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Editorial

World soils and global issues

Human welfare is intimately lined to soil quality and its management. Principal global issues of the 21st century, whose solution to a great extent depends on sustainable management of world soils, include food insecurity and hidden hunger, global warming and carbon sequestration, water scarcity and eutrophication, soil degradation and desertification, energy scarcity and biofuels, excessive urban and industrial wastes, and environmental pollution. There exists a direct link between these global issues and sustainable use of world's finite and fragile soil resources, which must never be taken for granted. Scientists in Soil & Tillage Research and members of ISTRO may need to consider the following issues in prioritizing their long-term research plans.

1. Global issues

Global issues of the 21st century include: (a) a population of 6.5 billion and increasing by 1.3%/yr (Fischer and Heilig, 1997; Cohen, 2003), (b) per capita cropland area of 0.22 ha and decreasing to <0.07 ha by 2025 for at least 30 densely populated countries (Engelman and LeRoy, 1995a,b), (c) land area of about 2 billion ha (Bha) prone to degradation processes and increasing by 5–10 million ha (Mha)/yr (Oldeman, 1994), (d) per capita grain consumption of 300 kg/yr and decreasing (Kondratyev et al., 2003) especially in countries of sub-Saharan Africa, (e) renewable fresh water supply of <1000 m^3 for 30 countries with population in 58 countries prone to water stress by 2050 (Vörösmarty et al., 2005; Gardner-Outlaw and Engelman, 1997; Gleick, 2003), (f) atmospheric CO_2 concentration of about 380 ppm and increasing by 0.5% or 1.8 ppm/yr (WMO, 2006), and (g) global energy use of 435 Quads (1 Quad = 10^{15} BTU)/yr and increasing by 1.5%/yr between 2001 and 2025 (Weisz, 2003; Vorholz, 2006; EIA, 2004). These issues cut across national/political borders, because people and nature are inextricably linked irrespective of political boundaries. However, a significant part of solution to these issues, which must be objectively and urgently addressed, lies in the judicious and sustainable management of world's soil resources. Achieving food security for 850 million food-insecure population (Rosegrant and Cline, 2003), reducing hidden hunger of 3.7 billion suffering from nutrient/elemental deficiencies caused by dependence on food grown in impoverished and degraded soils, and reducing risks or respiratory and infectious diseases spread by dust blown from desertified lands and water contaminated by non-point source pollution are achievable through improvements in soil quality by adoption of recommended tillage and soil management practices.

2. World's food demand

Almost the entire increase in future population will occur in developing countries, where soil and water resources are already under great stress. Of the projected 3.4 billion increase in population between 2000 and 2050, 2 billion will occur in Asia and 1.4 billion in Africa (Fischer and Heilig, 1997; Cohen, 2003). Per capita crop land availability by 2025 will be only 0.03 ha in Egypt, 0.05 ha in Bangladesh, 0.06 ha in China and 0.07 ha in Pakistan (Engelman and LeRoy, 1995a,b; Brown, 2004). Soils of developing countries are also prone to degradation, which affect 2.6 billion people, 73% of range lands in dry lands, 47% of marginal rain fed croplands, and 2 Bha of total land worldwide (Oldeman, 1994). Thus, soil management strategies will have to be identified to meet the food demands for additional 3.4 billion people and the likely change in food habits of population in emerging economies (e.g., India, China). Average grain yields of cereals in developing countries will have to be increased

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from 2.6 Mg/ha at present to 3.6 Mg/ha by 2025 and 4.3 Mg/ha by 2050 to increase global cereal production from 1270 million Mg (Tg) now to 1700 Tg in 2025 and 2000 Tg in 2050 (Wild, 2003). Likely change in dietary habits would necessitate increasing cereal yields in developing countries to 4.4 Mg/ha in 2025 and 6.0 Mg/ha in 2050 (Wild, 2003). Such production targets can be met through adoption of land-saving technologies and agricultural intensification which involve, first and foremost, restoration of degraded soils, improvement of soil structure and enhancement of soil quality through improving soil organic matter reserves, conservation of water in the root zone and control of soil erosion, and adoption of genetically improved varieties grown in diverse cropping/farming systems. And then, and only then, a judicious use of fertilizers is needed to create a positive nutrient balance and improve soil fertility (Sanchez, 2002). During the past 10,000 years, since the dawn of settled agriculture, world's population has doubled 10 times from less than 10 million to 6.5 billion and will stabilize at about 10 billion mark (Annonymous, 2005). It was the increase in agricultural production, especially during the second half of the 20th century, which made this increase in population possible and proved that the Malthusian concept was wrong. Yet, the human population will never double again, and Malthus will be proven wrong one more time and for the last time because increase in food security, improvement in human health and increase in standards of living will eliminate the need for having more children by impoverished farming communities of the developing countries, through adoption of improved soil management technologies. Indeed world soils have the capacity to feed 10 billion by 2050, not only for an adequate amount of calories but also for nutritious and healthy diets which would eliminate the hidden hunger.

3. Energy use and biofuels

Primary energy consumption worldwide increased 40 times between 1860 and 2005 to 435 Q/yr, and is increasing by 1.5%/yr to reach 625 Q in 2025 (Weisz, 2003; Vorholz, 2006; EIA, 2004). The U.S. energy consumption is about 25% of the world's energy use, of which biofuels presently account for 3.5 Q/yr (Wiesz, 2003). Ethanol production in the U.S. was about 4 billion gallons in 2005, and the U.S. 2005 Energy Bill mandates a 3.5 billion gallon increase in the production of biofuels by 2012 (Energy Policy Act, 2005). However, crop residues (corn, wheat, barley) are neither a waste (Lal, 2004a) nor a viable source of lignocellulosic feedstock for producing ethanol. Using crop residues as soil amendments is essential to conserving soil, reducing water runoff and minimizing non-point source pollution, improving soil quality by strengthening nutrient cycling, and for sequestering carbon (C) to reduce net emission of CO_2 (Lal, 2004a). It is important, therefore to identify new lands to grow 1 Pg (gigaton) of biomass for the U.S. and 4–5 Pg/yr for the world. One Mg of lignocellulosic biomass is equivalent to 250–300 L of ethanol, 16 million BTUs or about 2 barrels of diesel (Lal, 2004a). The energy return on investment (EROI) of biofuel needs to be systematically assessed, and optimized for envisaged biofuel/energy plantations. Biofuel plantations, comprising of short rotation woody perennials (e.g., poplar) and warm season grasses (e.g., switch grass), are needed to produce the feedstock for biofuel production, including natural vegetation (Tilman et al., 2006). A large quantity of biosolids as municipal solid waste (114 Tg/yr), and by-products of animal (132 Tg/yr) and food-processing industry in the U.S. can also be used as biofuel feedstock, while the residues are returned to the soil as compost and biofertilizers (USEPA, 2007).

4. Soils and climate change

World soils, prudently managed for achieving food security and producing biofuel feedstocks, can also mitigate climate change by absorbing atmospheric CO_2 and converting it into humus through the process of soil C sequestration. World soils constitute the third largest global C pool (1500 Pg of organic C and 950 Pg of inorganic C to 1-m depth), which is about 3.3 times the atmospheric pool (760 Pg) and 4.5 times the biotic pool (560 Pg) (IPCC, 1999). The atmospheric pool has increased from 280 ppm in around 1750 to 380 ppm in 2006, and is increasing at the rate of 3.3 Pg C/yr due to fossil fuel combustion (7.3 Pg C/yr) and land use conversion including tropical deforestation and soil cultivation (1.7 Pg C/yr) (WMO, 1999). While the ocean absorbs 2.3 Pg C/yr, the differences or the so-called missing sink is believed to be terrestrial ecoregions including world soils (IPCC, 2001). The C sink capacity of world soils is about 1 Pg C/yr, which can annually off-set 0.47 ppm of CO_2 increase in the atmosphere (IPCC, 1999; Lal, 2004b, 2005). Increasing soil C pool is also essential to improving water quality because soil is a biomembrane which filters and denatures pollutants. Soil quality restoration improves quality and quantity of water resources within a watershed (Lal, 1997).

Indeed, C sequestration in soils is a win–win strategy. With 850 million food-insecure people, mostly

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in sub-Saharan Africa and South Asia, improving soil quality is essential to advancing food security. Increasing soil organic carbon pool by 1 Mg/ha yr in the root zone, which is a challenging task for soil scientists and land managers, can increase production of food grains by 30–40 Tg/yr (million t and those of roots and tubers (cassava, yam, sweet potatoes) by 8–10 Tg/yr (or million t/yr) (Lal, 2006). Such increases, challenging as they may be, can meet the current and projected food deficits in sub-Saharan Africa and else where in the world.

5. Water resources

The per capita renewable fresh water supply is rapidly declining, especially in dry and hot climates. There may be 1–3 billion people experiencing water stress by 2025 (Gardner-Outlaw and Engelman, 1997). As many as 2.3 billion people in the year 2000 lived in river basins with water stress or in regions where the per capita annual water supply was $<1700\ m^3$ (Johnson et al., 2001). Of these, 74% (1.7 billion) resided in river basins with per capita renewable supply of $<1000\ m^3/yr$. The low per capita annual water supply in many countries is indicative of a strong need for a careful planning and judicious use of this scarce but precious resource (Johnson et al., 2001). In many cases, fossil/non-renewable water is also being depleted. Yet, the water use efficiency is low especially in outdated/primitive flood irrigation system widely practiced in South Asia, China, Egypt and elsewhere in developing countries.

Pollution and eutrophication caused by agricultural runoff remains to be a serious issue. The global pesticide use has drastically increased from 2.6 Tg (million t) in 1990 to 3.75 Tg in 2000 and is projected to be 15.6 Tg by 2020 and 25.1 Tg by 2050 (Tilman et al., 2001). A large portion of these chemicals are used on agricultural land, and along with fertilizers, are principal contaminants of natural waters.

Water scarcity will also be exacerbated by the change in diet of the large population in emerging economies (e.g., India, China). The water requirement per kg of animal-based diet is 3–4 times more than for chicken-based and 15–20 times more for beef-based than for cereal-based.

Improving water use efficiency of agricultural/livestock production systems, decreasing non-point source pollution, conserving soil and water resources and restoring degraded soils and ecosystems are important strategies of enhancing and improving supplies of fresh water resources in river basins with severe deficits.

6. World soils and the modern civilization

For both issues, food security and environment improvement, the global future lies in soils beneath our feet. In the old Roman Empire, all roads led to Rome. In modern civilization, all roads lead back to the soil (Hambridge, 1938). We have to go back to our roots to effectively address these global issues through sustainable management of world soils, which must never be taken for granted. Soils must be used, improved and restored for generations to come. Scientists in Soil & Tillage Research and members of ISTRO can make a difference in effectively addressing these issues through development of soil-specific technology for predominant global ecoregions. The importance of soil tillage and surface management practices on these issues cannot be over-emphasized.

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