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Research article

Soil organic carbon pool's contribution to climate change mitigation on marginal land of a Mediterranean montane area in Italy

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ABSTRACT

To evaluate the mitigation potential provided by the SOC pool, we investigated the impact of woody encroachment in the 0–30 cm depth of mineral soil across a natural succession from abandoned pastures and croplands to broadleaves forests on the central Apennine in Italy. In parallel, to assess the effect of the land use change (LUC) from cropland to pasture, a series of pastures established on former agricultural sites, abandoned at different time in the past, were also investigated.

Our results show that woody encroachment on former pastures and croplands contributes largely to mitigate climate change, with an increase of the original SOC stock of 45% (40.5 Mg C ha^{-1}) and 120% (66.5 Mg C ha^{-1}), respectively. Also the LUC from croplands to pastures, greatly contributes to climate change mitigation trough a SOC increase of about 80% of the original SOC (45.9 Mg C ha^{-1}).

The management of abandoned lands represent a crucial point in the mitigation potential of agriculture and forestry activities, and particularly the role of the SOC pool. A policy effort should focus on minimizing the risk of speculative management options, particularly when the value of woody biomass become convenient to supply new energy systems allowing monetizing a long term forests productivity.

In conclusion, despite both the land abandonment and the LUC can have a different impact on the SOC pool under different climatic conditions, these results can be useful to improve the SOC estimates in the National greenhouse gases Inventory at country level.

1. Introduction

In Europe, agricultural land abandonment is a common phenomenon since the beginning of the 20th century (Garcìa-Ruiz and Lana-Renault, 2011; MacDonald et al., 2000), and it is forecast to continue over the next decades (Pointereau et al., 2008; Rounsevell et al., 2006). The increase in abandonment of farmland is particularly severe on mountain areas of the southern and eastern countries of Europe (Estel et al., 2015; Terres et al., 2015). Lasanta (2014) observed that more than 75% of arable land is no longer worked in European mountains, a percentage that reaches 100% in some Mediterranean mountains. The phenomenon is due to socio-economic aspects, climate change as well as the reflection of European policies carried out during several international negotiations on market and environment (Van Vliet et al., 2015; Renwick et al., 2013). In the last three decades, the Common Agricultural Policy (CAP) has promoted the reduction of production and, at the same time, has fostered more sustainable agricultural practices. The measures like set-aside and afforestation, introduction of the agro-environmental schemes, the decoupling of Agenda 2000, the definition of cross-compliance in the Middle Term Review of 2003 and the greening introduced by the CAP 2013 reform, have changed the production structure of European agricultural market and jeopardized environmental impacts (Kristensen et al., 2016; Passeri et al., 2016). The outline of the European agricultural policies has promoted, in many cases, more sustainable agricultural practices, but, at the same time, has resulted in some European contexts to an acceleration of the phenomenon of agricultural production

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deactivation, contributing over time to the abandonment of farmlands in marginal contexts, often classified as less favoured areas (Lasanta et al., 2017; MacDonald et al., 2000).

In connection with land abandonment, the woody encroachment is a widespread phenomenon throughout Europe (Piussi, 2000) and worldwide (Chiti et al., 2017; Eldridge et al., 2011; Zhang et al., 2010). In Italy, woody encroachment on abandoned lands characterizes both the Alps and the Apennines (Piussi, 2002; Corona et al., 2005).

The latest National greenhouse gases (GHG) Inventory, submitted by Italy in 2017 to the UNFCCC, shows a progressive contraction of cropland areas by 2 million ha over the last 25 years: from 10.8 million ha in 1990 to 8.8 million ha in 2015 (NIR, 2017). The causes of the cropland contraction are twofold: urbanization and/or abandonment. The abandoned agricultural area is subject to grass and woody encroachment, leading, in the long term, into forest establishment. Indeed, according to the National Inventory Report (NIR, 2017), forest land has increased its surface over the last 25 years of nearly the same amount of cropland contraction: 1.7 million of hectares. In the NIR (2017) it is assumed that forest land is expanding exclusively on grassland, that therefore often represents an intermediate state of land cover between cropland and forest land in the woody encroachment process.

As a consequence, the woody encroachment on abandoned croplands can be considered as an indirect human induced land cover change, which causes an associated change in carbon (C) stocks at ecosystem level (Foley et al., 2005). The contribution of the abandonment of agricultural practices in favour of a grass and woody encroachment is likely to provide a large contribution in term of climate change mitigation, through the removal of CO_2 from the atmosphere and the consequent storage of the C in the above ground woody biomass (Risch et al., 2008) and in the soil. The balance between C inputs and outputs from soils controls the soil organic carbon (SOC) pool, and land use changes (LUC) may impact both the C input as well as output fluxes from an ecosystem (Guo and Gifford, 2002). Thus, after a LUC, soil can act as a source or a sink of C according to the ratio between inflows and outflows. Recent studies from montane areas of the Mediterranean basin, suggested a major role of soil in contributing to climate change mitigation trough SOC sequestration during the woody encroachment process (Novara et al., 2017; Nadal-Romero et al., 2016; Romero-Díaz et al., 2016).

In Italy, the land use, land use change and forestry sector (LULUCF) is responsible of a net sink of 36,218 Gg CO_2eq in 2015, that increased on average by about 2000 Gg CO_2eq per year, mainly due to the expansion of grassland and forest land (NIR, 2017). In particular, the conversion of 1.3 million ha from grassland to forest land between 1996 and 2015 led to a sink of 1937 GgC yr^{-1}, of which 242 GgC yr^{-1} are attributed to the SOC pool. However, the SOC estimations in the National GHG Inventory are very poor due to lack of specific data at country level, using a single value of SOC content for the whole Italy in grassland, forest land and cropland categories respectively.

The aim of this research is to assess the variation in SOC levels due to the most representative LUC occurring in montane areas of Central Italy: a) natural successions from abandoned pasture and cropland to broadleaves forest; b) change in land use, from cropland to pasture.

Furthermore, the study gives policy recommendations on the management of rural development policies related to the increase in SOC and tries to draw some reflections on the overall impact of a "C oriented" agricultural policy for the rural areas and communities of the Central Italian Apennine.

2. Materials and methods

2.1. Site description

The study area (44° 8′ 16.9" N; 11°18′ 57.5" E) is located on the Apennine ridge in the Mugello valley in Tuscany, 50 km north of Florence, at an average elevation of 800 m a.s.l. (Fig. 1). The climate of the investigated area is temperate Mediterranean with a mean annual temperature of 9.2 °C and a mean annual precipitation of about 1000 mm. Since the 1950 both temperature and precipitation experienced a gradual decrease (Fig. 2). According to Sanesi (1977), the soils of the area are generally classified as Cambisols, following to the FAO classification (IUSS Working Group WRB, 2014). These soils are moderately depths or swallow, with a clay texture and sometime rich in gravel. The pH is moderately alkaline with carbonates only in the lower part of the profile.

Historical and census data concerning LUC dynamics for the Mugello valley indicate that over the last century the agricultural activities decreased substantially, particularly in the mountain areas, which are those more exposed at risks on land abandonment (Terres et al., 2015).

2.2. Experimental design

The study was conducted in 2012 considering three contiguous farms, one of which is active since the middle of the last century, while the other two closed their activity at the end of the 20th century.

To investigate the effect of woody encroachment and of a shift in land use, both after land abandonment, we identified three chronosequences: a) from pasture to forest, b) from cropland to forest and, c) from cropland to pasture. Croplands are cultivated for fodder production that is consumed by cows during winter, while pastures are grazed by cows with a low intensity. In the first chronosequence, to have a strong baseline for SOC we considered three pastures currently grazed to represent the zero point. Then, were identified five pastures abandoned at different time in the past (6, 15, 30, 42, 54 years before), where woody encroachment is currently ongoing. A forest developed over a pasture abandoned 70 years before represents the final point of this chronosequence (Table 1). Similarly, in the second chronosequence were considered three croplands currently managed to represent the zero point. Then were considered two croplands abandoned at different time in the past (14 and 50 years before), and a forest developed on a cropland abandoned 64 years before (Table 1). The three croplands representing the zero point of the second chronosequence were also used as a baseline for the third choronsequence, where two pastures established on former croplands, abandoned 14 and 35 years before and always managed as pastures, were considered. A pasture currently grazed was used as a final point of this choronsequence.

2.3. Soil sampling strategy

To determine the variations in SOC stocks following this natural LU change, it was adopted the soil sampling protocol proposed by the European Commission to certify changes in SOC (Stolbovoy et al., 2007). This sampling protocol is based on a randomized sampling template with a grid of 100 cells enabling a random sample collection with a distance threshold to be determined. The spatial parameters of the template are flexible and adjusted to the size and geographical coordinates of the sampling plot (e.g. pasture). To define the dimension of the template, the minimum and maximum X and Y axes of the area need to be known. Since all