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Agricultural influences on carbon emissions and sequestration

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ABSTRACT

Agricultural systems contribute to carbon emissions through several mechanisms: the direct use of fossil fuels in farm operations, the indirect use of embodied energy in inputs that are energy intensive to manufacture (e.g. fertilizers), and the cultivation of soils resulting in the loss of soil organic matter. However agriculture can also sequester carbon when organic matter accumulates in the soil or above-ground woody biomass acts as a permanent sink or is used as an energy source that substitutes for fossil fuels. The latest empirical data on agricultural carbon emissions and carbon sequestration opportunities in agricultural systems are reviewed and the necessary land use and management practices that will need to be employed to optimise carbon sequestration are considered.

POTENTIAL OF SOIL FOR CARBON SEQUESTRATION

Agricultural systems contribute to carbon emissions through the direct use of fossil fuels in food production, the indirect use of embodied energy in inputs that are energy-intensive to manufacture, the cultivation of soils and/or soil erosion resulting in the loss of soil organic matter. The direct effects of land use and land use change (including forest loss and conversion of use) have led to a net emission of 1.7 Gt C yr^{-1} in the 1980s and 1.6 Gt C yr^{-1} in the 1990s (IPCC, 2000). On the other hand, agriculture can also be an accumulator of carbon, offsetting losses when organic matter is accumulated in the soil, or when above-ground biomass acts either as a permanent sink or is used as an energy source that substitutes for fossil fuels and so avoids carbon emissions. We therefore identify three mechanisms by which positive contributions that can be made by farmers (Table 1).

Mechanism A:-Increase carbon sinks in soil organic matter and above-ground biomass. It has been established that SOM and soil carbon can be increased to new higher equilibria with sustainable management practices. A wide range of long-term comparative studies show that organic and sustainable agricultural systems improve soil health through accumulation of organic matter and soil carbon, with accompanying increases in microbial activity (IPCC 2000).

Mechanism B:-Reducing direct and indirect energy use to avoid carbon emissions. Nitrogen fertilizers, pumped irrigation and mechanical power account for more than 90%

of the total direct and indirect energy inputs to most farming systems (Leach, 1976). According to the OECD (1993), the absolute energy consumption per hectare increased in OECD countries by 39% between 1970 and 1989. On average, some 1734 MJ are consumed per hectare of agricultural land, rising to 46,400 MJ for the highest consumer, Japan. Sustainable agriculture systems that substitute goods and services derived from nature rather than externally-derived fertilizers, pesticides and fossil-fuels, increase the energy-efficiency of food production (Pretty, 1995, 1998).

Table 1. Mechanisms and measures for increasing carbon sinks and reducing carbon dioxide and other greenhouse gas emissions in agricultural systems

Mechanism A. Increase carbon sinks in soil organic matter and above-ground biomass
• Replace inversion ploughing with conservation- and zero-tillage systems • Adopt mixed rotations with cover crops and green manures to increase biomass additions to soil • Adopt agroforestry in cropping systems to increase above-ground standing biomass • Minimise summer fallows and periods with no ground cover to maintain soil organic matter stocks • Use soil conservation measures to avoid soil erosion and loss of soil organic matter • Apply composts and manures to increase soil organic matter stocks
Mechanism B. Reduce direct and indirect energy use to avoid greenhouse gas emissions (carbon dioxide, methane and nitrous oxide)
• Conserve fuel and reduce energy use in buildings and stores • Use conservation or zero-tillage to reduce CO_2 emissions from soils • Use composting to reduce manure methane emissions • Substitute biofuel for fossil fuel consumption • Reduce machinery use to avoid fossil fuel consumption • Reduce the use of inorganic nitrogen fertilizers and adopt targeted- and slow-release fertilizers, as fertilizer manufacture is highly energy intensive • Reduce use of pesticides to avoid indirect energy consumption
Mechanism C. Increase renewable energy production to avoid carbon emissions
• Cultivate annual crops for biofuel production, such as ethanol from maize and sugar cane • Cultivate annual and perennial crops, such as grasses and coppiced trees, for combustion and electricity generation, with crops replanted each cycle for continued energy production • Use biogas digesters to produce methane, so substituting for fossil fuel sources

Sources: Adapted from Lal et al. (1998), IPCC (2000), Robertson et al. (2000), USDA (2000)

Mechanism C:-Increase renewable energy production to avoid carbon emissions. Biomass energy can be used to avoid greenhouse gas emission by providing equivalent energy for heat and electricity generation, and for transportation fuel. If biomass is harvested and burned, and the same area replanted or regenerated, there are no net carbon emissions over the harvest cycle.

THE COST OF CARBON SEQUESTRATION

There have been a number of studies that have attempted to quantify the marginal opportunity cost of sequestering carbon in agriculture. Earlier studies suggested that agriculture could operate in the range \$10 to \$25 t^{-1} C (Pretty and Ball (2001). These estimates of costs seem high in relation to the current estimated value of carbon permits. Pretty and Ball (2001) highlight that the range of prices in some pilot schemes is between \$1 and \$38 t^{-1} C, though most current estimates are in the \$2.50 to \$5.00 range. Earlier work seems to have been more optimistic about the price of permits, with estimates of the value of carbon emissions permits ranging between \$20 and \$30 (Renwick et al. 2001). It has been estimated that carbon could increase the net farm income of the US farming community by 10%. Though the estimates placed on the value of a tonne of carbon vary considerably, the evidence does increasingly point to a fairly low price. This would suggest that whilst the additional income to farmers in temperate climates would be welcome (especially in the current economic climate) it is clear that farmers are unlikely to become just carbon farmers.

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