Strategies to Protect and Conserve Soil Resources

By Ana Wingeyer and Fernando O. García

The growing global demand for food, feed, fiber, biofuels, and biomaterials has placed a high level of pressure on agro-ecosystems in which soils are a key non-renewable resource. Soil management practices should address this global demand by providing not only for agricultural productivity, but also for protection and conservation of soils. Best management practices (BMPs) for soil management should be socially acceptable, economically viable and environmentally sustainable.

Land and soil management practices affect soil processes and properties at different scales of intervention (UNEP, 2014). The effectiveness of these practices for meeting various soil management needs should be evaluated simultaneously at the field/farm, watershed and regional/global scales.

Adoption of **conservation tillage practices**, including no-tillage (NT), has been a leading practice in South America. Common benefits of NT include better economic results, improved or more stable yields through improved water use efficiency, erosion control, saving of fuel and labor/time, improved soil biological activity, among others. No-tillage has been adopted in approximately 70 to 90% of the field crop area in Paraguay, Brazil, Argentina, Bolivia, and Uruguay (**Table 1**).

Table 1. Area under no-tillage in countries of South America (Derpsch and Friedrich, 2009).

Country	No-tillage area (2008-09), ha	% of total cropped area
Brazil	25,502,000	70
Argentina	19,719,000	70
Paraguay	2,400,000	90
Bolivia	706,000	72
Uruguay	655,100	82

However, adoption of NT without the implementation of necessary water and wind erosion controls (e.g., windbreaks, terraces), crop rotations, balanced nutrition, and other practices would result in a failure to sustainably fulfill stakeholder expectations for agricultural productivity and soil protection.

Soybean monocultures provide less C inputs and promote increased soil organic C (SOC) decomposition rates than **crop rotations** with corn or sorghum, which can lead to a loss of 3 t SOC/ha/y under soybean monoculture regardless of NT implementation (Huggins et al., 2007). Crop rotations would provide for soil protection through continuous soil cover; diversification in crops and rooting patterns and depth; microbial populations and activity; return of residues; improved water and nutrient use; reduction in diseases and pests; more efficient weed control; and even better social and working conditions. These effects of crop rotations and cover crops have been verified through indicators such as SOC, biological activity, water use efficiency, and soil physical parameters. Intensification of land use (e.g., reduction of fallow period, use of double crops), cover crops and inclusion of pasture in the crop rotation is associated with larger SOC stocks and better aggregate stability under NT (Novelli et al., 2013). The increase of the frequency of a given crop in the rotation (i.e., towards monoculture) has negative impacts on both SOC stocks and aggregate stability (**Figure 1**). Soybean frequency index was the most closely associated index to the reduction of SOC stocks and aggregate stability.

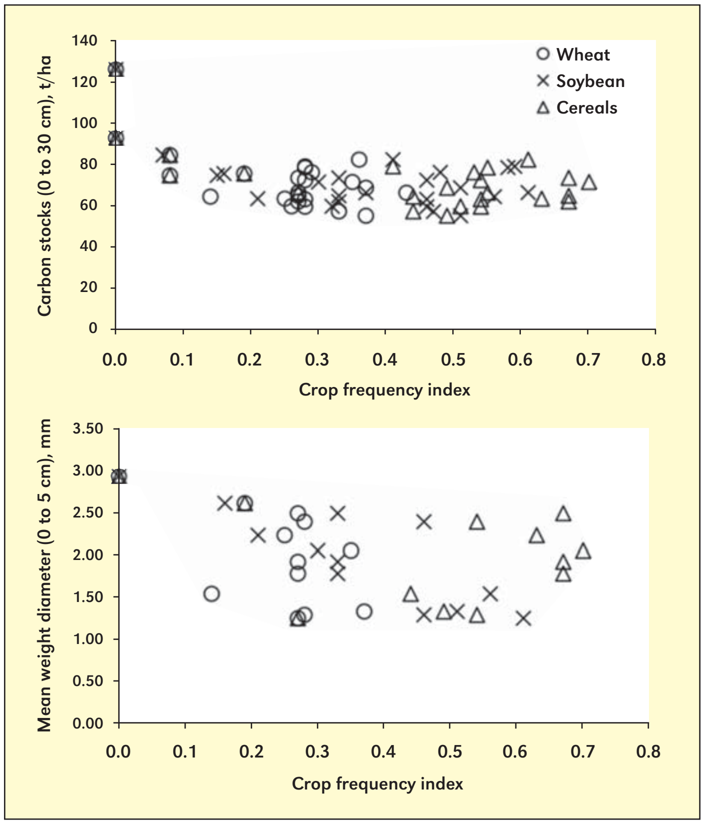

Figure 1. Soil organic carbon stocks in the 0 to 30 cm depth of a Vertisol and a Mollisol (top) and mean weight diameter of soil aggregates in the 0 to 5 cm depth of a Mollisol (bottom) as a function of crop frequency in the rotation under no-till (Adapted from Novelli et al., 2013).

Incorporation of **cover crops** in between cash crops would emphasize many of the benefits indicated for crop rotations. Soil protection from wind and water erosion, reduction of nutrient losses through runoff, sediment transport, leaching or gaseous losses, incorporation of N through biological fixation by legumes, soil biological activity and SOC sequestration are among the most frequently cited processes that benefit with the use of cover crops.

Residue management is a key component of ecosystem services at different scales (**Figure 2**). Agricultural productivity, soil and water conservation, and soil quality are positively impacted by residue retention. On average, crop residues contain 40% C, 0.8% N, 0.1% P, and 1.3% K, providing food and habitat for soil biota. Removal of crop residues for use as biofuel, feed, or other competing purposes increases nutrient

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; C = carbon; mean weight diameter = an index of soil aggregation status.

Soybeans planted directly into preceding maize straw residue at María-Teresa, Santa-Fe, Argentina.

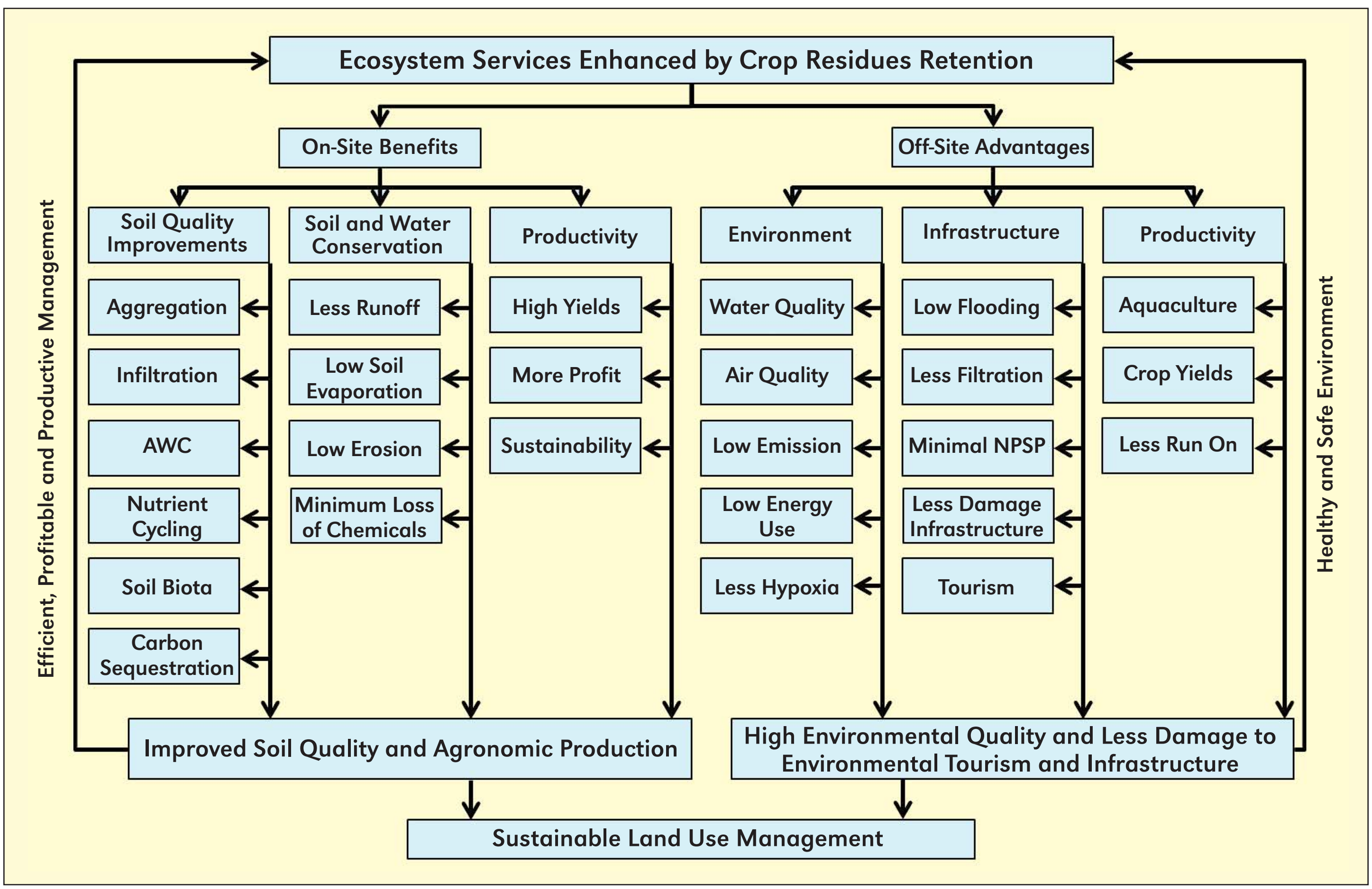

Figure 2. Agronomic productivity and environmental quality impacts of crop residues retention. AWC = available water capacity, NPSP = non-point source pollution (Adapted from Lal, 2008).

removal by agriculture and exposes soil to erosion and degradation, with multiple off-site adverse impacts on soil, air and water quality. Thus, soil amendment with crop residue is necessary to enhance/maintain soil quality and sustain agronomic productivity.

Balanced nutrition contributes to agricultural productivity and soil health. **Figure 3** shows the effect of balanced nutrition on microbial activity and glomalin concentration. Glomalin is a substance that accumulates in the cell walls of soil fungi and contribute to soil aggregate formation. Implementation of 4R Nutrient Stewardship (i.e., application of the right nutrient source at the right rate, time and place) would also help avoid, or decrease, externalities associated to water or air pollution.

Protection and conservation of soil resources through appropriate management techniques is essential to sustainable agro-ecosystems, and to fulfill the global demands for food, feed, biomaterials, and biofuels. Practices, as the ones described above, would contribute to this goal. BC

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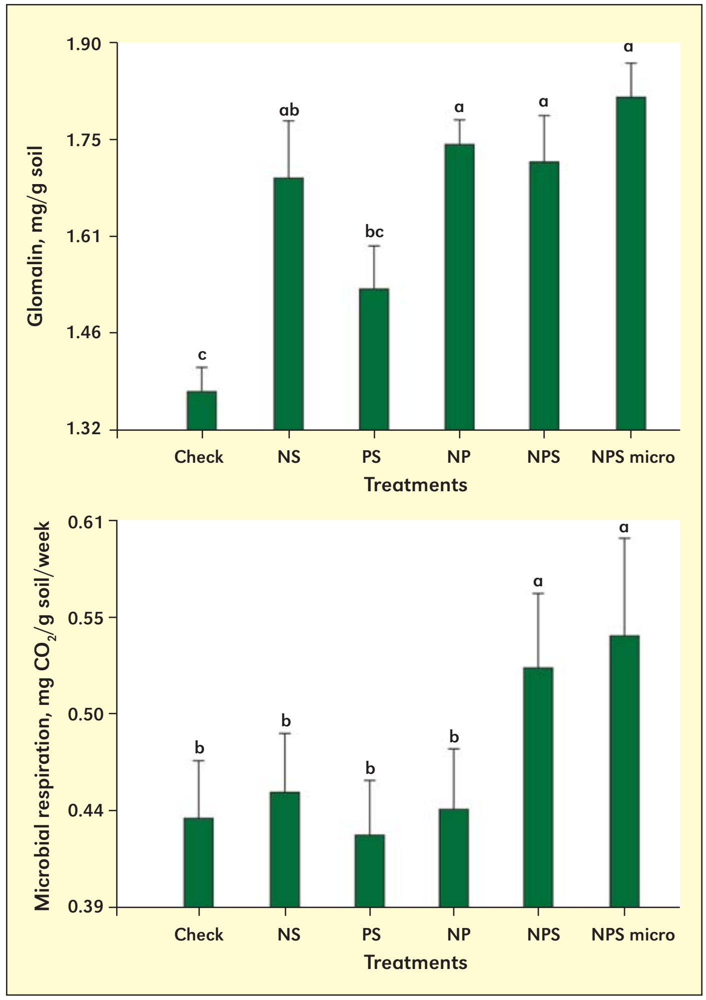

Figure 3. Soil glomalin concentration (top) and microbial activity (bottom) under different fertilization treatments in southern Santa Fe province, Argentina (Grümberg et al. 2012). Letters above columns denote significant differences between treatments at p = 0.05.

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