FEATURE

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Ten tenets of sustainable soil management

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From the dawn of settled agriculture 10 to 13 millennia ago to the onset of the industrial revolution ~1750, principal soil functions were (1) medium for plant growth, (2) foundation for buildings and civil structures, and (3) raw material for industry (e.g., bricks). Considering the serious global issues of the 21st century, additional soil functions include (4) sequestering carbon to mitigate climate change, (5) denaturing and filtering pollutants, (6) disposing of industrial and urban wastes, (7) being an archive of human and planetary history, (8) being repository of germplasm and biodiversity, (9) maintaining and strengthening cycles of water and elements (N, P, S) and moderating impacts of natural and anthropogenic perturbations on the environment, and (10) maintaining aesthetic and cultural and artistic values of landscape and ecosystem and preserving cultural heritage. Of these 10 soil functions, sustaining and enhancing net primary productivity (NPP) and agronomic yields to meet the demands (for food, feed, fiber, and fuel) of the growing world population is an urgent issue of global importance. Equally important are the concerns about climate change, water quality, and biodiversity.

It is in this context that the importance of sustainable management of world soils cannot be overemphasized. The issue is even more significant now than ever before because world soil resources are finite; unequally distributed among ecoregions; fragile and prone to degradation by misuse, mismanagement, and threat of global warming; and nonrenewable over the human timescale of generation(s). Thus, sustainable management of this precious resource must be based on fundamental tenets:

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1. ***Causes of Soil Degradation.*** The biophysical process of soil degradation is driven by economic, social, and political forces. The effectiveness of managing biophysical processes in minimizing degradation risks and enhancing restoration mechanisms depends on addressing the human dimensions that affect land misuse, soil mismanagement, and prevalence of extractive farming practices.
2. ***Soil Stewardship and Human Suffering.*** When people are poverty stricken, desperate and starving, they pass on their sufferings to the land. The stewardship concept is important only when the basic needs are adequately met. A sermon about the virtues of saving a tree falls on deaf ears when there is no fuel for cooking the family meal.
3. ***Nutrient, Carbon, and Water Bank.*** Analogous to a bank account, it is also not possible to take more out of a soil than what is put in it without degrading its quality. In addition to the amount taken out, soil quality also depends on the rate, timing, method, and form of what is being extracted or replaced. Thus, managed ecosystems are sustainable in the long term if the output of all components produced balance the input into the system.
4. ***Marginality Principle.*** Marginal soils cultivated with marginal inputs produce marginal yields and support marginal living. The sustainable soil management strategy is to cultivate the best soils by best management practices to produce the best yields so that surplus land can be saved for nature conservancy.
5. ***Organic Versus Inorganic Source of Nutrients.*** Plants cannot differentiate the nutrients supplied through inorganic fertilizers or organic amendments. Rather than an "either/or" question, it is a matter of logistics and practicality in making nutrients available in sufficient quantity, appropriate form, and at the critical time needed for optimum crop growth and desired yields.
6. ***Soil Carbon and Greenhouse Effect.*** Mining carbon has the same effect on global warming whether it is through mineralization of soil organic matter for releasing nutrients through plowing and extractive farming or it is through burning fossil fuels (coal, gas, oil), using petrol-based products, or draining peat soils.
7. ***Soil as Sink for Atmospheric CO_2.*** World soils can be a major sink for atmospheric CO_2 and CH_4 through conversion to a restorative land use adoption of recommended management practices that lead to positive carbon and nutrient budgets. Filling the carbon sink capacity of the pedosphere (~3 Pg C y^{-1}; ~1 Pg C y^{-1} each in soils of croplands, grazing lands, and degraded/desertified lands) being economic and a natural process, has numerous ancillary benefits. While advancing food security and improving water quality, carbon sequestration in the pedosphere also mitigates climate change.
8. ***Soil Versus Germplasm.*** Even the elite varieties, developed through biotechnology and genetic engineering, cannot extract water and nutrients from any soil where they do not exist. The yield potential of improved germplasm can be realized only if grown under recommended management practices of soil, water, and crop husbandry.
9. ***Engine of Economic Development.*** Being the foundation of agrarian societies, sustainable management of soils is the engine of economic development, political stability, and transformation of rural communities in developing countries.
10. ***Traditional Knowledge and Modern Innovations.*** It is important to build upon the traditional knowledge and avail the benefits of modern innovations. It is not an "either/or" scenario. Modern science must synthesize the traditional knowledge and build upon it. Those who refuse to use modern science to address urgent global issues must be prepared to endure more suffering.

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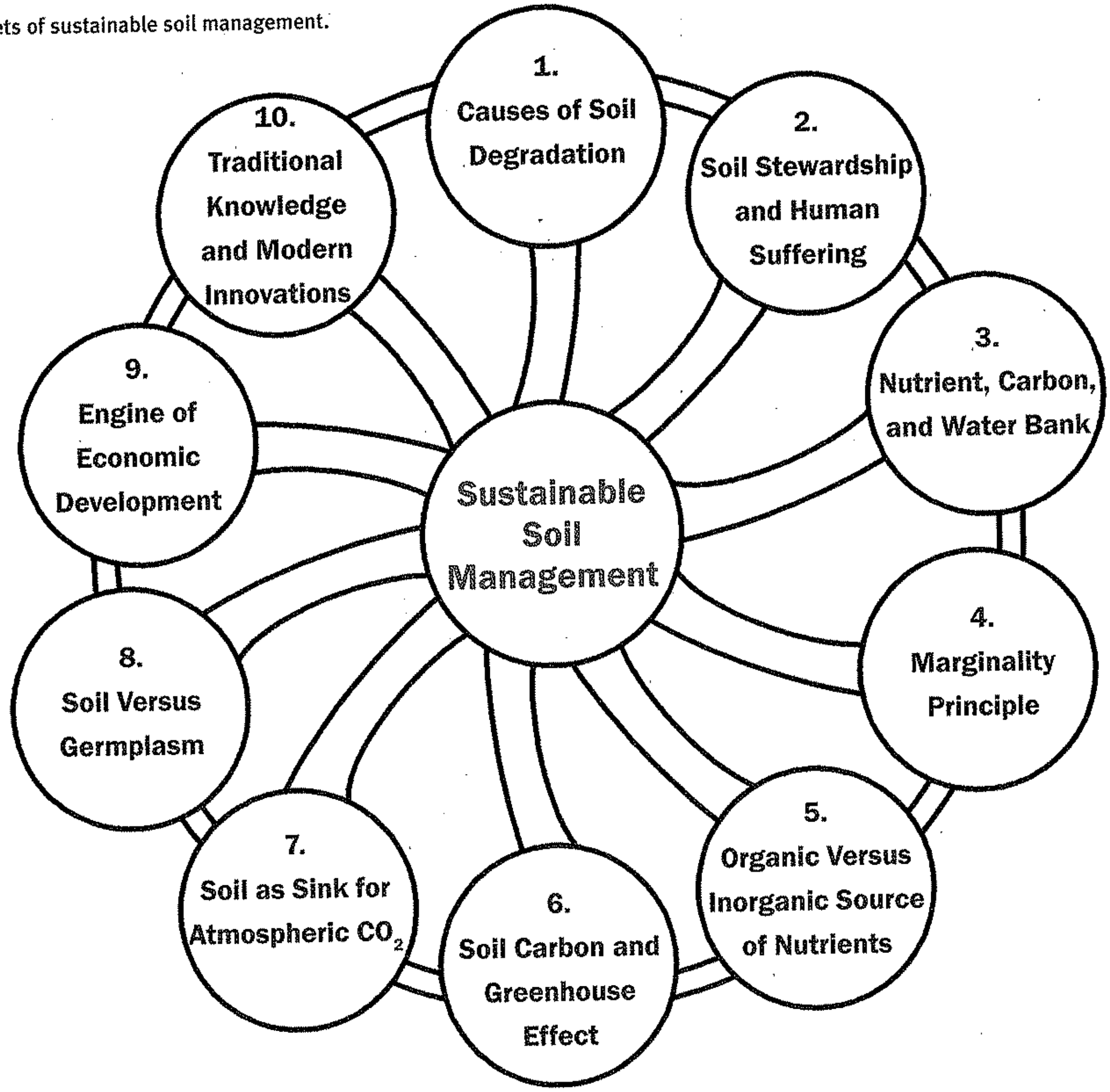

The demands on world soil resources for biofuel, food production, and nature conservancy must be objectively assessed in view of the 10 tenets of sustainability (see figure). It is only through a strict observance of these basic laws that it would be possible to meet the needs of the present population of 6.75 billion and of the future population of ~10 billion by 2100. While these laws have wider applicability, technologies are soil and site specific. These technological innovations, as promising and exciting as they seem, must be used prudently; using "technology without wisdom" can be a serious folly.