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Soil Plays a Key Role in the Sustainability of Agricultural Systems

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Abstract

Soil is a complex, dynamic, multiphase system that comprises the surface of the Earth's crust, providing the essential nutrients, water and physical support needed for plant growth responsible for production of food, fiber and energy. Soils also are important for filtering, purification, (re)cycling, storage and transformation of elements and chemicals; climate regulation and carbon sequestration; control of erosion; habitats for living creatures; gene pools; source of raw materials; archaeological heritage, and source of multiple cultural and leisure services. In the face of the growing population, agricultural systems are becoming more intensive and utilizing more of Earth's arable land. Thus, maintaining soil health is critical to the development of sustainable agrosystems, ecosystem services, and worldwide sustainability. As such, major efforts to better understand, model and quantify the services provided by soils to facilitate better management are underway. But, to achieve healthy soil and sustainable ecosystems, better integration and education of all sectors of society is required. The aim of this paper is to review the importance of soil properties, functions and services to educate and encourage broader participation of improving soil health and creating more sustainable ecosystems and better agricultural practices.

Keywords: *Soil Functions; Ecosystem Services; Economic Viability; Population Growth*

Introduction

The term soil comes from Latin *Solum* and denotes support, base, surface [1]. Soil is located in the upper portion of the earth's crust, and is considered the epidermis of the Earth, and thus exchanges matter and energy with the surrounding environment (atmosphere, surface water, organisms, and subsurface) [2]. Soil is the product of the interaction of environmental factors such as climate and organisms with parental material and relief over time; occurring weathering reactions, and the *pedogenesis* [3,4]. Soil is the central interface between the atmosphere, hydrosphere, lithosphere and biosphere, and is a continuous, open, dynamic and complex three dimensional system [5,6].

The soil system has properties and processes originated from the interrelationships that occurred during its genesis and evolution [4,7]. Such properties and processes are reflected in multiple functions performed by the soils, resulting in ecosystem services that generate environmental, social and economic benefits to communities [7,8]. Thus, the soil provides several ecosystem services that are vital to support living beings and society [5,8,9].

Given the relationship between soil functions and ecosystem services, a conceptual understanding to distinguish these terms is needed [8]. Soil functions are products of the multiple complex interactions of natural processes occurring within soils and are the basis for the functioning of terrestrial ecosystems and development of life on earth. Ecosystem services are the direct and indirect contributions and benefits of ecosystem processes and components to human wellbeing, defined based on the human perception, and can alter according to the social context [8,10,11]. Soil functions and ecosystem services as well as examples of both are presented in table 1.

Ecosystem services	
1)	Provision services, provision of food, water, fiber, wood, energy (bioenergy), biologic products;
2)	Regulation services, climatic and erosion regulation, control of floods and diseases;
3)	Support services, soil formation, water and nutrients cycling, production of atmospheric oxygen, provision of habitats;
4)	Cultural services, benefits recreation, ecotourism, educational, aesthetic and spiritual;
Soil functions	
I)	Natural support for plants growth;
II)	Production of food, forage, fiber, wood and bioenergy;
III)	Storage, filtering and transformation of components (carbon and nutrients);
IV)	Water cycling: water purification, plant available water, water infiltration and groundwater recharge;
V)	Nutrient cycling and recycling: storage of nutrients, availability of nutrients to plants;
VI)	Retention, filtering and buffering of organic compounds: pollutants, pesticides and antibiotics;
VII)	Retention, filtering and buffering of inorganic compounds: potentially toxic elements and trace elements;
VIII)	Habitat for living being and genetic resources pool;
IX)	Storage and capture of carbon: soil organic matter, soil microorganisms;
X)	Release and sequester gases from the atmosphere;
XI)	Degradation of pollutants;
XII)	Acidity buffering;
XIII)	Resource raw materials, crafts and cosmetics
XIV)	Engineering medium;
XV)	Archiving cultural;

Table 1: *Soil functions and some relevant ecosystem services.*

Adapted from: Duru., et al. (2015); European Commission (2006); Millennium Ecosystem Assessment (2005); Weil and Brady (2017).

The provision of ecosystem services depends on complex biological, physical and chemical soil properties and their interaction with crops and management techniques [14,15]. The United Nations (UN) Sustainable Development Goals explicitly identify soil resources as being of crucial importance for sustainable development and food security, contributing directly to the goals of "no poverty", "zero hunger", "clean water and sanitation" and "life on land"; and indirectly to the remaining goals [16]. To achieve the goals, the UN promotes the protection of soil resources to achieve the zero land degradation by 2030 [17-19]. Land degradation is caused by erosion, contamination, salinization, desertification, and acidification. Protection of soil resources will create healthy soil[1].

Perception of farmers about ecosystem services provided by soil

The importance of ecosystem services for alleviating poverty and achieving the UN Global Sustainable Development Goals has been increasingly considered in scientific research and policy making [19]. However, more attention must be given to one of the most important actors in a sustainable agricultural system: the farmers.

[1]"Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans" (USDA NRCS).

Through interviews carried out in Germany, Dietze., *et al*. (2019) observed that farmers were knowledgeable about all ecosystem services without calling them by this name. They use at least a very similar understanding of socio-ecological benchmarking in their management decisions. Farmers recognized various factors that have an influence on ecosystem services, as well as their interactions. But, for some services, farmers don't know how their agricultural practices can influence on them.

In the study of Dietze., *et al*. (2019), "Food" was seen as the most important ecosystem service for farmers because it is the basis of farmers' income. While "Buffering and Mediation of Nutrient Release" were ranked as the second most important ecosystem service. Farmers considered "biomass as renewable energy" as a critical service, being in competition with the provision of food and fodder.

Baude., *et al*. (2019) identified an intensification of biomass production from 1750 till today in Europe. The intensification has likely led to a decline in the capacity of the landscape to provide other ecosystem functions, especially regulation of groundwater quantity and quality and a decline of the capacity of the landscape to protect the soil against soil erosion. Intensification also leads to a decrease in biodiversity [20], which results in decreased soil resilience when faced with land use changes stressors [21,22].

Although agricultural production and climate regulation are highly interlinked, farmers do not seem to consider "climate regulation" as a very important soil service. Farmers had only a limited understanding of how they could consider "climate regulation" in their agricultural practices [15]. This indicates how the knowledge of farmers about several ecosystem services and their environmental and economic benefits is still limited.

Soil threats and the economic trade-offs

Soil health is facing many threats worldwide [23,24]. Intensification and competing uses of soils for cropping, pasture, forestry, and urbanization are increasingly impacting the provision of life-supporting services, such as food production, clean water for drinking, flood mitigation, and habitat for plants and animals [23]. Soil erosion is one of the main processes of land degradation and major threat to agricultural soil productivity [18,25]. A global soil erosion assessment carried out by Borrelli., *et al*. (2017) estimated 35.9 Pg yr^{-1} of soil eroded in 2012, and estimations carried out by Panagos., *et al*. (2019) for the European Union suggest that soil loss due only to crop harvesting removes an average of 14.7 million t yr^{-1} per harvest for the period 2000 - 2016.

Farmers are aware of the risk of losing soil, but they do not see erosion as a threat to production capacity of their soils [15]. An explanation for this could be that farmers are already partially implementing soil conservation measures like crop rotation and reduced tillage. However, despite current conservation efforts, soil erosion caused by water reduces global agri-food production by 33.7 million tones, incurring a global annual cost of eight billion US dollars to the global gross domestic product [27].

Globally, 10 to 20% of land is degraded, 52% of agricultural land worldwide is moderately or severely affected by soil degradation, and worldwide 75 billion of tons of arable lands are lost annually as a result of degradation [28]. Much of this degradation stems from management to optimize production and profit. However, sustainable management of soils can have economic returns; it is estimated that 75.6 trillion US dollars can be obtained from the adoption of sustainable practices, as well as the economic rates of return of invested capital can be 12 to 40% from the implementation such practices [28].

A major challenge for society is to improve agricultural production to achieve the increasing demand for food [24] without compromising environmental quality [29]. Any discussion about best management practices in the agriculture sector should consider, at least, the following four dimensions: agricultural practices; sustainable development; agricultural policies; and costs-benefits relations [29]. In some cases, the costs-benefits relations may be a constraint towards implementing best practices, however, there are several examples where the adoption of sustainable approaches is more profitable [29]. Anyway, preserving high-quality soils should be recognized as a policy target that surpasses the sole need for balancing economic interests [16,30].

Conclusion

Besides the multiple ecosystem services delivered by soil, globally, the health of soils is under threat and soil degradation is reducing ecosystem services. Most of the soil degradation causes are provoked by mismanagement that leads to erosion, deforestation, compaction and sealing, pollution, salinization, urbanization and desertification. Pressures on soils and ecosystems have increased dramatically in the past century, resulting in high rates of degradation and loss of biodiversity, compromising billions of people and threatening the future sustainability of the whole planet. The alterations are fast, often not linear, and multi-causal, thus complicating mitigation strategies. To overcome these problems, sustainable management plans must be adopted that preserve and protect soil resources and optimizes ecosystem services. The plans need to include soils and its services in policy and decision-making programs.

Bibliography

1. Kampf N and Curi N. “Conceito de solo e sua evolução histórica”. In: Ker JC Curi, N Schaefer, CE Vidal-Torado P, editor. Pedologia fundamentos. 1st Edition. Viçosa, MG: SBCS (2012): 1-20.
2. Simonson RW. “Concept Of Soil”. *Advances in Agronomy* 20 (1968): 1-47.
3. Buol SW., *et al*. “Soil Genesis and Classification”. 6th Edition (2011): 556.
4. Schaetzl R and Anderson S. “Soils Genesis and Geomorphology”. Cambridge: United States of America by Cambridge University Press (2005): 791.
5. Bouma J. “Implications of the Knowledge Paradox for Soil Science”. *Advances in Agronomy* 106 (2010): 143-171.
6. Weil RR and Brady NC. “The Soils Around Us. In: The Nature and Properties of Soils”. 15th edition. Pearson Education Limited (2017): 19-50.
7. Greiner L., *et al*. “Soil function assessment: review of methods for quantifying the contributions of soils to ecosystem services”. *Land Use Policy* 69 (2017): 224-237.
8. Wiesmeier M., *et al*. “A systemic approach for modeling soil functions”. *Soil* 4.1 (2018): 83-92.
9. Dominati E and Mackay A. “An Ecosystem Services Approach to the Cost of Soil Erosion and Value of Soil Conservation”. New Zealand (2013).
10. Duru M., *et al*. “How to implement biodiversity-based agriculture to enhance ecosystem services: a review”. *Agronomy for Sustainable Development* 35.4 (2015): 1259-1281.
11. Hauck J., *et al*. “Benefits and limitations of the ecosystem services concept in environmental policy and decision making: Some stakeholder perspectives”. *Environmental Science and Policy* 25 (2013): 13-21.
12. European Commission E. “Thematic Strategy for Soil Protection (COM 2006, 231 final)”. Brussels (2006).
13. Millennium Ecosystem Assessment. “Ecosystems and human well-being: biodiversity synthesis. Millennium ecosystem assessment”. Washington, DC (2005).
14. Adhikari K and Hartemink AE. “Linking soils to ecosystem services - A global review”. *Geoderma* 262 (2016): 101-111.
15. Dietze V., *et al*. “Farmers consideration of soil ecosystem services in agricultural management - A case study from Saxony, Germany”. *Land Use Policy* 81 (2019): 813-824.
16. Zambon I., *et al*. “Soil Matters? A Multivariate Analysis of Socioeconomic Constraints to Urban Expansion in Mediterranean Europe”. *Ecological Economics* 146 (2018): 173-183.
17. Keesstra SD., *et al*. “The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals”. *Soil* 2.2 (2016): 111-128.
18. Panagos P., *et al*. “Soil loss due to crop harvesting in the European Union: A first estimation of an underrated geomorphic process”. *Science of the Total Environment* 664 (2019): 487-498.
19. Fortnam M., *et al*. “The Gendered Nature of Ecosystem Services”. *Ecological Economics* 159 (2019): 312-325.

20. Baude M., *et al*. "Land use change in an agricultural landscape causing degradation of soil based ecosystem services". *Science of the Total Environment* 659 (2019): 1526-1536.
21. Plaas E., *et al*. "Towards valuation of biodiversity in agricultural soils: A case for earthworms". *Ecological Economics* 159 (2019): 291-300.
22. Babin D., *et al*. "Impact of long-term agricultural management practices on soil prokaryotic communities". *Soil Biology and Biochemistry* 129 (2019): 17-28.
23. Drobnik T., *et al*. "Soil quality indicators - From soil functions to ecosystem services". *Ecological Indicators* 94.1 (2018): 151-169.
24. FAO. "The state of the world's land and water resources for food and agriculture (SOLAW) - Managing systems at risk". Rome and Earthscan, London (2011).
25. Montanarella L. "Agricultural policy: Govern our soils". *Nature* 528.7580 (2015): 32-33.
26. Borrelli P., *et al*. "An assessment of the global impact of 21st century land use change on soil erosion". *Nature Communications* 8.1 (2017).
27. Sartori M., *et al*. "A linkage between the biophysical and the economic: Assessing the global market impacts of soil erosion". *Land Use Policy* 86 (2019): 299-312.
28. ELD. "Economics of Land Degradation Initiative: Report for policy and decision makers". Reaping economic and environmental benefits from sustainable land management. German (2015).
29. Martinho VJPD. "Best management practices from agricultural economics: Mitigating air, soil and water pollution". *Science of the Total Environment* 688 (2019): 346-360.
30. USDA NRCS. Soil Health.

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