



## Neof ormation of pedogenic carbonates by irrigation and fertilization and their contribution to carbon sequestration in soil



Mansoor A. Bughio<sup>a,f</sup>, Panlei Wang<sup>a</sup>, Fanqiao Meng<sup>a,\*</sup>, Chen Qing<sup>a</sup>, Yakov Kuzyakov<sup>b,e</sup>,  
Xiujun Wang<sup>c</sup>, S.A. Junejo<sup>d</sup>

<sup>a</sup> College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China

<sup>b</sup> Department of Soil Science of Temperate and Boreal Ecosystems, Department of Agricultural Soil Science, Georg-August-Universität Göttingen, Büsgenweg 2, 37077 Göttingen, Germany

<sup>c</sup> Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20740, USA

<sup>d</sup> Department of Geography, University of Sindh Jamshoro, Pakistan

<sup>e</sup> Institute of Environmental Sciences, Kazan Federal University, Kazan, Russia

<sup>f</sup> Agriculture Extension, Agriculture Department, Government of Sindh, Pakistan

### ARTICLE INFO

#### Article history:

Received 14 November 2014

Received in revised form 31 July 2015

Accepted 1 August 2015

Available online 15 August 2015

#### Keywords:

Land use

Organic fertilization

Secondary carbonates

Stable C isotopes

Irrigation

Subsoil processes

### ABSTRACT

The impact of land use change and farming management on soil organic carbon (SOC) and soil inorganic carbon (SIC), particularly pedogenic carbonates (PC), was assessed in a semi-humid region of China. The SOC and SIC content and stocks were measured, and  $\delta^{13}\text{C}$  values were used to calculate the percentage of PC and lithogenic carbonates (LC) in the total SIC. Over the 39-year period, organic fertilizers at high and low rates (OFH and OFL), mineral fertilizers (MF), and a control site without fertilizers (CK) showed an increase of PC compared to a natural fallow plot (F). The main pathway of SIC accumulation was the neof ormation of pedo-atmogenic carbonates contributing to C sequestration of at least 0.38, 0.27, 0.23, and 0.12  $\text{Mg C ha}^{-1} \text{ yr}^{-1}$  for the OFH, OFL, MF, and CK treatments, respectively. The LC stock remained similar in all treatments except for the CK, where LC was significantly lower than all of the other treatments which suggested dissolution. An increase in OC stocks in response to organic fertilization was not limited to the surface soil, but it continued down the soil profile to a depth of 160 cm. The maximum potential for neof ormation of PC depends on  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  availability; in this study these cations were provided by irrigation water. However, organic and mineral fertilizers modify this potential. Without organic and mineral fertilization, the PC formed at the expense of dissolution and re-precipitation of LC, even when substantial quantities of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  were present in the soil. Our experimental results indicate that the neof ormation of PC should be considered during estimation of soil carbon stocks and sequestration for the development of optimal fertilization, irrigation and land use practices.<sup>13</sup>

© 2015 Elsevier B.V. All rights reserved.

### 1. Introduction

Atmospheric  $\text{CO}_2$  concentrations have increased by 31% since the 1750s due to the combustion of fossil fuel and land use changes. This has necessitated the identification of mitigation strategies in response to global warming and climate change (Lal, 2004). Agricultural land occupies 37% of the earth's land surface and it is believed that agriculture could offset, at full biophysical potential, about 20% of the total annual  $\text{CO}_2$  emissions (Smith et al., 2008). The impact of agricultural management on soil organic carbon (SOC) is relatively well known. However, the effect on soil inorganic carbon (SIC), which is another potentially important carbon (C) sequestration mechanism, to date has been poorly studied (Lal and Kimble, 2000), especially in soils under semi-humid climate. SIC sequestration involves the transfer of atmospheric  $\text{CO}_2$  into the soil C pool through the formation of secondary carbonates

(Lal, 2007). The turnover time of SIC is much longer (85,000 years, Schlesinger, 1985) than that of SOC (200–1200 years, Trumbore, 2000). The global SIC pool is estimated to be about two-thirds of the SOC pool to a depth of 1 m (Eswaran et al., 2000). As carbonate precipitation occurs at depths as deep as 2 to 3 m, the contribution of SIC to global C stocks is greater when deeper soil profiles are evaluated (Díaz-Hernández et al., 2003). Carbonates can be classified as primary or lithogenic (mainly from the parent material) or secondary/pedogenic (newly developed as a result of dissolution and recrystallization of primary carbonates and other soil forming processes) (Kuzyakov et al., 2006). The depth of pedogenic carbonate formation increases with increasing mean annual precipitation, with shallow formations in arid climates and deep formations in semi-arid and sub-humid climates (Gocke et al., 2012; Lal, 2007).

Flows of inorganic carbon in the biosphere have three dominant processes: weathering of silicate minerals (Sommer et al., 2006), carbonate dissolution, and pedogenic carbonate formation (Sanderman, 2012). The first two processes are very slow-acting on geological time scales, and they have limited C sequestration potential in agro-ecosystems.

\* Corresponding author.

E-mail address: [mengfq@cau.edu.cn](mailto:mengfq@cau.edu.cn) (F. Meng).