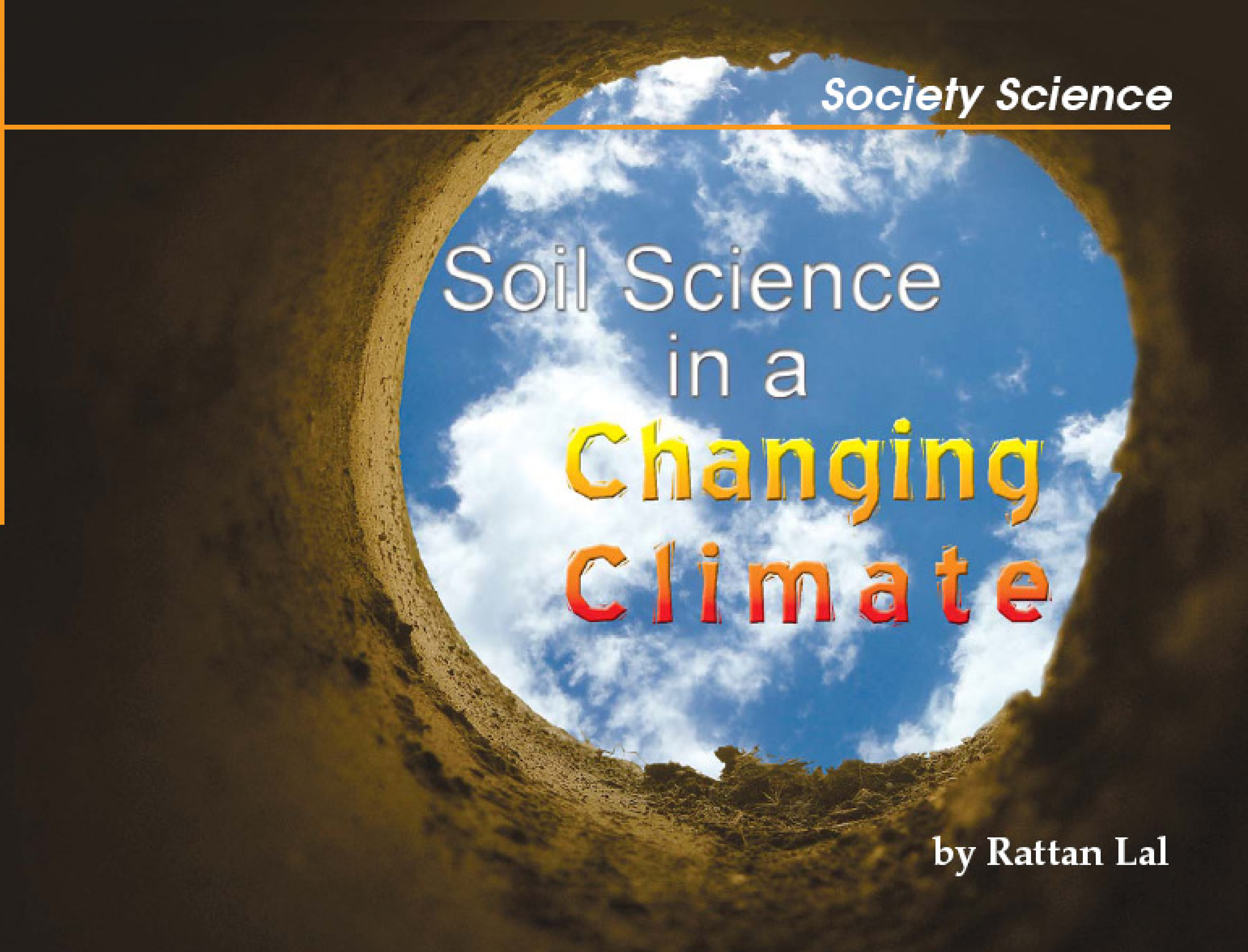
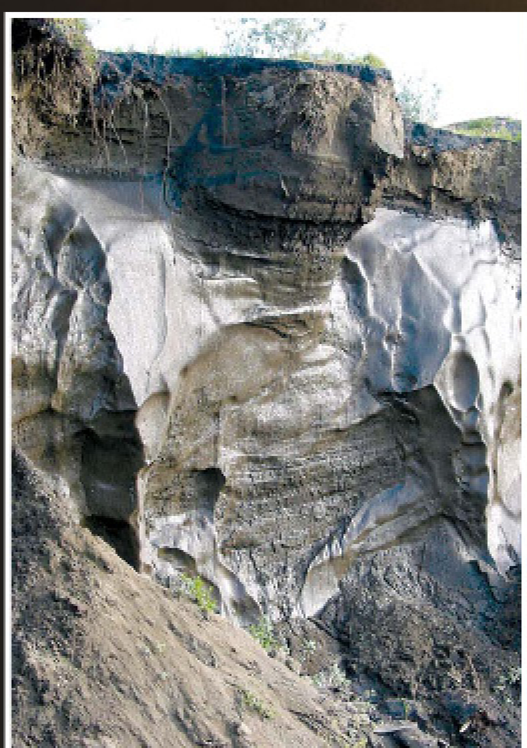
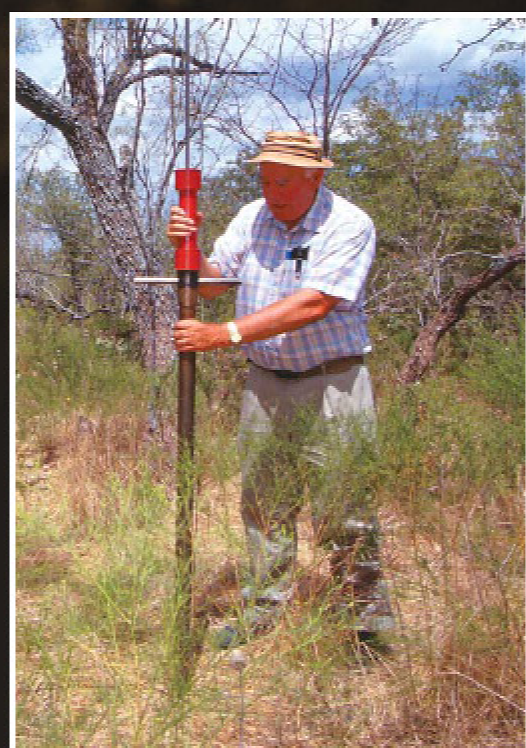


Soil Science in a Changing Climate

by Rattan Lal



LEFT: Permafrost soil thaws in this photo shot in northeastern Siberia in July 2005, with the uppermost thawed soil contrasting with the still-frozen unthawed soil beneath. Scientists have estimated that nearly 400,000 square miles of permafrost soil in this region contain nearly 100 times more carbon than is released by the burning of fossil fuels each year. That means it could become a potent and unstoppable contributor to global warming if it continues to thaw. Photo by Edward "Ted" Schuur (University of Florida). RIGHT: To determine the influence of woody plants on soil carbon storage, ecologist Hyrum Johnson takes a 10-foot soil core sample in grassland invaded by honey mesquite. Photo by Scott Bauer (USDA-ARS).



From 1950 to 2000, the number of people fed by a single U.S. farmer increased from 19 to 129 (Bond, 2000). Global food grain production grew from 630 million tons (Mt) in 1950 to 1,079 Mt in 1970, approaching 2,000 Mt in 2000 (Kondratyev et al., 2003). The world grain production per person increased from 250 kg in 1950, when the population was 2.5 billion, to 303 kg in 2000 when the population was 6 billion. Globally, wheat yield increased by 2.92% yr^{-1} from 1961 to 1979 and 1.78% yr^{-1} between 1980 and 2000, keeping ahead of population growth. Similar gains were made in production of corn, rice, and other food crops. Soil scientists have contributed greatly with studies on seedbed preparation including conservation tillage, soil-specific application of fertilizer for different crops, and cropping systems that include integrated nutrient management, on-farm water management including surface and subsurface drainage and supplemental irrigation (e.g., fertigation), and erosion control measures among others.

Today, there are new and emerging issues of global significance that soil scientists must address. These issues, which transcend production agriculture and deal with environmental problems that cut across disciplines, include:

1. increasing risks of global warming,
2. increasing energy demands,
3. increasing urban and industrial wastes,
4. deteriorating water quality,
5. perpetual food insecurity in Sub-Saharan Africa (SSA), south Asia, and elsewhere in developing countries,
6. exacerbating risks of soil degradation under conditions of unstable political/economic conditions, and
7. widening gap between the traditional graduate/undergraduate curricula and the societal needs of trained professional in soil sciences.

Soil scientists need to be proactive in addressing these emerging issues.

Global Warming and Soil Carbon

Global surface temperatures have increased by 0.6 ± 0.2°C during the 20th century and are projected to increase by 1.5 to 5.8°C by the end of the 21st century (IPCC, 2001). The observed and projected global warming is attributed to an increase in atmospheric concentration of CO_2, CH_4, and N_2O. The concentration of CO_2 has increased by 35% from 280 ppm in

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Abbreviations: MSW, municipal solid waste; SOC, soil organic carbon; SOM, soil organic matter; SSA, Sub-Saharan Africa.

1750 to 377 ppm in 2004 and is presently increasing at the rate of 0.47% yr^{-1} or 1.8 ppm yr^{-1} (WMO, 2006). World soils constitute the third largest global pool comprising of 1,550 Gt (1 Gt = gigaton = 1 Pg = petagram = 10^{15} g = 1 billion metric tons) of soil organic carbon (SOC) and 950 Gt of soil inorganic carbon to a 1-m depth (Batjes, 1996). The soil C pool of 2,500 Gt is 3.3 times the biotic pool and 4.5 times the atmospheric pool and plays an important role in the global C cycle. There are three sources of CO_2 enrichment in the atmosphere: land use change, fossil fuel combustion, and cement manufacturing. Land use change, deforestation, biomass burning, and soil cultivation have been the sources of atmospheric CO_2 since the dawn of settled agriculture and domestication of plants (Ruddiman, 2003). Fossil fuel combustion has increasingly become the source of CO_2 since the beginning of agriculture and the onset of the industrial revolution around 1750. Historic, anthropogenic emissions from land use change are estimated at 320 Gt during the preindustrial era compared with 136 ± 55 Gt during the postindustrial era (Table 1). Of this, 78 ± 12 Gt of C is estimated to have been contributed through decomposition of soil organic matter (SOM) reserves. Emissions contributed by world soils (78 ± 12 Gt) include those exacerbated by accelerated soil erosion, estimated at 26 ± 6 Gt (Lal, 1999). The contemporary global C budget indicates the strong effect of land use change, deforestation, and soil cultivation even during the early part of the 21st century (Table 2). Indeed, the so-called missing C, estimated between 1.8 and 2.4 Gt C yr^{-1}, is supposedly a terrestrial sink including soils (Table 2). Of the total 8.7 Gt of C emitted by human activities, 6.5 Gt (about 75%) is absorbed by the terrestrial sinks (Table 2) in which soil sequestration plays an important role. Lal (2004a, 2004b) estimated the C sink capacity of the world soils at 0.6 to 1.2 Gt yr^{-1}, or about 11% of the emissions by fossil fuel combustion. Thus, the global C budget shown in Table 2 is a gross approximation because it does not list several unknown sources (e.g., soil erosion). Lal (2003) estimated that accelerated soil erosion is a net source of about 1 Gt C yr^{-1}. The erosion-induced emission is not accounted for in the data shown in Table 2, although the unknown/missing sink is often presumed to be the sediment-borne C transported into the oceans and depositional sites (Renwick et al., 2004; Smith et al., 2001; Stallard, 1998; Van Oost et al., 2004; Lal et al., 2004a, 2004b). Indeed, management of world soils to sequester atmospheric CO_2 will remain an important strategy among the technological options to mitigate global warming for generations to come.

Table 1. Estimates of anthropogenic CO_2 emission by agricultural activities and the industrial revolution (IPCC, 2001; Lal, 1999; Ruddiman, 2003, 2005).

Eras	Emission
	Gt
Preindustrial	320
Postindustrial	
Fossil fuel	270 ± 30
Land use	136 ± 55
Soil	78 ± 12
Erosion	26 ± 6

Table 2. Contemporary global C budget and the importances of terrestrial C sinks (IPCC, 1999; WMO 2006).

Parameter	1980s	1990s	2000s
		Pg C/yr	
Sources			
Fossil fuel combustion	5.4	6.3	7.1
Land use change	1.7	1.6	1.6
Total	7.1	7.9	8.7
Sinks			
Atmosphere	3.3	3.2	3.3
Ocean	1.9	1.7	2.2
Land	0.2	1.4	1.4
Total known sinks	5.4	6.3	6.9
Estimated unknown terrestrial sinks	1.7	1.6	1.8

Global Energy Demand and Soil Resources for Biofuel Production

The world energy consumption increased 40 times between 1860 and 2005. The global energy consumption was 207 Q (1 Q = quad = 10^{15} BTU = 2.5×10^{14} kcal = 1.06×10^{18} joules) in 1970, 285 Q in 1980, 348 Q in 1990, 400 Q in 2000, and 422 Q in 2003 (EIA, 2004a, 2004b). The projected world's energy demand is increasing at the rate of 2.23% yr^{-1} and will be 471 Q in 2010 and 623 Q in 2025. Energy consumption in the U.S. is about 100 Q yr^{-1}, or about 23.7% of the global energy use (Weisz, 2004). The increasing energy demand is being met through increased fossil fuel consumption. The oil demand (million barrels day^{-1}) in 2000 and 2025, respectively, was (and will be) 20.00 and 21.11 (+6%) in the U.S., 4.55 and 6.59 (+45%) in China, 2.31 and 2.60 (+12%) in India, 1.58 and 2.60 (+30%) in Saudi Arabia, and 1.30 and 1.58 (+21%) in Iran (Bahree and Cummins, 2006). China is the second largest importer of oil. Rapid increase in energy demand of the emerging "oil-ohlics" (e.g., China and India) will have a drastic impact on the demand and price of global energy and on CO_2 emissions. National emission of CO_2 equivalents (million tons of CO_2 equivalent) in 2005 was 6,928 in the U.S., 4,938 in China, 1,915 in Russia, 1,854 in India, 850 in Brazil, 680 in Canada, 654 in the U.K., and 521 in South Korea. The emission of CO_2 equivalent in China in 2005 was equal to that of India, Russia, Canada, and South Korea combined. Yet, per capita energy use in China is 10% of that in the U.S. and 20% of that in Japan. In comparison, India's per capita energy use is only 5% of the U.S.'s and 10% of Japan's. In contrast to the current and emerging trends, per capita emissions (tons C person^{-1}) in 1992 were 5 for the U.S., 4.8 for Kazakhstan, 4.2 for Australia, 4.1 for Canada, 3.9 for Russia, 3.2 for Ukraine, 3.0 for North Korea, 2.9 for Georgia, 2.8 for Germany, 2.6 for the U.K., 2.5 for Poland, 2.5 for Japan, 2.2 for South Africa, 1.9 for ITA, 1.9 for South Korea, 1.7 for France, 1.6 for Spain, 0.95 for Iran, 0.90 for Mexico, 0.6 for China, and 0.2 for India. These trends have been changing drastically during the first decade of the 21st century. Presently, North America uses eight times as much energy per person as does Latin America. The oil price has rapidly increased since 2000 to an all-time high of \$75 barrel^{-1} in the summer of 2006 with a corresponding retail price of more than \$3 gallon^{-1} (Newell, 2006). An increase in oil price by \$1 barrel^{-1} means an additional \$7.4 billion cost to the car-centric culture of the U.S.

It is in this context that there is a strong and growing interest in renewable energy in general and biofuels in particular (Brown, 1999; Herrera, 2006; NEC, 2006). Presently, biofuel accounts for only 2.8% of the total energy supply in the U.S. (EIA, 2004a), and liquid biofuels play a minor role in supplying the energy demand of the U.S. and the world. It is expected that biofuels will supply 5% of the U.S. power and 20% of its transport fuels by 2030 (USDOE, 2005). By 2010, 6% of all fuel consumed in the EU countries is expected to be grown on farmlands (Vorholz, 2006).

Ethanol consumption increased from 660 million liters (176 million gallons) in 1980 to 2.9 billion liters (0.77 billion gallons) in 1990, 5.6 billion liters (1.48 billion gallons) in 2000 (USGAO, 2002; Baldwin, 2002), 15 billion liters (3.96 billion gallons) in 2005 (RFA 2005a, 2005b), and 16 billion liters (4.3 billion gallons) by January 2006 (Cassman et al., 2006). As much as 11% of the U. S. maize and sorghum production was consumed by the ethanol industry. The industry capacity is expected to be 26.5 billion liters (7.0 billion gallons) by January 2008 (Cassman et al., 2006).

Pacala and Socolow (2004) proposed bioethanol as one of the 15 technological options (wedges) with a potential to stabilize the atmosphere by 2054 by offsetting 1 Gt C yr^{-1} through global production of 36 million barrels (2 billion gallons) per day of ethanol. Identifying sources of bioethanol feedstock is both a high priority and a debatable issue. Many have considered harvesting residues of crops (e.g., corn, wheat, and barley) for ethanol production (Kim and Dale, 2004). Tilman et al. (2006) observed that low-input high-diversity (LIHD) grassland biomass can sequester atmospheric CO_2 at the rate of 4.4 t ha yr^{-1} in soil and roots. In contrast, emission of CO_2 by production of LIHD can be 0.32 t ha yr^{-1}.

Crop residues and other ligno-cellulosic materials are rich sources of energy. While a small amount (<25%) of residues can be removed from some soils (Larson et al., 1972; Wilhelm et al., 2004), residue removal in others may increase the risks of soil and environmental degradation, especially in those regions where soil resources are already under great stress (Lal, 2006). Thus, the strategic questions are: should the residues be used for C sequestration, soil quality enhancement, and improving ecosystem services or for producing energy? Will we favor short-term economic gains or the long-term sustainable use of natural resources? Should the need for fuel override the urgency to achieve global food security?

The answer lies in identifying additional land for establishing biofuel plantations. Pacala and Socolow (2004) estimated that production of 36 million barrels of ethanol per day by 2054 would require an additional 250 million hectares (Mha) of land worldwide. The additional land (e.g., agricultural surplus or marginal land, restored degraded/desertified/mined lands) would be used for growing dedicated biofuel crops with a potential to produce high aboveground biomass for ethanol production and a prolific belowground root biomass for soil C sequestration.

Several tree species can be grown for fuel wood production in developing countries so that crop residues and animal dung can be used as soil amendments. Important among these are *Capparis decidua*, *Acacia* spp. (*A. tortilis*, *A. nilotica*, and *A. auriculiformis*), *Albizia lebbek*, *Dalbergia sissoo*, and (*Terminalia arjuna*). These species also improve soil quality and enhance SOC pool (Lal et al., 1999).

Waste Management

Large quantities of urban and industrial wastes can be a liability or an asset depending on the management/disposal strategy. Total solid wastes produced in the U.S. increased from 269 Mt in 1990 to 375 Mt in 1999 at an annual rate of growth of 10.6 Mt yr^{-1} during the 1990s (Glenn, 1999). Of the total solid waste generated, the municipal solid waste (MSW) is 215 Mt yr^{-1} (USEPA, 2006). The amount of MSW produced in the U.S. increased from 89 Mt in 1960 to 215 Mt in 2003 at an average rate of increase of 2.9 Mt yr^{-1}. The MSW generated in the U.S. doubled between 1970 and 2003, and the per capita MSW generated increased from 1.2 kg $person^{-1}$ yr^{-1} in 1960 to 2.0 kg^{-1} $person^{-1}$ yr in 2000 (USEPA, 2006).

The amount of animal manure generated in the U.S. is about 132 Mt yr^{-1}. Of this, cattle manure (from feedlot beef, dairy cows, and other cattle) contributes more than 80%. Biosolids contribute more than 50% of the total MSW generated in the U.S. Both animal manure and biosolid MSW can be used as a source of biofuel feedstock or composted and recycled as soil amendment or biofertilizers.

Over and above MSW and animal manure, there is a serious question of safe disposal of the industrial wastes, laden with extremely hazardous pollutants. Being a biomembrane, soils can be used as a filter and a biodegrader of some industrial pollutants. A thorough examination of soil properties and site characteristics must precede land application of industrial pollutants.

Global Soil Degradation and Desertification

The effects of soil degradation are especially severe now, with the world population at 6.5 billion and increasing rapidly in developing countries where the resources are scarce, fragile, and stressed by a harsh climate. The severity of soil degradation is caused by land misuse, soil mismanagement, and either insufficient use or abuse of inputs. Most degraded soils and ecosystems exist in developing countries where the institutional support and infrastructures required to achieve the desired goals are in need of major improvement. These are also the countries where either the resource-poor small landholders cannot obtain the prohibitively expensive inputs (e.g., fertilizers, erosion control measures, and irrigation) or such essential inputs are not available. There is a strong need to restore degraded/desertified soils and ecosystems in SSA, which are needed to loosen the grip of perpetual hunger, malnutrition, poverty, and substandard living. Conversion to a restorative land use and adoption of recommended soil/crop management practices can reverse the degradation trend and lead to a gradual improvement in soil quality.

The success story of implementing a soil conservation program in the U.S. is a relevant example. Most land areas affected by severe erosion in the "dust bowl" of the 1930s have been restored. Utz et al. (1938) reported that 91 Mha of U.S. land was devastated by severe erosion in the 1930s. Yet, the land area affected by erosion in the 1990s was merely 24 Mha (Trimble, 1999; Lal et al., 2003). Translation of scientific data into site-specific technological intervention and farmer participation can lead to restoration of degraded/desertified soils of Africa and in developing countries, improving productivity and enhancing the environment.

Water Resources

Agriculture is the largest consumer of water (Gleick, 2003). Most of it is used for irrigated crop production in drylands. Industrial and urban uses are also rapidly increasing, posing a serious competition to agricultural use (Kandratyev et al., 2003). In 1900, the relative water use was 81.4% for agriculture, 7.0% for industry, and 4.7% for urban purposes. In 2000, the relative water use was 56.7% for agriculture, 31.7% for industry, and 3.7% for urban purposes. Total water use was 430 billion m^3 in 1900 compared with 6,050 billion m^3 in 2000, which reflects a 14-fold increase over the 20th century.

Some regions are facing severe problems due to: (a) scarcity of water resources and (b) pollution of natural waters. The per capita renewable fresh water supply is rapidly declining, especially in dry and hot climates. There may be 1 to 3 billion people experiencing water stress by 2025 (Gardner-Outlaw and Engelman, 1997). As many as 2.3 billion people in 2000 lived in river basins with water stress or in regions where the per capita annual water supply was <1,700 m^3 (Johnson et al., 2001). Of these, 74% (1.7 billion) resided in river basins with per capita renewable supplies of <1,000 m^3 yr^{-1}. The data on low per capita annual water supply in many countries are indicative of a strong need for careful planning and judicious use of this scarce but precious resource. In many cases, fossil/nonrenewable water is also being depleted. Yet, the water use efficiency is low, especially in the outdated/primitive flood irrigation system widely practiced in South Asia, China, Egypt, and elsewhere in developing countries.

Pollution caused by agricultural runoff remains a serious issue. The global pesticide use has drastically increased from 2.6 Mt in 1990 to 3.75 Mt in 2000 and is projected to be 15.6 Mt by 2020 and 25.1 Mt 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 and China). Clay (2004) estimated that the water requirement per kilogram of an animal-based diet is three to four times more than for a chicken-based diet and 15 to 20 times more for a beef-based than cereal-based diet.

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

Food Security

Earth's population increased 10-fold from 600 million in 1700 to 6.3 billion in 2003 (Cohen, 2003). It took from the dawn of human evolution to 1927 to achieve a population of 2 billion, only 47 years to double to 4 billion by 1974, and only 25 years to reach 6 billion by 1999 (Cohen, 2003). Similar to increases in population, global food production tripled during the second half of the 20th century from 650 Mt in 1950 to about 2,000 Mt in 2000 (FAO, 2005; Kondratyev et al., 2003). The drastic increase in food production was brought about by the use of fertilizers, mechanized farming, and irrigation on input-responsive improved varieties. Despite the impressive gains, however, severe and chronic food deficit persists in South Asia and SSA. Food-insecure population in developing countries is estimated at about 850 million (Tweeten, 1999). There may be an additional 100 million food-insecure people by 2015. It is widely feared that the U.N. Millenium Goals of cutting hunger by half by 2015 will not be met. The problem is exacerbated by agrarian stagnation (or even regression) in SSA. The quantum jump in food production required in SSA will have to come through:

1. restoration of degraded and desertified soils in relation to soils,
2. improvement in quality of agricultural soils in relation to soil structure, organic matter reserves, and nutrient and water retention capacities,
3. provisions for supplemental irrigation, and
4. conservation of soil through adoption of conservation-effective measures.

Fig. 1. Components of land-saving and improvised technologies.

Increasing the area under irrigated crop production is a high priority for Africa. Total irrigated area in SSA is 7.0 Mha (FAO, 2005), which is barely 2.5% of the world's irrigated land area of 275 Mha (FAO, 2005). Developing small-scale irrigation programs, rather than undertaking grandiose schemes, is a high priority for SSA.

Soil degradation is a serious problem in Africa. Among numerous causes of the extent and severity of the situation, an important factor is the widespread use of extractive farming practices in which soil fertility has been perpetually mined and nutrients removed by crop/animal harvest and not replaced.

Yield of cereal crops in SSA and elsewhere in developing countries must be strongly increased to meet the future production demands. This quantum jump can be made through conversion to a restorative land use for restoring degraded soils and ecosystems, adoption of land-saving technologies, and use of improved varieties within intensive cropping/farming systems. Important components of land-saving technologies are: techniques to enhance soil fertility using integrated nutrient management, systems to improve the plant-available water reserves through conservation in the rest zone, and water harvesting and recycling (Fig. 1). Improvement in soil quality through C sequestration in the root zone is a win-win option. Lal (2006) reported that an increase in the SOC pool can enhance food production in SSA by 6.3 to 11.6 Mt yr^{-1}, which is sufficient to meet that region's current and projected food deficit.

New Curricula in a Flat World

Soil science has advanced more since the 1950s than in all prior history. This momentum needs to be maintained by training and nurturing the brightest and the best. This mission necessitates making soil science research relevant to societal issues. The real purpose is to train students to address emerging global issues facing humanity (e.g., biofuels, climate change, water quality, loss of biodiversity, water disposal, desertification etc.). Students with degrees in soil science must be innovative problem solvers, original thinkers, and above all respectable citizens of the world family. The curricula must address emerging issues with regards to the functions of soil, which in the 21st century, are:

1. moderation of the environment,
2. repository of the germplasm,
3. medium for plant growth,
4. an adaptable and dynamic system,
5. a biomembrane,
6. a laboratory for denaturing pollutants,
7. an open system in close interaction with other spheres (e.g., atmosphere, hydrosphere, lithosphere, and biospheres), and
8. a reactor.

The world is getting flatter by the day (Friedman, 2005). The developing country institutions are now equal partners in implementing jointly projects of mutual interest, and not just the grant recipients. Institutions in the U.S. and Europe can learn as much or more from those in the developing countries.

> *"Soil scientists must develop and strengthen channels of communication with policy makers and legislators, so that scientific data is translated into appropriate language that policy makers understand and can use."*

We must also prepare soil science students to address the rural poverty in developing countries with improved agriculture. Even modest improvement in crop yields can have a strong impact on the standard of living of resource-poor farmers. Benefits of genetic research can be fully realized only through improvements in soil quality.

There is a lot of discussion about taxing emission of C, and the high court has also heard the climate case (New York Times, 2006; Morgan, 2006). Sequestering C in soil and trees for offsetting fossil fuel emissions can be a good business (Breslau, 2006). While the CO_2 price in the EU market crashed in May 2006 (Brahic, 2006), the price at Chicago Climate Exchange (CCX) has increased from \$0.90 t^{-1} of CO_2 in December 2003 to \$4.25 t^{-1} of CO_2 in December 2006. Soil C improves soil quality and enhances ecosystem services and is now a tradable commodity similar to corn, soybeans, meat, or milk. Soil scientists must work closely with economists and policy makers to develop methodology for measuring, monitoring, and verifying C sequestration to facilitate the process. Trading C credits provide an opportunity for resource-poor farmers of developing countries to restore degraded soils and ecosystems and invest in erosion control, irrigation, fertilizers, and reforestation.

Communication with Policy Makers

Soil scientists must also develop and strengthen channels of communication with policy makers and legislators, so that scientific data is translated into appropriate language that policy makers understand and can use. Research needs to be demand driven and meet immediate and future needs for land managers, policy makers, and the public at large. The need for biofuel production will make a very strong demand on crop residue as a source of feedstock. To make an objective decision, policy makers must have a clear understanding of the effects of residue removal on soil quality, erosion, nonpoint source pollution, hypoxia, biodiversity, and long-term sustainability of natural resources.

The Green Revolution of the 1960s bypassed SSA, and this has perpetuated hunger, malnutrition, poverty, desertification, and even exacerbated the political instability. There is a wealth of published scientific data on methods of land development, erosion control, and soil fertility management (Lal, 1987; Sanchez, 2002). However, there is a major disconnect between scientists and policy makers and land managers and policy makers. The disconnect has been exacerbated by the lack of initiatives and efforts towards translating the valuable and credible scientific data into practical technology in a simple language that policy makers and land managers can understand and relate to. This serious disconnect must be addressed through establishing channels of communication. It is important to develop mechanisms so that soil science meets the needs of the world community it serves and can prioritize demand-driven issues, which address immediate needs and future concerns.

Conclusion

Among principal global concerns of the 21st century are:

1. food insecurity due to a rapid increase in the world population,
2. soil degradation by land misuse and soil management,

3. anthropogenic increase in atmospheric greenhouse gases, and
4. decline in water quality and availability.

These and many other issues are closely linked to the sustainability of soil quality. All ecosystem services provided by soil are affected by the quality and quantity of SOM and its dynamic, which has been depleted and needs to be restored. Conversion to a restorative land use and replacement of extractive farming practices with recommended management practices would be a step in the right direction.

As the world population increases, arable cropland decreases, renewable fresh water resources diminish, and the risks of global warming increase, there will be a strong need for using, improving, and restoring the finite and fragile soil resources of the world. As has been the case in the past, supporters of Malthusian views will again be proven wrong. The world has the capacity to meet the needs of current and future populations provided that known technologies are adopted and new ones developed to address the emerging issues. Indeed, human welfare and world peace and stability are intimately linked to soil quality. It must never be taken for granted.

A major shift is the focus on enhancement of soil quality for diverse functions including mitigation of the greenhouse effect, disposal of industrial and urban wastes, production of feedstock for biofuels, improvement of water resources and decreasing hypoxia, and restoration of desertified/populated soils. In this regard, there is a strong need for innovative, original, and interdisciplinary soil science research. There is also a strong need to translate scientific data into simple language that policy makers and land managers can understand. New curricula must be developed to prepare students for addressing the global issues of the 21st century.

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Do Enhanced Stormwater Runoff Basins Improve Water Quality?

Urban development is associated with elevated nutrient and sediment levels in stormwater runoff, impacting area streams and downstream water bodies such as the Chesapeake Bay. Stormwater detention facilities (also known as best management practices or BMPs) are increasingly being used in urban areas to manage this runoff by replacing functions, including flood protection and water quality improvement, that were originally performed by wetlands prior to area development. Stormwater detention facilities may be designed to focus only on decreasing urban flood risk by detaining stormwater, or they may be enhanced to also provide water quality benefits (nutrient and sediment removal and retention) at the same time.

Dianna Hogan, a research scientist with the Eastern Geographic Science Center of the U.S. Geological Survey (USGS), and Mark Walbridge, a biologist at West Virginia University, studied two types of commonly used urban stormwater detention facilities in the Northern Virginia suburbs of Washington, DC. Both types were constructed to retain peak stormwater flows for flood mitigation, but one type was enhanced to improve water quality. Funded by the United States Environmental Protection Agency (EPA) and in collaboration with George Mason University, Hogan and Walbridge compared the nutrient and sediment retention characteristics of "flood control only" and "enhanced detention" stormwater facilities with one another and with natural wetlands in the same area—the system whose function they are intended to emulate. Results

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Example of the inflow for a flood control only facility.