Agriculture, Ecosystems and Environment 266 (2018) 17–30

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Using present and past climosequences to estimate soil organic carbon and related physical quality indicators under future climatic conditions

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ARTICLE INFO

Keywords:
Climate change
Cropping system
Soil physics
Soil quality indicators
Soil type
Mediterranean

ABSTRACT

This research aimed at testing the use of present and past climosequences to estimate soil organic carbon (SOC) and related physical quality indicators under future climatic conditions. The influence of climate on soil features was studied for four combinations of typical Mediterranean soil types and cropping systems, placed along climosequences of the past (P1: 1961–1990), present (P2: 1981–2010) and future (P3: 2021–2050). The four test areas were located in Italy, each one characterized by the same soil typology and cropping system, placed on similar morphological position and parent material, wide enough to cross climatic boundaries. Legacy soil profiles that were sampled in the P1 time-period were re-sampled in 2010–2011, to check for possible variations in soil characteristics. Besides SOC content and stock (C_{stock}), we examined some physical quality indicators for which the existence of relations with SOC is well-known, namely soil compaction and soil crusting susceptibility, soil erodibility, and soil loss by water erosion.

Among several climatic indexes, the de Martonne index (IDM) resulted the most correlated with SOC. The IDM vs. SOC relationship was significant and not different in both P1 and P2 climosequences, highlighting the temporal stability of the relation between climate and SOC content. In the Vertisols of Sicily, cultivated under cereals, the P3 climosequence predicted a SOC reduction of more than 11%. This will lead to an increase of soil erodibility, susceptibility to compaction, and surface crust formation. On the contrary, in the Luvisols under forage crops of the Po Plain, a substantial C_{stock} increase (28.8%) is expected, with a consequent improvement in soil physical indicators. For the Luvisols under meadows of Sardinia, an increase in erosion of 13.5% is expected, because of increased precipitation volume (7.4%) and aggressiveness. In the Andosols under olive trees of Campania there is a predicted reduction in the C_{stock} (-6.3%) and an associated increase in soil loss (4.6%), while no marked variation is expected for the other soil physical indicators.

We can conclude that climosequences are a useful tool to predict the future dynamics of some soil physical characteristics affected by climate change. C_{stock} and soil loss by water erosion are expected to change significantly under future climatic conditions, while minor changes are observed for erodibility, compaction and crusting susceptibility, even when SOC variations are significant. In the climosequences, the considered soil physical quality indicators resulted proportionally more affected by the cropping system than by the climate and, within the same cropping system, more variable according to the climate than the time. This outcome confirms the fundamental role of soil physics in controlling the resilience of the soil system to climate change.

1. Introduction

Agricultural production is dramatically affected by climate variability and change (Parry et al., 2004; Lal, 2004; Olesen et al., 2011; Lobell et al., 2011). Producers, land managers, and other decision makers need information about the effects of climate change on cropping systems, to develop mitigation and adaptation strategies, and policy measures (Smit et al., 2000; Olesen and Bindi, 2002). Due to the great variability of climate and soil cover, adaptation measures should be tailored according to specific conditions to be really effective (Thornton et al., 2009; Walthall et al., 2012).

Planning specific interventions and prescriptions should be based upon scientific findings and monitoring activities. However, estimates on the real impact of climate change on definite cropping systems have

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https://doi.org/10.1016/j.agee.2018.07.015
Received 6 October 2017; Received in revised form 17 July 2018; Accepted 20 July 2018

produced variable results, in function of the local climatic conditions, intensity and velocity of change, and adoption of different management options (Loarie et al., 2009; Lal et al., 2011). Some authors even consider a moderate climate change beneficial for specific cropping systems and environments, if adaptation options are implemented (Hatfield et al., 2011; Howden et al., 2007). Nevertheless, there is a common agreement that in many areas of the world crop yields might be depressed under the climatic conditions of next decades, if current management practices are not modified (Tubiello et al., 2000; Ciais et al., 2005).

Although land use and management changes are expected to play a greater role than climate change on soil properties and functions (Valentin et al., 2005; Huang et al., 2007; Lal et al., 2011; Fantappiè et al., 2011), projected climatic conditions seem to jeopardize several soil qualities and functions (Lal, 2004). Soil organic matter (SOM) and its components, including biological activity, are the most sensitive and dynamic properties, frequently used as crucial indicators for monitoring land degradation processes, as well as adaptation and restoration strategies (Kirschbaum, 1995; Harris, 2003; Fantappié et al., 2010; Costantini et al., 2016). The study of soil physical and hydrological variations related to climate change is much less investigated, in spite of their paramount importance in shaping soil services (Powlson et al., 2011).

Future changes of soil physical and hydrological characteristics have been estimated in Chinese and Mediterranean watersheds, where soil erodibility is deemed to show a significant increasing trend, especially in cultivated fields (Zhang and Liu, 2005; Nunes et al., 2008). Under most probable climate change scenarios, the hydrological characteristics of Calcic Chernozems of Hungary are estimated to deteriorate (Hernádi et al., 2009). In Scotland, soil workability is foreseen to worsen in the changed climate, because of an expected increase in winter rainfall (Cooper et al., 1997).

It is well known that the study of climate change impact on properties of agricultural soils can be pursued with several approaches

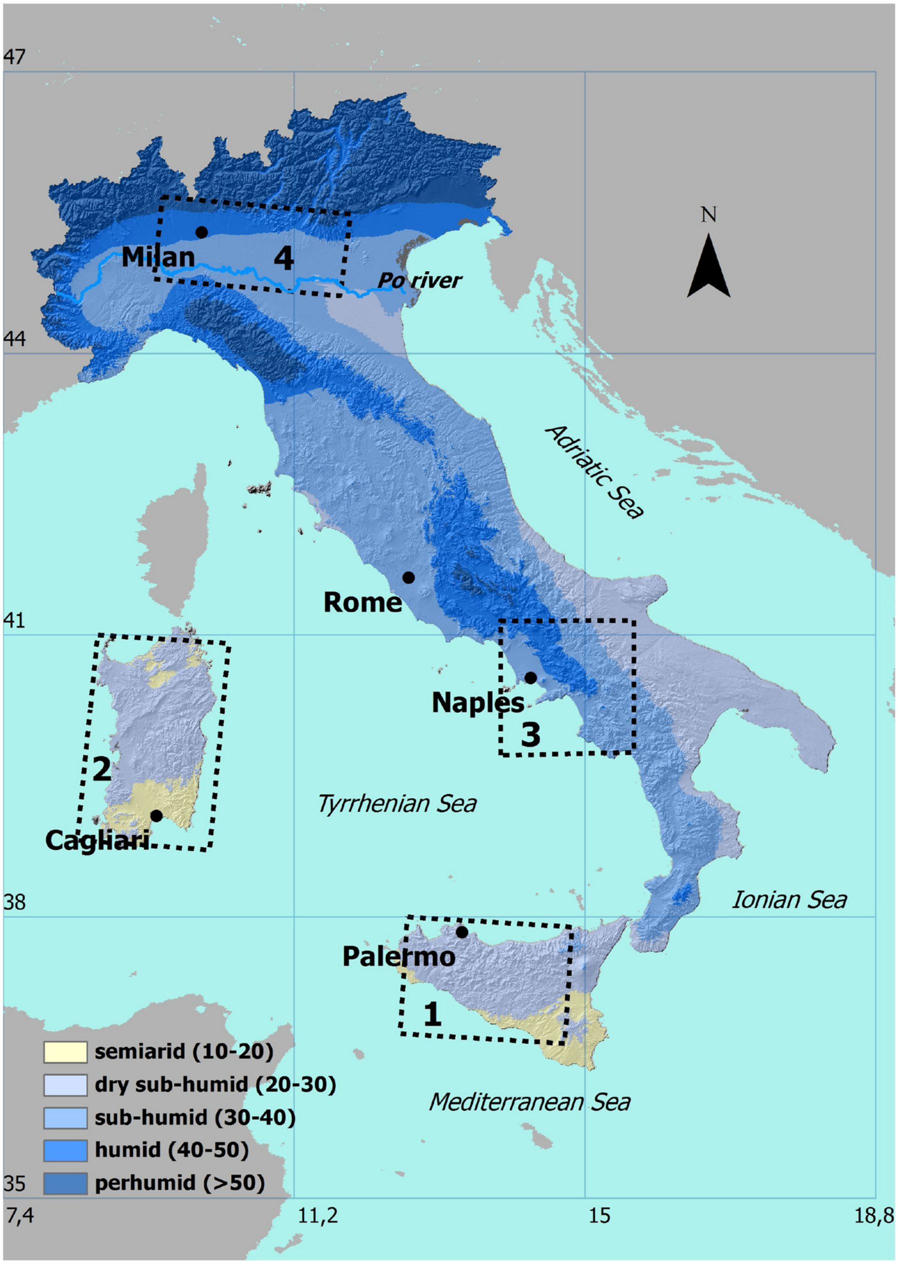

Fig. 1. Test areas and aridity classes (1981–2010) of Italy according to the de Martonne (1926) classification. The numbers from 1 to 4 identify, in the order, the test areas of Sicily, Sardinia, Campania and Po Valley.