The Anthropocene: Politik–Economics–Society–Science

Sabit Erşahin · Selim Kapur
Erhan Akça · Ayten Namlı
Hakkı Emrah Erdoğan *Editors*

Carbon Management, Technologies, and Trends in Mediterranean Ecosystems

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Internal title page photo: Red poppy (Papaver rhoeas) and pistachio nut tree (Pistacia vera) grafted to terebinth (Pistacia terebinthus). The cover photo was taken from the Mediterranean Highlands, Southern Turkey by Erhan Akça who granted permission for its use.

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Mediterranean Soil Ecosystems: Publication of the Soil Science Society of Turkey

Publication of the Soil Science Society of Turkey (SSST)

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Preface

Mediterranean Soil Ecosystems (MSE) is a series of formal scientific publications of the Soil Science Society of Turkey (SSST). Established in 1964, the SSST supports wide range of research in soil science and related disciplines. Mediterranean Soil Ecosystems invites contributions on topics in soil ecosystems, soil and land degradation and desertification, agroecosystem management, carbon dynamics and management systems and ancient land use in the Mediterranean environment and context, palaeopedology and geopedology, and the changing soils and soils of tomorrow and their likely use under climate change scenarios.

Mediterranean Soil Ecosystems also aims to improve communication and develop holistic integrated approaches for achieving a sustainable management of the environment. The MSE welcomes all aspects of soil science and its interrelations to soil and earth sciences, agriculture, forestry, biology, botany, climatology, ecology, ecological economics, environmental sciences and engineering, environmental law, carbon policies, and information sciences related to environmental integrity. Mediterranean Soil Ecosystems welcomes readers, authors, and research results from academia, business, government, research institutes, and public interest groups.

This book covers ecologic and socio-economic aspects of carbon management in Mediterranean ecosystems. The chapters were selected among those presented at the 1st Istanbul Carbon Summit, held at Istanbul Technical University, 2–4 April, 2014 and subsequently peer reviewed by the members of editorial committee.

Discussion on multiple interactions between soil carbon and environment were covered in first three chapters. Carbon treading issues in different Mediterranean nations and related policies, application, and implementations are covered in Chap. 4. Chapter 5 covers a unique discussion on how recent developments and related ecological disturbance affected life of Nubians, one of the most ancient peoples in the world, their civilization started more than 8,000 years ago in Egypt. Chapter 6 discusses the results of a study on relationships between carbon dioxide emissions and exports in terms of carbon dioxide emissions, total exports, agricultural exports, industrial exports, and service exports in 23 countries from different income levels and different regions. Chapter 7 introduces a functional 'energy–economy–ecology–engineering' integrated model that calculates final energy consumption from primary energy supply and discusses its application in Turkey and Chap. 8 covers discussion on the cost/benefit assessment of implementing Land Use, Land Use Change and Forestry (LULUCF) accounting the regulations in Turkey in the future. Chapter 9 discusses carbon certification applications in Turkey and finally, Chap. 10 discusses results of a long term study on carbon sequestration and mycorrhizae in two soil series located in the eastern Mediterranean region of Turkey (Adana). The editors of this book profoundly express their gratitude to the series editor Hans G Brauch for his everlasting and sincere efforts which led us to made this book a worthwhile achievement. We also thank N Özçelik and S Sabancılar who designed the İznik tile pattern on the front cover.

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June 2016

Contents

Chapter 1
Soil Carbon Impacts on Functionality and Environmental Sustainability

Rattan Lal

Abstract The term soil functionality implies utilization of soil for specific purposes so that ecosystem functions and services are sustained. Soil functionality strongly impacts environmental sustainability in relation to climate change, water quality and renewability, biodiversity, elemental cycling and transformations. There is a wide range of soil parameters which impact soil functionality. These include physical (texture, structure, pore size distribution, continuity), chemical (pH, E_h, charge density, nutrient reserves, elemental toxicology), biological (microbial biomass carbon, soil respiration, biodiversity) and ecological (soil organic carbon concentration and quality, elemental transformation). The choice of specific indicator depends on specific functions. These parameters can be combined into a soil functionality index. Soil functionality can be measured indirectly be assessing soil quality. Soil functionality also depends on the parent material, land use and management, climate and CO_2 enrichment. Soil functionality can be restored by creating a positive soil/ecosystem carbon budget, carbon sequestration in soil and terrestrial biosphere, enhancement of biodiversity and control of soil erosion. The concept of soil functionality can be used to address global issues such as climate change, food and nutritional security water quality and renewability and biodiversity.

Keywords Soil quality · Ecosystem services · Soil functionality index · CO_2 enrichment · Soil structure and porosity

1.1 Introduction

The term 'sustainability' implies: (1) longtime period, and (2) the need for a steady growth. However, Bartlett (1997) opined that the term "sustainable growth" is an 'oxymoron' (Daly 1990). Among the list of seventeen laws proposed by Bartlett,

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law #13 states "Humans will always be dependent on agriculture, and the central task in sustainable agriculture is to preserve agricultural land." The law #12 states that, "The chief cause of problems is solutions." When asked if, after independence, India would attain British standards of living, Mahatma Gandhi replied, "It took Britain half the resources of the planet to achieve its prosperity, how many planets would a country like India require…?" (Goodland 1992). Gandhi's response is even more relevant in 2016 than it was in 1940s. Therefore, the issue of environmental sustainability is on the forefront of any global agenda. Soil degradation plagued several ancient civilizations (e.g., Mesopotamia in the Tigris-Euphrates Valley, and Mayan in Central America). However, it is the mushrooming of the scale at which it is happening in the 21st Century, which is a major concern and an urgent issue to be addressed.

The emphasis on environmental sustainability during 2010s is attributed to the: (i) high rates of exploitation of renewable resources, (ii) continuous increase in generation of pollutants (pesticides, chemicals, gaseous emissions), (iii) a rapid depletion of non-renewable resources, (iv) extinction of biodiversity, and (v) severe degradation (and even extinction) of soils. Therefore, environmental sustainability involves a strategy of making prudent decisions on natural resources (soil, water, vegetation, etc.) management to reduce the human footprint encompassing indicators such as soil degradation, eutrophication of water and non-point source pollution, emission of greenhouse gases (GHGs), drainage of wetlands, cultivation of peat soils etc.

Judicious management of soils is integral to environmental sustainability (Kerzhentsev 2010). Ignoring the soil-environmental nexus and its ramifications can endanger some fragile resources by accelerated erosion (Tennesen 2014) along with severe adverse impacts on soil biodiversity (Tsiafouli et al. 2015). Soil structure, strongly affected by mycorrhizae (Rilling/Mummey 2006) and other biota, is prone to degradation through management-induced perturbations of the surface layer leading to strong adverse impacts on soil functionality.

Therefore, the objective of this article is to describe soil functionality, and discuss the impact of soil organic carbon (SOC) concentration and other properties on soil functionality and the environmental sustainability.

1.2 Soil Functionality

Soil is a dynamic entity, and its properties are strongly influenced by natural and anthropogenic factors. Thus, it is important to understand how and which soil properties change because of biotic and abiotic stresses, on short and long-term, and in the surface and sub-surface horizons. Thus, soil use and management can be chosen to advance the goals of environmental sustainability. It is in this context that soil functionality is multi-dimensional characteristics with ecological, economic, social and political ramifications.

Table 1.1 Principal functions of soils

	Function	Example
1	Food production	Medium for plant growth, Reservoir of water and nutrients, Support for root growth, Resistance against diseases and pathogens, Elemental transformation and reducing phytotoxicity
2	Agronomic	Sustaining productivity, Moderating use efficiency of inputs, Strengthening resilience against climate change
3	Gene pool	Habitat for biota, Reservoir for seed, Preserving germplasm over millennial time scale
4	Environmental/Ecologic	Recycling and retention of nutrients, filtrating and purifying water, Storing C and moderating atmospheric chemistry, Regulating gaseous exchange between pedosphere and the atmosphere, Resisting soil erosion, Buffering against perturbations
5	Industrial	Raw materials, Minerals, Pharmaceutical, Antibiotics
6	Anthropogenic	Physical and cultural heritage, Aesthetic and artistic values, Spiritual, Therapeutic, Human and planetary history, Evolutionary archive
7	Foundation	Platform for man-made structures, Foundation for dams, buildings, etc.

Source The author

The term soil functionality means utilization of soils for specific purposes at an optimal level so that the ecosystem functions and services are sustained. In other words, “it is the capacity of a specific soil to function under designed circumstances to meet its planned intentions or requirements without any loss of original functional capability” (Yong et al. 2012). The soil functionality concept addresses the performance aspects of a specific soil according to the specific goals or functions.

There are numerous soil functions (Table 1.1), including plant growth, and the food production through agronomic management. A German saying in the context of food production states, “Es ist die Erde, die gibt uns das Brot” or it is the soil, which gives us the bread. Food being essential to human survival, it is pertinent to state that we are soil. Thus, Gandhi stated that, “To forget how to dig the Earth and tend the soil is to forget ourselves.” Important among ecologic functions of soils are: recycling and retention of nutrients, filtration and purification of water, storing of carbon (C) and moderating atmospheric chemistry, moderating gaseous exchange between the pedosphere and the biosphere, resisting soil erosion, buffering against natural and anthropogenic perturbations, and providing habitat and energy for soil biota. There are also anthropologic and industrial functions. Therefore, protection of soil resources and their functionality is of a paramount importance (Blum et al. 1993).

Through its critical role in numerous functions (Table 1.1), soil functionality impacts water resources (renewability and quality), climate change (mitigation, adaptation and stabilization), food and nutritional security (quality and quantity), and biodiversity (above and belowground). Soil functionality is the engine of economic development.

1.3 Indicators of Soil Functionality

There is a strong interaction between environmental sustainability and soil functionality (Fig. 1.1). Principal indicators of soil functionality which impact environmental sustainability are physical, chemical, biological, and ecological (Table 1.2). There is a strong relationship between the functionality of physical and chemical attributes and the parent material of soil (Jenny 1941). An example of the effects of parent material on soil functionality is documented in a study from Brazil de Arúgo Filho et al. (2013) observed that in the Itapric region of Brazil, soils derived from the sandy parent material contained low nutrient reserves and high permeability. In contrast, soils derived from the fine sediments contained higher nutrient reserves and low permeability. These indicators are important soil properties, and the specific set of properties varies among functions (agronomic,

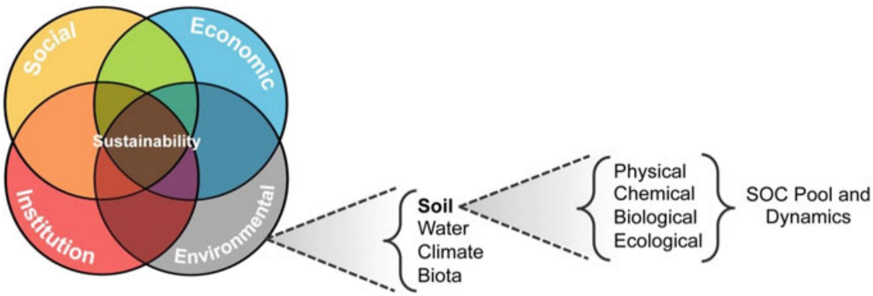

Fig. 1.1 Environmental sustainability in relation to soil functionality and soil organic carbon (SOC) pool and its dynamics. *Source* The author

Table 1.2 Important indicators of soil functionality

Indicator	Parameter
Physical	Texture, structure, bulk density, pore size distribution and continuity, water retention and transmission, thermal capacity and conductivity
Chemical	pH, E_h, charge density, nutrient reserves, elemental transformation, nitrification, denitrification
Biological	Microbial biomass carbon (MBC), biodiversity (macrofauna), soil respiration, potentially mineralizable N
Ecological	Soil organic carbon (SOC), biogeochemical transformations, methanogenesis, gaseous exchange and diffusivity, erosion, soil formation

Source The author

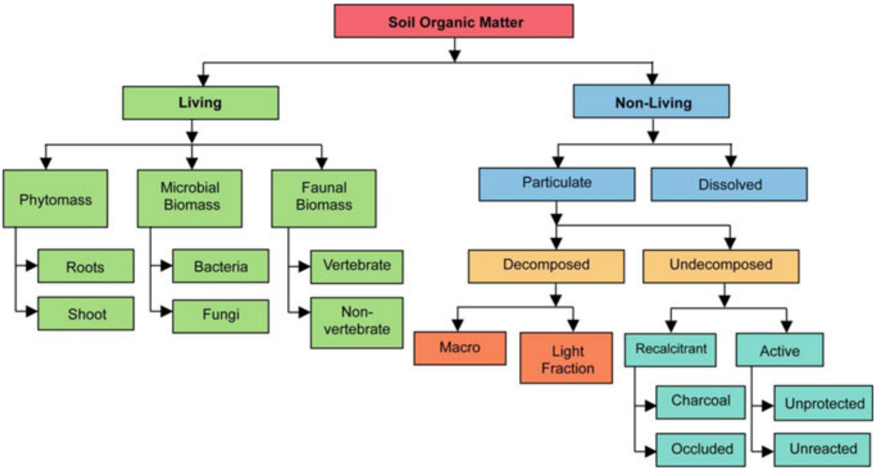

Fig. 1.2 Living and non-living components of soil organic matter content which impact soil functionality. *Source* The author

environmental, food production). Both soil organic C (SOC) concentration and pool are important determinants of soil functionality and environmental sustainability. In addition to the amount, composition of SOC also affects numerous properties and processes. It cuts across a range of soil functions of relevance to human wellbeing and nature conservancy. The SOC pool, as the principal component of soil organic matter (SOM), comprises of living and non-living organisms in soil (Fig. 1.2). It is the amount, quality and dynamics of SOC pool that governs soil functionality (Fig. 1.3) through changes in physio-chemical, biochemical, eco-biological processes and transformations are over time. These transformations are influenced by natural and anthropogenic factors, and biotic and abiotic stresses. Thus, judicious management of SOC pool is essential to sustainability of soil functionality. Indeed, the critical levels of SOC concentration in the root zone may be ~2 % for soils of the temperate regions (Kemper/Koch 1966; Greenland et al. 1975; Loveland/Webb 2003), and ~1.1 % for those of the tropics (Aune/Lal 1997).

It is not easy to measure soil functionality. Indeed, "most important things cannot be measured and still must be managed" (Edward Demmings 1900–1993). In other words, "manage what you can't measure." Thus, the question with regard to soil functionality is: what is there in the soil that can be measured in terms of what it does. What is does is soil functionality.

Because soil functionality is difficult to measure directly, it is measured indirectly by measuring soil quality index (Mukherjee/Lal 2014) or soil functionality index (SFI). Yong et al. (2012) defined SFI as a ratio of the value x_n of a soil parameter at time t_n to a reference base soil functionality value (x_{base}) for each specific indicator. If SOC concentration is selected as an indicator of soil functionality, then SFI of SOC is:

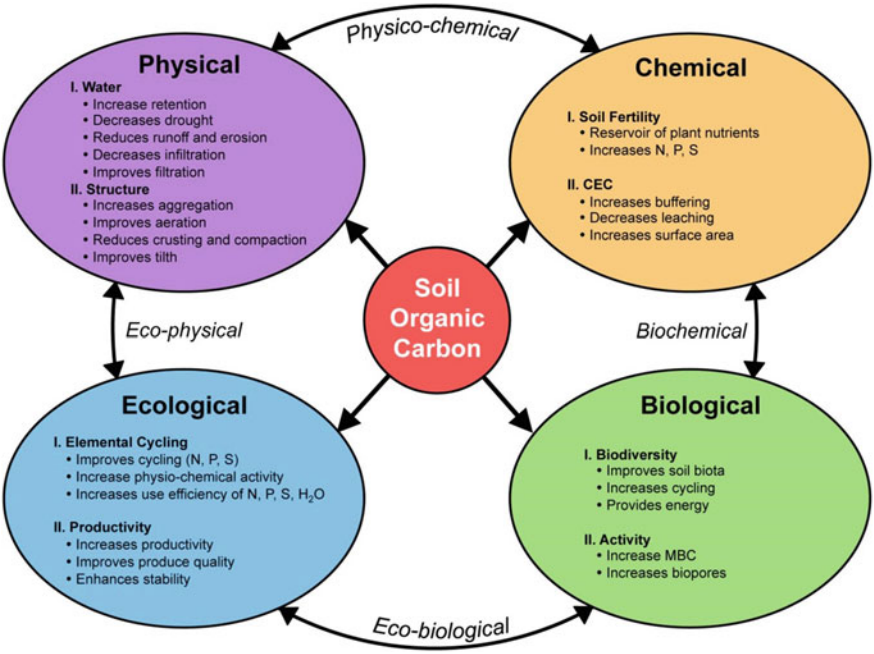

Fig. 1.3 Impacts of soil organic carbon pool on soil properties and processes which impact soil functionality. *Source* The Author

$$SFI_{(SOC)} = SOC_n : SOC_{base}$$

Therefore, SOC depletion occur for SFI < 1 and sequestration for SFI > 1. Similar to SQI, SFI must also be the one that soil scientist can quantify and farmers can understand and relate to.

1.4 Management of Soil Functionality

The Law of Return by Sir Albert Howard states that, "the nutrients harvested from soil must be returned. Harvesting without returning is a robbery of the soil and banditry; a particularly mean form of banditry, because it involves robbing of future generations, which are not there to defend themselves" (Howard 1931). Lal (2009a) proposed ten tenants (laws) of sustainable management (Table 1.3), which also indicate that soil is like a bank account and maintaining a positive balance of key indicators of soil functionality is essential to its sustainable use over time of the finite but an essential resource.

Whereas, the vulnerability of a soil to degradation increase with increase in mean annual temperature (Law 4, Table 1.3), the SOC pool increase with decreases