Agriculture and Greenhouse Gas Mitigation: Who, What, How, Where and When ?

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Today I'd like to present an overview of agriculture's role in reducing greenhouse gases, looking at who are the major players, what are the practices and potentials, how can they be achieved, where the greatest opportunities lie and when will we see agriculture playing a major role in mitigating greenhouse gases. (slide 1)

The issue of greenhouse gases and global warming is by now familiar to most people, although not necessarily where agriculture fits into the picture. Recently, increased attention has been focused the potential for agriculture to contribute to reducing greenhouse gas emissions. The UN Framework Convention on Climate Change and the countries working on the implementation of the Kyoto Protocol to reduce emissions have agreed to include agricultural sinks, i.e., soil carbon sequestration, within a country's portfolio of mitigation options. Here in the US, President Bush's new policy on reducing greenhouse gas emissions per unit of economic activity, announced just over a week ago, includes a strong role for agriculture. Included in his statements were that "…we will look for ways to increase the amount of carbon stored by America's farms and forests through a strong conservation title in the farm bill. I have asked Secretary Veneman to recommend new targeted incentives for landowners to increase carbon storage. " (slide 2)

What then are the major gases of concern for agriculture? It turns out that all three of the major gases of general concern for global warming, carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), are all important for agriculture. The concentration of each of these gases has increased dramatically over the past several decades due to human activities, including agriculture. The overwhelming source of CO_2 is from fossil fuel use (largely for energy production, where agriculture has a relatively minor contribution compared to the whole economy), with deforestation and biomass burning an important source in the tropics. Agriculture provides a potential sink for CO_2, through building up soil organic matter stocks, which incorporate CO_2 taken from the atmosphere by plants. Agriculture is an important source for N_2O emissions, which occur as a consequence of nitrogen cycling in the soil, where nitrogen added through fertilizers are of particular concern. There are no significant sinks or uptake mechanisms for N_2O in agricultural systems, so that the mitigation focus is entirely on emission reductions. Within agriculture, methane is emitted by animal (especially ruminants - cows, sheep, goats) digestive processes (the proverbial cow belches) and from livestock waste systems. Flooded rice cultivation is a major source world-wide, but of less importance in the US. Reducing emissions is the most important component of mitigation of methane, but well aerated soils also act as a sink (that is, take up and oxidize CH_4). The most effective sinks are in non-agricultural soils – cultivated and fertilized soils take up less methane than less intensively managed soils. An important point to consider in the overall effect of greenhouse gases is the relative difference in 'warming effect', also know as global warming potential. Relative to CO_2 (assigned a GWP of 1), N_2O has about 300 times the effect of CO_2 and CH_4 about 20 times the effect. Thus, while the concentration and flux rates of N_2O and CH_4 are much lower than for CO_2, their effects are significant due to the characteristics of those gases with respect to global warming. (slide 3)

Looking at total greenhouse gas emissions for the US (1990-1999), expressed as carbon equivalents relative to CO_2 (as explained above), the overwhelming share is due to energy use. However, of the other major sectors, agriculture is one of the larger contributors, accounting for about 10% of gross emissions. It is also worth noting that land use, especially forestry, constitutes a significant net sink for CO_2, which helps to offset some emissions. Agriculture presently contributes to this sink but the largest portion of the sink is attributed to forests. (slide 4)

Within agriculture, the largest emission sources (expressed as C equivalents relative to CO_2) are attributed to N_2O, stemming largely from fertilizer use, and methane emissions from livestock. CO_2 emissions include the use of fossil fuels for farm machinery and operations as well as fossil fuels used in the manufacture of nitrogen fertilizers. Carbon sequestration in agriculture has increased somewhat over the past 10 years and roughly offsets the total emissions attributed to fossil fuel use. (slide 5)

For each of the major greenhouse gases, there are significant mitigation opportunities within agriculture. Enhancing soil carbon (C) sequestration is a major opportunity for mitigating CO_2 and agriculture can also be a main source of biofuel energy; both of these options can also contribute towards offsetting CO_2 emissions from other sectors of the economy. As with other energy consuming industries, agriculture can also reduce emissions though increased energy efficiency. For nitrous oxide, the best mitigation opportunities lie in the development of new fertilizers, as well as wider use of nitrification inhibitors, and in general, a more efficient use of nitrogen fertilizers. Methane losses from livestock can be reduced by improving overall livestock productivity, including breeding and nutrition. Technology exists for greatly reducing methane emissions from manure handling facilities. Methane capture and use as energy (i.e. natural gas) has a 'double' effect in that the energy produced can offset CO_2 emissions from fossil fuel. (slide 6)

Agricultural carbon sequestration is based on the use of practices that can increase the amount of soil organic matter or humus– which contains about 50% carbon by mass. Historically, many soils used for agriculture have lost 20-40% or more of their carbon through practices that led to low rates of C addition to soil (e.g. poor crop production, crop residue removal) and increased oxidation of soil organic matter (e.g. from intensive tillage, soil drainage, erosion). Since agricultural soils contain substantial C stocks – typically several tens of tonnes per acre in the top foot of soil (more than in the vegetation of most forests) – these historical losses have been substantial. (slide 7)

Employing practices that reverse this trend, that is, adding more organic matter to soils and slowing its oxidation can rebuild carbon stocks. A variety of practices that are increasingly being used, such as reduced and no-till (i.e. conservation tillage), conservation buffers and reserves, cover crops, improved crop rotations, etc., can achieve these soil carbon gains. (slide 8)

Thus, there are a variety of practices that can increase carbon storage in soils. There is also the potential to improve management of cultivated organic soils (that is, 'peat' or muck soils, **not** soils that are managed 'organically'), which are major sources of CO_2 emissions. Overall, the technical potential for carbon sequestration, with today's practices, on America's croplands has been estimated at 80-200 million metric tonnes of carbon (MMTC) per year, which is equivalent to 5-12% of all GHG emissions in the US from all sources. While the economic potential for sequestration is certainly less, the mitigation potential for soil C sequestration is nevertheless substantial (slide 9)

Currently, it's estimated that agricultural and private grazing lands are sequestering around 27 MMTC per year on mineral (i.e. 'upland') soils, with the highest rates in the central and eastern US and the Pacific NW. Cultivated organic soils ('peat' soils) are estimated to be a net source of CO_2, of around 6 MMTC per year, reducing the overall agricultural sequestration rate to just over 20 MMTC per year. (slide 10)

Organic (peat) soils make up a small portion of the total agricultural area (< 1% of cropland) but can emit large amounts of CO_2 on an area basis. Highest concentrations of cultivated organic soils are in the Lake States, Florida and the Pacific NW and the highest rates of emission per acre are in warmer areas such as Florida and California. Thus the highest total emissions are from the southeastern US. (slide 11)

For the other two greenhouse gases, a variety of practices are possible to reduce emissions. For nitrous oxide emissions, the key is to reduce the amount of nitrogen cycling through the soil while still meeting plant nutrient needs. The most effective practices are to improve the efficiency of nitrogen fertilizer use by better forecasting of actual plant needs, better timing of application, better application methods and improvements in fertilizer formulations and additives. Reducing methane from livestock is possible through improving the diet, nutrition and food assimilation of the animals. Such practices are already widespread in the US (although further improvements are possible) and in other developed countries, but much greater potential gains are possible with improved livestock management in developing countries. Improved manure management, especially methane capture and use as biofuel has considerable potential. Techniques exist to reduce methane emissions from rice paddies through better water and nutrient management. (slide 12)

A key issue in designing effective mitigation policies is to consider the effects of management on different gases and what the overall effects are on global warming potential. In a study from southern Michigan where all three gases were monitored, researchers found that compared to conventional annual crops, carbon sequestration under a no-till system greatly reduced the net GHG emissions. However, CO_2 emissions associated with fossil fuel use (e.g. fuel and fertilizer) as well as N_2O emissions were slightly higher, on a carbon equivalent basis, such that the no-till system remained a small net source. An organically managed cropping system, which had less fossil fuel use but also lower carbon sequestration, had higher GHG emissions than the no-till system, but still less than the conventional. A recently established grassland (analogous to a conservation set aside) had both high C sequestration as well as reduced N_2O emissions, making it a strong net sink for greenhouse gases. (slide 13)

Such knowledge can be used in selecting management changes that result in reduced emissions and/or enhanced sequestration for all three gases, such that there is an overall synergistic effect. Examples of such management changes are shown in the figure. (slide 14)

Likewise, we need to be aware of the potential for promoting practices that reduce emissions for one gas but have the opposite effect on another gas, thereby partially offsetting the intended mitigation benefits, or even leading to an overall negative outcome. It is dangerous to generalize, since offsetting or negative outcomes may only occur in some cases and not in others, but a couple of examples can be given. For example, increasing N fertilizer rates in situations where nitrogen is already in relatively good supply, is likely to lead to more N_2O, offsetting any potential gains in soil C from increased productivity. However, on nutrient deficient sites and/or where other nutrients are needed and supplied (such as phosphorus), benefits to productivity and soil C gain may well outweigh the effects of increased N_2O emission. As another example, CH_4 emissions are increased where the manure is kept under anaerobic (oxygen-depleted) conditions, whereas N_2O emissions are favored by aerobic conditions. Thus, improvements in manure handling systems face a complex set of tradeoffs. (slide 15).

One of the most important features of agricultural greenhouse gas mitigation strategies are the many ancillary benefits that exist. Practices that enhance soil C sequestration will improve the quality and fertility of soils, help reduce erosion and improve water quality. Conservation reserve lands, one of the most effective mitigation options for all three greenhouse gases, provide wildlife habitat and increased biodiversity. Improved nitrogen management to reduce N_2O emissions will pay big dividends in improved water quality and can reduce fertilizer costs and waste. Better manure management systems can also improve air and water quality and potentially serve as a source of biofuel. (slide 16)

Finally, several issues remain which require additional research and pilot testing to better understand the potential for agricultural mitigation options. Among these issues is the need for comprehensive greenhouse gas accounting, which has been discussed at some length above. Added to this is the fact that we need to have knowledge of what is occurring across the entire landscape, and not just in selected systems, since all ecosystems are connected to and contribute to the atmosphere. It is important that accurate quantification procedures be used for developing and accessing mitigation strategies. Agricultural GHG are for the most part from 'non-point' sources, which makes direct measurement more difficult. However, different quantification procedures are possible, either based on sampling schemes to directly estimate emissions or through measurement and monitoring of different agricultural activities, which can be assigned appropriate emission factors. Present inventory procedures are largely based on the latter approach. Although technical potentials for mitigation may be high, there are a variety of barriers and/or incentive structures that need to be addressed to realize as much of that potential as possible. These factors include economic issues (e.g. profitability, risk) as well as behavioral and educational issues that need to be addressed. (slide 17)

The following presentations focusing on actual projects will undoubtedly provide some on-the-ground experiences of these feasibility issues.