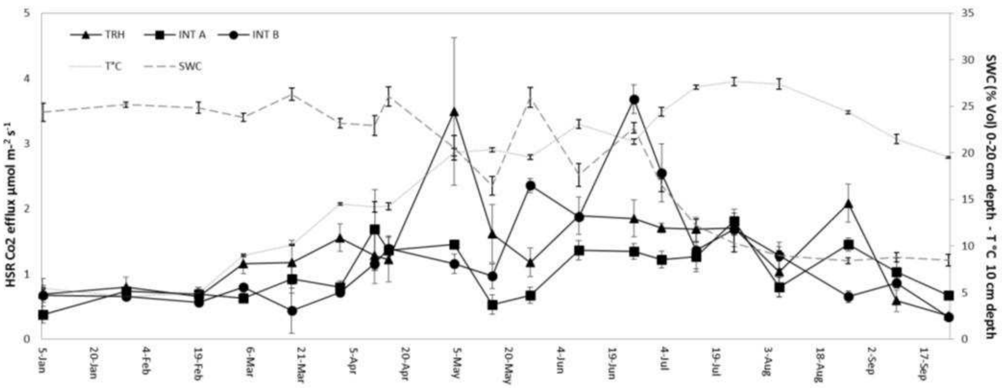

Fig. 2. Temperature (°C), Soil Water Content at 10 cm depth and HSR dynamics of the study area. The bars represent the standard error.

IV – Conclusions

Our results suggest that Soil Respiration dynamics are dependent both on soil temperature and water content therefore in line with scientific literature. Soil CO_2 emissions are higher in the alfalfa filed compared to the intensively cultivated fields. On the other hand, soil C content turned out to be higher where the transhumant farms system is present. The disappearance of the transhumant system in central Italy would increase soil C losses due to the management practices of the intensively cultivated fields. In order to estimate the potential of transhumant system in providing ecosystem services for climate regulation/adaptation, further analysis are needed to complete the study such as biodiversity assessment and Carbon Budget Assessments.

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