The potential of world cropland soils to sequester C and mitigate the greenhouse effect

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Abstract

Soil emission of CO2 is closely linked to soil degradation, decrease in soil organic carbon (SOC) content and decline in soil quality. Enhancing soil quality through adoption of best management practices (BMPs) and soil restoration can increase SOC content and soil productivity, and partially mitigate the greenhouse effect. The C sequestration potential through judicious management of world cropland includes 0.08–0.12 Pg/yr by erosion control, 0.02–0.03 Pg/yr by restoration of severely degraded soils, 0.02–0.04 Pg/yr by reclamation of salt-affected soils, 0.15–0.175 Pg/yr by adoption of conservation tillage and crop residue management, 0.18–0.24 Pg/yr by adoption of improved cropping system and 0.30–0.40 Pg/yr as C offset through biofuel production. The total C sequestration potential of the world cropland is about 0.75–1.0 Pg/yr or about 50% of annual emission of 1.6–1.8 Pg by deforestation and other agricultural activities. This finite soil-C sink could be filled over a 20 to 50-year period, during which energy related emission reductions gradually take effect at global scale. Improving soil quality is a win–win strategy, while increasing productivity it also improves environment and partially mitigates the greenhouse effect. Intensification of farming and increasing biomass production can lead to increased sequestration of C in soils, and to partly meet commitments under the Kyoto Protocol at national and global scales. Global reduction in C emission may have to be substantial if the atmospheric concentration of CO2 is to be stabilized at 550 ppmv. However, realization of this potential would require developing channels of communication between scientists and land managers and policy makers, and providing economic incentives. © 1999 Published by Elsevier Science Ltd. All rights reserved.

Keywords: C cycle; Agricultural intensification; Global warming; Environmental quality

1. Introduction

The world cropland area is estimated at about 1338 million ha (Mha) (FAO, 1996). Because of disturbance and exposure of the soil surface due to tillage and soil management practices, cropland soils are prone to numerous degradative processes. Degradation of cropland soils is a serious issue (Oldeman, 1994), with drastic adverse impacts on global food security and environment quality. Two important environmental impacts of soil degradation are declining water quality

(Lal and Stewart, 1994) and feed backs to the greenhouse effect (Lal, 1995).

Atmospheric concentration of CO2 has increased from about 285 ppmv in 1850 to 365 ppmv in 1996, and is increasing at the rate of 0.5%/yr (IPCC, 1995). This increase is attributed to three principal anthropogenic activities i.e. fossil fuel combustion, cement manufacturing and changes in C sequestration caused by land use such as lack of regeneration after wood harvesting, extended shifting cultivation, drainage, soil erosion and use of soil mining practices for an extended period. Conversion of natural to agricultural ecosystems leads to emission of C from the soil C pool. In regions with low inherent fertility due to soil-
related constraints (e.g. Al and Mn toxicity, P deficiency), conversion to arable land use and application of fertilizer amendments may increase biomass productivity and enhance the SOC pool (Fisher et al., 1994). In such a situation, afforestation following an extended period of arable land use with best management practices (BMPs) may not lead to soil organic carbon (SOC) enhancement (Alriksson, 1998). In most cases, however, conversion to an arable land use leads to a rapid depletion of SOC content (Jenkinson, 1991; Donigian et al., 1994; Paustian et al., 1997). For world croplands, Dalal and Carter (1999) reported the rate of loss of SOC at 0.06% C/yr of cultivation. In the Amazon region, Nieß and Davidson (1999) observed that conversion of forest to pasture lost 5% of surface soil C per year. In southern Cameroon, Woomer et al. (1998) reported the loss of SOC over a 15-year period at the rate of 6.8 Mg/ha/yr with a cumulative loss of 102 Mg/ha. On a long-term experiment in western Nigeria, Lal (1996) reported that SOC content of the top 0–10 cm layer decreased from 2.0% under forest to 1.4% with cultivation for 10 years. Kang (1993) observed that SOC content declined on Alfisols in western Nigeria from 1 to 0.3–0.6% in a 10-year period. In Guinea savanna zone of west Africa, Jones (1973) observed that SOC content decreased from 1.03% in uncultivated soils to 0.58% in soils cultivated for 23 years. In the Pampane semi-arid region, Galantini (1994) observed a 10 to 30% decrease in SOC content due to cultivation. In Vertisols of Australia, Grace et al. (1998) observed that 50 years of cultivation caused 60% reduction in the initial SOC level. In most cases, therefore, cultivation has caused 50–70% reduction in the initial SOC level.

The global soil C pool is estimated at about 2500 Pg (comprising 1500 Pg of SOC and 1000 Pg of soil inorganic C (SIC) to 1-m soil depth) compared with about 550 Pg of the biotic pool and 750 Pg of the atmospheric pool (Lal et al., 1998a). Soil degradation accentuates the emission of CO₂ through depletion of the soil C pool (Lal et al., 1995, 1998a,b). Global emissions of CO₂ by deforestation and agricultural activities are estimated by IPCC (1995) at 1.6 Pg/yr (Pg is petagram, is 10¹⁵ g), which accounts for about 20% of the annual increase in radiative forcing. The global release of C from mineralization of SOC due to agricultural activities is about 800 Tg C/yr (Tg is teragram is 10¹² g) (Schlesinger, 1990). The cumulative historic loss of C from world agricultural soils is estimated at 55 Pg (IPCC, 1995) and from soils and vegetation at 150 Pg (Houghton, 1995). Therefore, there exists a potential to sequester C into the soil through restoration of ecosystems and soil quality enhancement by adoption of BMPs to the magnitude of about 75% of this loss or about 40 Pg (IPCC, 1995) to 112 Pg.

The objectives of this report are to (i) demonstrate the potential of world cropland for C sequestration and partially mitigating the greenhouse effect and (ii) show that rather than being the cause, adoption of BMPs and properly planned agriculture can be part of the solution to global environment problems.

2. Mechanisms of C sequestration in soil

The principal strategy is to restore, and enhance soil quality by improving the SOC content. Soil quality is defined as “the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health” (Doran and Parkin, 1994, 1996). It refers to “soil’s capacity or fitness to support crop growth without resulting in soil degradation or otherwise harming the environment” (Carter et al., 1997). There also exists a strong relationship between soil quality and soil resilience (Lal, 1997a,b), and soil quality and the greenhouse effect (Bezdicek et al., 1996; Flach et al., 1997). Soil resilience refers to the ability of a soil to restore itself following a disturbance (Lal, 1997a,b). Resilient soils are characterized by high soil quality and vice versa. Decrease in SOC content leads to decline in soil resilience, reduction in soil quality, biomass productivity and soil’s environmental moderating capacity. In contrast, increase in SOC content improves aggregation, plant available water capacity, ion exchange capacities, soil biodiversity, and soil quality (Lal, 1997a,b).

Decline in soil quality and resilience accentuates the potential greenhouse effect through emissions of radiatively-active gases (CO₂, N₂O) from soil to the atmosphere. The process is set-in-motion by decrease in aggregation and exposure of C encapsulated (sequestered) within aggregates to microbial decay. Decline in aggregation also leads to crust formation, compaction, low infiltration rate, high runoff and accelerated soil erosion. Soil erosion is a principal degradative process resulting in decrease in effective rooting depth, nutrient and water imbalance in the root zone, and reduction in productivity (Lal, 1998). Soil erosion leads to preferential removal of SOC and clay contents. As much as 20% of the C transported by eroded sediments may be released into the atmosphere as CO₂ (Lal, 1995).

The SOC dynamic is related to land use history and management practices. Major loss of SOC follows conversion of virgin forest and grassland to cropland and subsequent plowing and related activities (Jenkinson, 1991). Anthropogenic activities that accentuate SOC loss in soil include plowing, biomass burning, residual removal, drainage, low fertilizer input, lack of or low level of application of organic amendments, summer fallowing and low frequency of incorporating cover
crops in a rotation cycle. Principal agricultural activities that may lead to increase in SOC content, and therefore, C sequestration in cropland soils include conservation tillage and residue management, soil fertility improvement, restoration of salt-affected soils, restoration of degraded soils, irrigation/water management and adoption of improved cropping systems with frequent use of cover crops, liberal use of organic amendments, and adoption of BMPs (Cole et al., 1995; Lal, 1997a,b; National Land Care Program, 1997). Agricultural intensification, adoption of BMPs on prime land and reverting marginal and degraded lands to restorative measures, is a viable option for improving food security and enhancing environment quality (Greenland et al., 1997).

3. Global soil erosion and C dynamics

It is difficult to estimate the total amount of C displaced by soil erosion from the world’s cropland. Total sediment transport to oceans by the world’s rivers is 19.0 Pg/yr (Lal, 1995), or 1.5 Mg/ha for a total of 13 billion ha of land area. Erosion rate from cropland can be 3 to 4 times that of silvicultural or pastoral land uses. Therefore, average soil erosion rate from cropland may be 5 Mg/ha/yr for water erosion and 3 Mg/ha/yr for wind erosion. Considering the land area affected by erosion (Table 1), total soil erosion may be 1.3 Pg by water and 0.3 Pg by wind erosion. Assuming a delivery ratio of 10% (Walling, 1993; Walling and Webb, 1996), total sediment displaced by soil erosion on cropland is estimated at 16 Pg/yr. It is assumed that the SOC content of eroded sediments be 3% (Baumgartner and Reichel, 1975; Kempe, 1979; USGS, 1993; Lal, 1995). Therefore, total amount of SOC displaced by soil erosion is about 0.5 Pg. Assuming 20% of the C displaced is emitted into the atmosphere (Lal, 1995), direct emission of C by soil erosion from the world cropland may be 0.1 Pg/yr.

Table 1

<table>
<thead>
<tr>
<th>Type of soil degradation</th>
<th>Cropland area affected (10^6 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil erosion</td>
<td></td>
</tr>
<tr>
<td>Water erosion</td>
<td>266</td>
</tr>
<tr>
<td>Wind erosion</td>
<td>87</td>
</tr>
<tr>
<td>Chemical degradation</td>
<td>133</td>
</tr>
<tr>
<td>Physical degradation</td>
<td>66</td>
</tr>
<tr>
<td>Total</td>
<td>522</td>
</tr>
</tbody>
</table>

Widespread adoption of conservation-effective measures can lead to reduction in some of the 0.1 Pg of C/yr emitted due to accelerated soil erosion.

4. Restoration of degraded soils and C sequestration

Restoration of degraded soils, a high priority due to economic and environmental reasons, may lead to increase in SOC content and enhancement of soil quality. Out of a total estimated degraded land area of about 2 billion ha, strong and extreme form of erosion-induced degradation affects 250 Mha (Oldeman, 1994). Regional distribution of the world total of 250 Mha includes 112 Mha in Africa, 88 Mha in Asia, 37 Mha in Latin America and 13 Mha in Europe. It is assumed that out of 250 Mha of severely degraded lands, most strongly degraded cropland area of the world is 100 Mha. These lands are not suitable for agriculture. With proper planning and use of fertilizer and organic amendments, these lands can be grown to appropriately adopted shrubs and tree species. Agricultural intensification and adoption of best management practices on prime land can facilitate restoration of strongly degraded soils by afforestation and adoption of other restorative measures (Cole et al., 1995). Assuming C sequestration rate of 0.25 Mg/yr (Lal et al., 1998a,b), the C sequestration potential of restoring severely degraded cropland soils is 0.025 Pg/yr. With adoption of BMPs, restoration of severely degraded soils has a high potential for C sequestration.

An important strategy for restoration of degraded soils is to grow specific species for biofuel production. Biofuels, those that can be burned directly for power generation, are valuable offset for fossil fuels (Sampson et al., 1993; Abelson, 1995; Giampietro et al., 1997). Use of appropriate species in different ecoregions can lead to net C assimilation of 5 Mg/ha/yr (Lal et al., 1998b). Smith et al. (1998) reported that afforestation of surplus arable land by appropriate species and using the material as biofuel would lead to C offset for fossil fuel in Europe at 40–60 Tg/yr. Proper planning is, however, necessary to growing biofuel. Biofuels must be produced near a power plant, and proper infrastructure must exist for refinement and transport. Assuming that 100 Mha of degraded croplands in different ecoregions can be used to grow biofuels, the total C assimilation will be 0.5 Pg/yr. With an energy substitution factor of 0.7 (IPCC, 1995), the net energy saving may equal 0.35 Pg C/yr.

Therefore, restoration of 100 million ha of degraded soils through conversion to biofuel production could lead to below ground C sequestration of 0.025 Pg C/yr as SOC and biofuel for fossil fuel offset of 0.35 Pg C/yr.
There is another aspect of cropland degradation, which is important to C sequestration. Salt-affected soils cover about 1/10th of the earth’s land (Szabolcs, 1998), and one-third of the arid and semi-arid regions (Rengasamy, 1998) and 930 Mha worldwide (Sumner et al., 1998). More than 100 countries have salt-affected soils, especially those that are irrigated. Because of severe structural degradation, and salt and water imbalance, these soils restrict biomass productivity. It is difficult to assess the exact area of cropland soils affected by high salt concentration in the root zone. However, at least 50% of the irrigated cropland in arid and semi-arid regions is prone to salt imbalance. Several experiments in India (Gupta and Abrol, 1990; Singh, 1989; Singh et al., 1994, 1997; Garg, 1998) and elsewhere have shown drastic improvement in SOC content through adoption of appropriate reclamation techniques. Even at a low rate of SOC enhancement at 0.2–0.3 Mg C/ha/yr, the potential of C sequestration through reclamation of 125 Mha of cropland soils is 0.02–0.04 Pg C/yr for about a 25-year period.

5. Conservation tillage and crop residues management

Conservation tillage (CT) refers to any tillage and planting system that maintains at least 30% of the soil covered by residue after planting to reduce water erosion; or where wind erosion is a primary concern, maintain at least 1000 kg/ha of flat, small grain residue equivalent of the surface during the critical wind erosion period (CTIC, 1997). There are numerous variants of CT system i.e. no till, ridge till, mulch till, chisel till etc. The CT system is widely adopted in North America (Carter, 1994), Europe (Riley et al., 1994; Christian and Ball, 1994; Ehlers and Claupein, 1994; Masse et al., 1994), the Pacific (Dalal, 1989; Choudhary and Baker, 1994; Steed et al., 1994) and some parts of the humid and subhumid tropics (Lal, 1989). Among several merits of CT is the increase in SOC content when converted from conventional (plow-based) to a CT system (Dalal and Mayer, 1986; Lal, 1989; Blevins and Frye, 1993; Kern and Johnson, 1993; Carter, 1994). Lal (1997a,b) estimated that global arable land area under CT may increase from 120 Mha in 1995 to 537 Mha in 2020, a total increase of 417 Mha over a 25-year period. Assuming that the rate of increase in C is 0.2 Mg/ha/yr over a 25-year period, the C sequestration potential of adopting a CT system is about 0.08 Pg/yr (based on average benefits of all CT systems). Adoption of conservation tillage may also save fossil fuel at the rate of about 8 Kg C/ha/yr (Paustian et al., 1997; Lal, 1997b; Lal et al., 1998b). With a total land area of 417 million ha, saving in fossil fuel due to conversion to conservation tillage may be 0.003 Pg C/yr.

Crop residue management is an integral component of a CT system. The amount of crop residue produced in the world is a large quantity, about 3.5 Pg/yr (Lal, 1997a,b). In addition to the crop residue, the weed and other biomass produced on the cropland is about 0.5 Pg. Smith et al. (1998) reported that incorporation of straw at 5 Mg ha/yr to all cereal land in Europe would lead to SOC sequestration of 26 Tg/yr. Regardless of the tillage method, only 50–60% of the residue produced may be returned to the soil. If 2 Pg of crop residue containing 40% C (0.8 Pg C) is returned to the soil and about 10% is converted into stable humus, additional potential of C sequestration through crop residue management is 0.08 Pg/yr (Lal, 1997b; Lal et al., 1998b). Considering all three components, total savings in C due to conversion of row crops to conservation tillage and judicious use of crop residue may be 0.16 Pg C/yr.

6. Improved farming/cropping systems

Adoption of BMPs is important to improving biomass production and agronomic yield (Cole et al., 1995). Experimental data from throughout the world show that adoption of BMPs can increase SOC content (Table 2). Principal components of improved cropping systems with a potential to enhance SOC content include the following:

6.1. Soil fertility management

Soil productivity is determined by its capacity to supply plant available nutrients and water. A productive soil has a large capacity to store and transform nutrients in a form readily available to plant roots. In traditional or extensive systems of the tropics and subtropics, farmers usually rely on plant nutrients available in soil. As a consequence of mining soil fertility for a long period of time (and often low inherent initial fertility), soils under low-input and subsistence agricultural practices have low inherent soil fertility, low productivity and low SOC content. The SOC content of such soils can be improved by judicious use of inorganic fertilizers, organic amendments and strengthening nutrient recycling mechanisms.

The current world fertilizer consumption stands at about 130 Tg of N, P2O5 and K2O per year, and an additional 90 Tg of N is biologically fixed in soil worldwide (Vlek et al., 1997). About 60% of the world’s fertilizer input is used in the developing world, but the rate of fertilizer use in sub-Saharan Africa and parts of Asia is extremely low. Total arable land area in developing regions of the world include 167 Mha in
Africa, 90 Mha in South America, 33 Mha in Central America and 429 Mha in Asia (FAO, 1995). In addition, soils of Eastern Europe also require fertility restoration. Therefore, total arable land area in need of soil fertility restoration is about 800 Mha. Judicious use of fertilizers and nutrient cycling practices (use of organic by-products, leguminous cover crops, improved rotations) can enhance SOC content (Jenkinson, 1991) at the rate of about 0.125 Mg/ha/yr. Therefore, C sequestration potential through soil fertility restoration of world cropland is 0.1 Pg/yr.

6.2. Organic manures and by-products

Recycling organic by-products is a major environmental issue (Gardner, 1997), and an important strategy of C sequestration in soils. In addition to crop residue, other agricultural by-products include animal waste (manure produced by beef and dairy cattle, horses, small ruminants and poultry). World population of farm animals include 1.3 billion cattle, 61 million horses, 15 million mules, 44 million donkeys, 900 million pigs, 1.1 billion sheep, 640 million goats and 13 billion chickens (FAO, 1995). The exact quantity of manure produced by these animals, although difficult to estimate, is huge and judicious use of this resource is a high priority. Long-term experiments conducted in India have shown increase in SOC content by manuring from 0.5 to 2.5% in 15 years for alluvial soils, 0.6–1.1% in 45 years for Vertisols and 0.4–0.9% in 10 years for Alfisols (Swarup et al., 1999).

Urban centers in the world are generating large amounts of by-products each year. Municipal by-products (biosolids and solid residues) produced in USA are about 300 Tg/yr (Sopper, 1993; Recheigl and MacKinnon, 1997; USDA, 1998). On proportional basis (260 million population vs. 6 billion population), the municipal by-products generated in the world may be as much as 2 to 4 (average 3) Pg/yr. On average, the per capita waste production is 0.5–1 Mg/yr. Smith et al. (1998) calculated that application of sewage sludge to soils of Europe at 1 Mg/ha/yr would lead to SOC sequestration of 15.7 Tg/yr. Assuming that one-third of the organic and agricultural by-products produced can be returned to cropland, and one-tenth of the C in it (40% C) can be converted into humus, the rate of C sequestration through utilization of organic by-products is 0.04 Pg/yr.

6.3. Water management

Drainage and irrigation constitute important aspects of water management. Irrigated land area in the world is about 250 Mha (FAO, 1995) and there is little scope for further expansion of irrigated land area. Therefore, improving water use efficiency and decreasing risks of salinization are important considerations. Adoption of BMPs on irrigated land has a potential to curtail salinization, enhance biomass productivity, and increase SOC content. The C sequestration potential of improved management of irrigated land is about 0.1 Mg C/ha/yr (Mayland and Murray, 1978; Lueking and Schepers, 1985; Kimmelshue et al., 1995). Therefore, the total potential of C sequestration in irrigated land is about 0.025 Pg C/yr. This potential is over and above that estimated for reclamation of salt-affected soils.

6.4. Improvements in crop yield

Biomass and agronomic yields in highly weathered soils of the tropics and subtropics are low (Sanchez and Buol, 1975; Swaminathan, 1980; Lal, 1987a). Widespread adoption of improved crop varieties, better crop rotations, integrated pest control measures, soil fertility enhancement and water management tech-
techniques can lead to rapid improvements in crop yields (Greenland, 1975; Swaminathan, 1980; Lal, 1987b). Total arable land area in need of adopting improved cropping systems is about 800 Mha, mostly in the tropics and subtropics of Africa, Asia and Latin America (FAO, 1996). However, increasing SOC content of soils of the tropics and subtropics is not easy. Adoption of improved management practices may lead to a yield increase from 1 to 5%/yr (USDA-FAS, 1991a,b; Crosson, 1992; Flach et al., 1997; Reilly and Fuglie, 1998), and to only a modest increase in SOC content of only 0.05 Mg/ha/yr (Lal et al., 1998b). Therefore, the total potential of C sequestration through adoption of improved cropping systems and bringing increase in biomass production is about 0.04 Pg/yr.

7. Potential of world cropland for C sequestration and relevance to the Kyoto Protocol

The total potential of world cropland for C sequestration through land restoration and adoption of BMPs is 0.45–0.60 Pg/yr (Table 3). In addition, C offset through fossil fuel exchange is 0.30–0.40 Pg. The total potential (0.75–1.0 Pg C) is about 50% of the global annual carbon emission from deforestation and other agricultural activities. In the best case scenario, soil’s capacity to sequester C through adoption of BMPs may be filled over a 20–50-year period (by the year 2050) (Lal et al., 1998b). With adoption of land restorative measures, the rate of C sequestration usually peaks within 10–15 years (Akala and Lal, 1998). Although C sequestration may continue for 100 years or more, the rate of sequestration is usually small beyond 25–30-year period. The fossil fuel offset option could last for a long time (beyond 20 to 50-year period).

Table 3
Estimate of the C sequestration potential of the world cropland soils

<table>
<thead>
<tr>
<th>Strategy</th>
<th>C sequestration potential (Pg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Arable crop land</td>
<td></td>
</tr>
<tr>
<td>(1) Soil erosion control</td>
<td>0.08–0.12</td>
</tr>
<tr>
<td>(2) Soil restoration</td>
<td>0.02–0.03</td>
</tr>
<tr>
<td>(3) Conservation tillage and residue management</td>
<td>0.150–0.175</td>
</tr>
<tr>
<td>(4) Improved farming/cropping systems</td>
<td>0.18–0.24</td>
</tr>
<tr>
<td>Subtotal</td>
<td>0.43–0.57</td>
</tr>
<tr>
<td>(b) C off-set through biofuel production</td>
<td>0.30–0.40</td>
</tr>
<tr>
<td>Total potential</td>
<td>0.73–0.87</td>
</tr>
</tbody>
</table>

Table 4
Human influences on global carbon cycle during the 1980s

<table>
<thead>
<tr>
<th>Activity</th>
<th>Flux (Pg C/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuel combustion</td>
<td>5.5</td>
</tr>
<tr>
<td>Land use modification (mainly tropics)</td>
<td>1.6</td>
</tr>
<tr>
<td>Increases in atmospheric CO2 (47% of emissions 1980 and early 90s)</td>
<td>3.3</td>
</tr>
<tr>
<td>Storage of anthropogenic C in oceans, soils vegetation</td>
<td>3.8</td>
</tr>
<tr>
<td>Estimated (this paper) potential cropland sequestration (for 20–50-year period)</td>
<td>0.75–1</td>
</tr>
</tbody>
</table>

Note: Pg (petagram) is 1000 million tonnes; one tonne C is 3.67 tonnes CO2.

The significance of the estimated total global potential for C sequestration, through conservation practices and degraded land restoration in croplands, of 0.75–1.0 Pg C/year should be viewed in light of other components of human influence on the global C cycle. Approximate estimates of the key factors are given in Table 4.

From Table 4, it can be seen that realizing the full potential for additional C sequestration in the world’s croplands would increase carbon uptake by oceans and terrestrial system by some 20–26%. Whether the land restoration and agricultural conservation practices needed to achieve such an effect could be implemented more quickly than reduction in fossil fuel combustion and emissions from land use sources would depend on policies adopted by countries. However, increased cropland C sequestration is clearly worth including in national mitigation plans in most countries.

In the shorter term the relationship of C sequestration of this magnitude to emission reductions required by the Kyoto Protocol (1997) to the U.N. Framework Convention on Climate Change is more relevant. Under the Kyoto protocol 38 industrialized countries (Annex 1) agreed to reduce emissions by an average of 5.2% of 1990 emissions. A five-year averaging period centered on 2010 is the ‘commitment period’ for achieving these reductions. While these 38 industrialized countries currently contribute more than half of global emissions, they are expected to be the source of only 25% of the emissions growth over the next 20 years, with rapidly rising emissions in developing economies of Latin America and Asia. The total emission reduction target represents approximately 0.16 Pg C/yr from 1990 levels. The actual reductions under the Kyoto Protocol would be much larger, because without implementing the reductions proposed emissions would continue to increase until the year 2010. Thus the potential of C sequestration in croplands, if realized over the next decade or two, could make a substantial contribution towards reducing the increase in atmospheric CO2 concentration.
The Kyoto protocol holds out some hope that increased C sinks in soils of cropland might be credited to countries taking measures to achieve this. However, Article 3.4 which addresses this matter, leaves to later sessions, decisions by the Conference of Parties (COP) to the Convention on how, when or even whether such measures should be credited to a country. The COP and its subsidiary bodies have, in turn, referred to the science assessment body, the Intergovernmental Panel on Climate Change, technical questions of measures that would increase C sinks in cropland, how to measure and verify amounts, and how long C sinks would be retained. IPCC is expected to produce a Special Report in the year 2000 covering these matters, as well as issues concerning forests as C sinks. It is unlikely that the COP will decide upon inclusion of such C sinks as part of country commitments, until after this consensus technical report is available. However, several countries have already expressed serious reservations about allowing credit for sinks because of difficulties in measurement and verification. On the other hand, where land use and land use changes are a net source of C rather than a sink, countries are required to add this to emissions from other sources when reporting to the COP (Article 3.7). This article applies to the 1990 baseline level and not to the 2008–2012 commitment period.

A further question arises from the Kyoto protocol as to whether increasing cropland C sequestration can be credited under the Clean Development Mechanism (CDM) (Article 12), or other emissions trading (KP Article 17) and joint implementation activities (Article 6).

The latter two apply only to countries that have accepted emission reduction targets i.e. Annex 1 Parties. However, the CDM would permit emission trading between developed and developing countries. Some of the latter are most interested in projects that would increase soil organic carbon, and could be funded under the CDM by industrialized countries. However, while COP 4 in Buenos Aires in November 1998 discussed the matter, the modalities of the CDM were not agreed. The question of C sinks as eligible for use in the CDM or under other emissions trading provisions was also deferred.

From a global policy perspective, it must be recognized that a program that restores degraded croplands, and increases soil organic carbon, as well as contributing to reduction of atmospheric CO₂, represents an enormous opportunity. Such a program could at the same time increase agricultural productivity especially in developing countries, and reduce rates of climate change. International organizations and countries concerned with food production and/or climate change should join forces in a major effort to move towards these dual goals.

References


