METHANE EMISSION REDUCTION AND WORLD FOOD SUPPLY

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Summary

Methane (CH_4), produced by anaerobic decomposition of organic matter, is a radiatively active trace gas in the atmosphere, second in importance to carbon dioxide in its effect on global warming. Atmospheric concentrations of CH_4 are increasing at a rate of 1% annually, and its effect on climate may become even more important in the future as it influences the atmospheric concentrations of ozone and hydroxyl. About 20% of the total annual CH_4 emissions can be attributed to the production and use of fossil fuel, while anthropogenic activities are responsible for about 60%–80% of current CH_4 emissions. Principal sources of CH_4 in the agricultural sector are enteric fermentation in ruminants, flooded rice fields, and anaerobic animal waste processing.

Successful development and implementation of mitigation strategies for agricultural sources of CH_4 require an understanding of the effects of land-use change and agricultural practices on fluxes of these gases and on controlling mechanisms. Useful mitigation measures for CH_4 emissions from flooded rice, ruminants, biomass burning,

and landfill exist, but these measures can be implemented only when users are convinced about the economic viability of such measures. Institutional intervention to provide economic incentives would be required and in view of the projected increases in CH_4 emissions, there is a certain urgency for rapid implementation of such policies.

1. Introduction

Since the 1980s there has been an increased awareness that anthropogenic emissions of various greenhouse gases have begun to alter the composition of the atmosphere, particularly through combustion of fossil fuels, manufacture and release of various chemicals, and changes in land use. These greenhouse gases warm the atmosphere by absorbing infrared radiation emitted from the surface, thereby creating the atmospheric greenhouse effect. The first scientific assessment of the Intergovernmental Panel on Climate Change (IPCC) concluded that the increase in atmospheric concentrations of greenhouse gases since the pre-industrial period (defined as several centuries preceding 1750) had altered the energy balance of the earth/atmosphere and that global warming would result.

Although it is recognized that the build up of carbon dioxide (CO_2) is likely to increase the earth's temperature during the twenty-first century, it is also possible that continued increases of methane (CH_4), chlorofluorocarbons (CCl_3F (F-11), CCl_2F_2 (F-12)), and nitrous oxide (N_2O) may together be as effective as CO_2 in warming the earth. While their separate effects may be small, continued increases in the concentrations of these trace gases have the potential to change the global environment.

Agricultural production systems provide both sources and potential sinks for atmospheric greenhouse gases. It is estimated that agricultural activities currently contribute about 14% of total carbon equivalent of greenhouse gas emissions including emissions of CO_2, CH_4, and N_2O and emissions of gases that contribute indirectly to global warming, such as nitrogen oxides and carbon monoxide.

CH_4 produced by anaerobic decomposition of organic matter is a radiatively active trace gas in the atmosphere, second in importance to CO_2 in its effect on global warming. From trapped air in dated ice cores, Craig and Chou have deduced that CH_4 concentrations have approximately doubled in the last 350 years with a greater rate of increase in the twentieth century. Atmospheric concentrations of CH_4 are increasing at a rate of 1% annually, and its effect on climate may become even more important in the future.

Total annual emissions of CH_4, inferred from atmospheric chemistry with an uncertainty of about 20%, are estimated to be about 500 Tg CH_4 per year (1 Tg = 1 teragram = 10^{12} g) (Cicerone and Oremland, 1988). Using radiative-convective model calculations, Ramanathan et al. calculated cumulative equilibrium surface temperature warming due to increase in CO_2 and other trace gases and showed that the surface warming due to all the trace gases is 1.54 K (i.e. 1.54°C). The increase in CO_2 contributes about 0.71 K, while CH_4 increase contributes about 0.14 K. It was concluded that the other trace gases can amplify the CO_2 surface warming by factors ranging from 1.5 to 3.

Hansen et al. estimated that in the 1980s, the relative contribution of CO_2 to global warming was 49% while that of CH_4 was 18%. Compared to CO_2 the equivalent warming effect (mol basis) of CH_4 is believed to be 32 times higher.

2. Effects of Methane Accumulation in the Atmosphere

CH_4 plays a large role in the photochemistry of the background atmosphere, as changes in the concentration of CH_4 have clearly identified chemical feedbacks. It is mainly decomposed in the troposphere by reaction with hydroxyl radicals (OH). This reaction initiates complicated reaction pathways leading to the formation of various intermediates that influence the atmospheric concentrations of ozone and hydroxyl. The OH, which is present in the atmosphere at an average volume mixing ratio of only 2×10^{-14}, is primarily responsible for the breakdown of natural and anthropogenic trace gases in the atmosphere.

Atmospheric CH_4 oxidation produces water vapor (H_2O); this H_2O source is most significant in the upper stratosphere and insignificant in the troposphere. Stratospheric CH_4 also interacts with chlorine (Cl) chemistry through its reaction with Cl atoms to produce hydrogen chloride (HCl). Tropospheric reactions destroy perhaps 90% of the CH_4 that enters the atmosphere; OH radicals initiate this attack. Atmospheric chemical species and processes involved in CH_4 oxidation are also central to the control of the oxidation state of the atmosphere.

3. Factors Contributing to Methane Accumulation in the Atmosphere

A number of factors contribute to CH_4 accumulation in the atmosphere. Although the major sources of CH_4 have been identified, there is considerable uncertainty regarding the contribution of each source. According to IPCC, about 20% of the total annual CH_4 emissions can be attributed to the production and use of fossil fuel, while anthropogenic activities are responsible for about 60%–80% of current CH_4 emissions. Natural wetlands appear to contribute about 20% to the global CH_4 emissions to the atmosphere. According to a summary of the current global annual emissions of CH_4 by source (Figure 1) presented by Burke and Lashof, human activities in the agricultural sector are major sources of atmospheric CH_4. Natural sources from wetlands, oceans, and lakes probably contribute less than 25% of the global CH_4 budget.

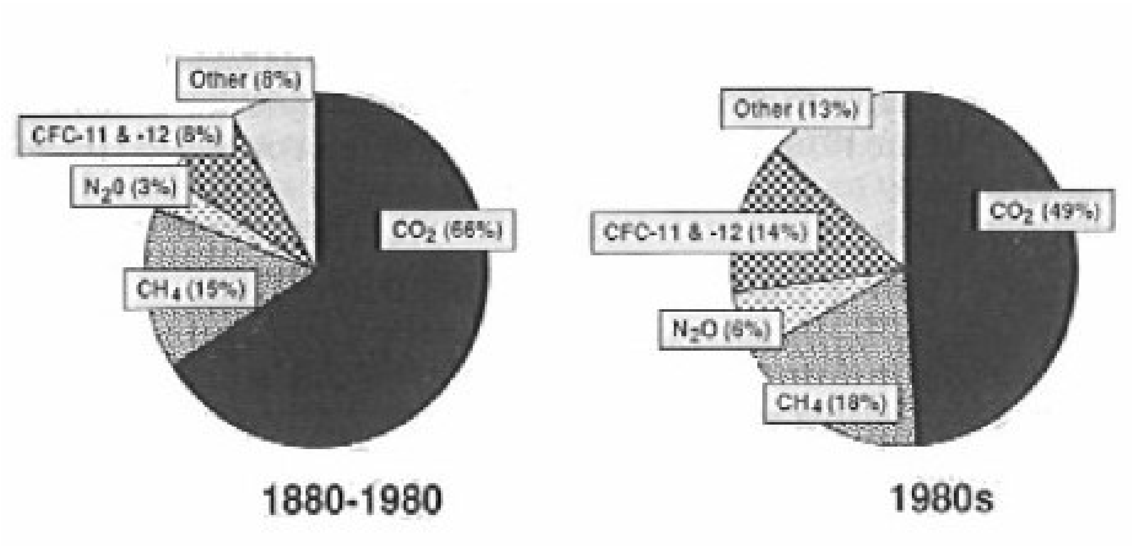

Figure 1. Relative contributions to the increase in the greenhouse effect. Greenhouse gases other than CO_2 accounted for about half of the increases in the greenhouse effect in the 1980s. The "other" category includes halons, tropospheric O_3, and stratospheric water vapor.
(*Source*: L.M. Burke and D.A. Lashof, Greenhouse gas emissions related to agriculture and land-use practices, *Impact of Carbon Dioxide, Trace Gases, and Climate Change on Global Agriculture* (Madison, Wisconsin: American Society of Agronomy, 1990))

Principal sources of CH_4 in the agricultural sector are enteric fermentation in ruminants, flooded rice fields, and anaerobic animal waste processing. Biomass burning associated with agriculture also contributes to the global CH_4 budget. Any factor that enhances primary productivity, such as elevated CO_2, nitrogen (N) deposition, or fertilization, is likely to increase CH_4 emissions because CH_4 production is limited by substrate availability. The possible extent of this enhancement is not yet clear. A detailed description of each of these sources is presented in the sections below.

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Biographical Sketch

M.V.K. Sivakumar is currently the chief of the Agricultural Meteorology Division in the World Climate Programme Department of the World Meteorological Organization. Since the early 1970s, he has lived and worked in four different continents: Asia, Africa, North America, and Europe. He carried out agroclimatology research at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), first at the ICRISAT Research Center in Hyderabad, India (1977 to 1983), and then at the ICRISAT Sahelian Center in Niamey, Niger (1984 to 1996). His major research interest is on macro- and micro-climatic analysis for developing strategies for sustainable agriculture around the world. He has done considerable research on climate change and climate variability and is actively involved in the promotion of seasonal- to inter-annual climate predictions in agriculture.