Climate Change and Crop Nutrients

By T.W. Bruulsema and W.K. Griffith

Climate change could affect every one of the Earth's 6 billion inhabitants. While conclusions are far from certain, it is clear that the concentration of carbon dioxide (CO_2) has reached levels in the atmosphere not seen in the past several hundred thousand years and is continuing to increase. In addition, concentrations of several other gases are increasing. Whether the increase in these gases is responsible or not for this century's 0.5 to 1.0ºF warming of the global climate is still debatable. However, future public pressure is likely to demand that such increasing trends be abated wherever possible.

Crop nutrients, particularly nitrogen (N), are intimately involved with the soil's exchange of gases involved in warming the global climate. While N fertilizer use has recently been associated with an increased role in the emission of nitrous oxide (N_2O), it also plays a positive role in the storage of carbon (C) in soils.

The gases that are mostly responsible for keeping the planet warm are CO_2 and water vapor. Without them, the global average temperature would be a chilling 5ºF instead of the balmy 60ºF we enjoy today. In addition, several other gases are active. Those of concern to agriculture are methane (CH_4) and N_2O. Recent estimates of the relative warming potential of emissions from agriculture are given in **Table 1**.

While it appears that each of the three is equally important, in fact they are individually unique. The net emission of CO_2 is dwarfed by the huge annual turnover of CO_2 involved in C assimilation by crops. At least 1,800 million tons of CO_2 are assimilated annually by North American crops. The turnover is so large that other sources of evidence indicate that the true net emission may actually be negative. That is, there is evidence that agricultural and forested land in the temperate latitudes of the northern hemisphere are actually a net sink for CO_2.

Methane emissions from soils arise mainly from lowland rice production and natural wetlands. There is little CH_4 emission associated with commercial fertilizer use. Ruminant animals and livestock manures are the main sources of CH_4 emissions in North American agriculture. Soils involved in crop production generally

TABLE 1. Some recent estimates of relative warming potential of gas emissions from North American agriculture.

Source	CO_2 equivalent, million tons U.S.	Canada	Total	Percent, %
CO_2	187	18	205	29
CH_4	211	22	233	33
N_2O	232	32	264	38
Total	630	72	702	100

TABLE 2. Estimates of nitrous oxide emissions from agricultural sources, based on new IPCC methodology.

Source	N_2O emissions, 10^3 tons			
Direct:	U.S. (1994)		Canada (1991)	
Fertilizer-N	204	27%	16	15%
Crop residues	144	19%	19	18%
Biological N fixation	77	10%	12	11%
Animal manures	67	9%	24	23%
Indirect:				
Nitrate leached	190	25%	29	28%
Atmospheric deposition	47	6%	3	3%
Sewage	20	3%	3	3%
Total	749	100%	106	100%

consume rather than emit CH_4, though the amount is small relative to the total sources.

Nitrous oxide emissions are very difficult to measure, and the relative importance of different sources is poorly understood. A 1995 U.S. Department of Energy estimate of N_2O emissions from agriculture attributed over 97 percent of the source to be fertilizer N. Recent changes in calculation methodology approved by the International Panel on Climate Control (IPCC) recognize that in addition to fertilizer N, any N source used in agricultural production such as animal manure, crop residues, legumes and municipal sewage are potential N_2O sources. This new methodology estimates that fertilizer N contributes approximately 27 percent of N_2O emissions from agriculture (**Table 2**). These figures are necessarily only crude estimates, because N_2O emissions are short-term events that occur rapidly in response to specific weather conditions. Recent research indicates that the use of nitrification inhibitors can substantially reduce direct emissions of N_2O. Research also indicates unexplained interactions between N fertilizer forms and episodic weather events.

Increased soil organic C can help mitigate increasing atmospheric concentrations of CO_2.

While N fertilizer is one of the direct contributors to N_2O emission, it also plays a positive role in the stabilization of soil C, and can help to mitigate CO_2 emissions. There are extensive reports from long-term trials indicating that wherever N enhances the yields of crops, the accumulation of C in the soil is increased. In addition, there is evidence that N itself is chemically involved in stabilizing soil C.

Data from a long-term experiment in Sweden provide the best demonstration of N stabilizing C in soil (**Figure 1**). In this experiment, the addition of N [71 lb/A as $Ca(NO_3)_2$] promoted the growth of the cereal crop. The increased root growth provided additional C to the soil, but the net storage in the long term was enhanced even more. Addition of N increased net C stored in response to additions of straw and sawdust as well. It is thought that nitrogenous compounds react with lignin in the process of humus formation, as a mechanism of C stabilization. In addition, most soil organic matter stabilizes with a C:N ratio of approximately 10:1, indicating again that if soil C storage is to increase, N is needed.

Another example of soil C increase in response to the addition of fertilizers was

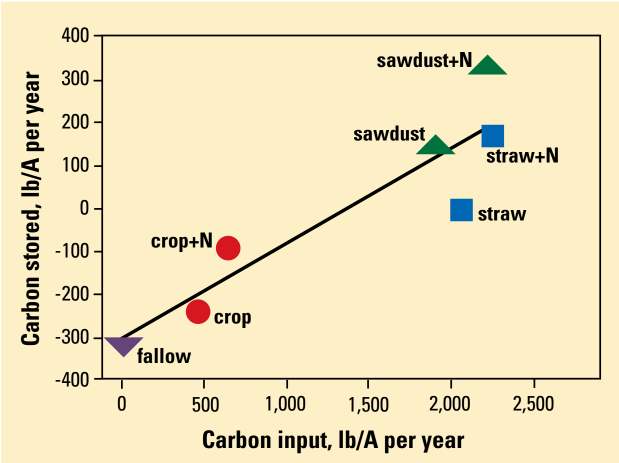

Figure 1. Annual change in soil C storage over 30 years in response to additions of N, presence of a crop, added straw and added sawdust. In all plots other than fallow, a cereal crop was grown each year and all above-ground crop residues were removed. (Adapted from Paustian et al., 1992; Soil Sci. Soc. Am. J. 56: 476-488).

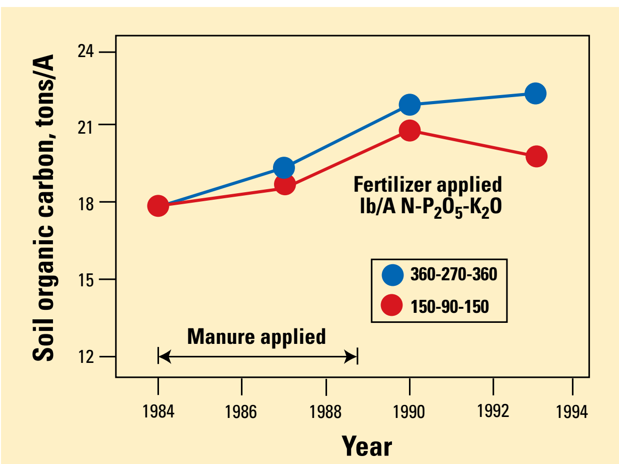

Figure 2. Soil organic C increase in response to manure and fertilizer additions in soil under continuous corn in Quebec. (Adapted from Liang et al., 1996; Soil Science 161 (2): 109-113).

observed in Quebec (**Figure 2**). In the first five years of this maximum yield study, manure was applied to all soils, while two different levels of NPK fertilizer were applied. Over the course of nine years, soil organic C levels tended to increase in all soils, but most with the high rate of fertilizer addition. The high rate of fertilizer produced about 9 percent more crop stover C than the lower rate.

The application of fertilizer nutrients to responsive crops, in combination with organic amendments, increases C storage in soils. Mitigation of increasing atmospheric concentrations of CO_2 can be added to the long list of positive benefits of increased soil organic C, including enhanced soil structure, improved tilth, and reduced erosion. BC

Dr. Bruulsema is Director, Eastern Canada and Northeast U.S., PPI, Guelph, Ontario. Dr. Griffith is former Eastern U.S. Director, PPI, and now with Agronomic Management Systems, Great Falls, Virginia.