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Agriculture and Climate Change

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Climate change or global warming is caused by the release of 'greenhouse' gases into the atmosphere. These gases accumulate in the atmosphere and increase the effect of radiative forcing on the climate, resulting in a warming of the atmosphere. The changes in greenhouse gas concentrations are projected to lead to regional and global changes in climate and climate-related parameters such as temperature, precipitation, soil moisture, and sea level. However, the reliability of the predictions surrounding the effects of climate change is uncertain. There are no hard facts about what will definitely be the result of increases in the concentration of greenhouse gases within the atmosphere, and no firm timescales are known.

Agriculture is one sector that is important to consider in terms of climate change. The agriculture sector both contributes to climate change, as well as will be affected by the changing climate.

IMPACT OF AGRICULTURE ON CLIMATE CHANGE

Agriculture accounts for approximately one-fifth of the annual increase in anthropogenic (man-made) greenhouse gas emissions (Figure 1, IPCC 1996). The sector contributes to global warming through the emission of Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) gases.

The greenhouse gases are so called because although they allow the transmission of light reaching the earth, they block the transmission of heat (infra-red radiation) trying to escape from the atmosphere, thus trapping the heat as in a 'greenhouse.' CH_4 has the highest global warming potential that is about 300 times the potential of CO_2, and about 20 times that of N_2O. The main sources of these gases are flooded rice fields, nitrogen fertilizers, improper soil management, land conversion, biomass burning, and livestock production and associated manure management. The livestock industry alone is said to account for between 5-10 percent of the overall contribution to global warming.

Carbon Dioxide (CO_2)

Deforestation, primarily due to agricultural expansion and land speculation, remains a major source of carbon emissions. When natural vegetation is converted into agricultural land, a large proportion of the soil carbon can also be lost as plants and dead organic matter are removed. This contributes approximately a third of the total CO_2 emissions globally.

CO_2 is also released during the burning of agricultural crop waste, for example, during the burning of sugar cane stubble and rice straw. In Asia, it is a common practice to burn large quantities of crop residue, including rice straw, since the burning kills insects and other pests as well as disease-causing organisms, and neutralizes soil acidity.

To a lesser extent CO_2 is released from the fossil fuels used in agriculture production and from livestock production. High-intensity animal production has become the biggest consumer of fossil energy in modern agriculture (IPCC 1996).

Methane (CH_4)

Within the agriculture sector CH_4 is the most significant greenhouse gas released. Most of the releases come from paddy fields (91%), and less significantly from animal husbandry (7%) and the burning of agricultural wastes (2%).

The quantification of emissions from rice paddies has proven difficult as the emissions vary with the amount of land in cultivation and also depend on fertilizer use, water management, density of rice plants and other agricultural practices. Among Asian countries, China is a very large source of CH_4 emissions.

Livestock and associated manure management contributes 16 percent of the total annual production of CH_4. These emissions are a direct result of the ability of cattle and buffalo to utilize large amounts of fibrous grasses that cannot be used as human food, or as feed for pigs and poultry. Cattle and buffalo account for about 80 percent of the global annual CH_4 emissions from domestic livestock.

Nitrous Oxide (N_2O)

Much of the agriculture-based N_2O emissions come from the use of nitrogen fertilizers, legume cropping and animal waste. Some N_2O is also released during biomass burning. Many farmers spread nitrogen fertilizers on their fields to enhance crop growth. Most of the nitrogen is taken up by the crop, but some leaches into surrounding surface and ground waters, and some of it enters the atmosphere. The flux of nitrogen depends on the microbial activity in the soil. For example, wet rice absorbs only one-third of the nitrogen in the fertilizers, while upland crops about half. The rest is denitrified and diffused into the atmosphere, contributing to global warming. However, the amount of N_2O emitted is much lower in volume than the amount of CH_4 (Table 1).

How much nitrogen is lost from the soil also depends on agricultural practices such as plowing and irrigation and on temperature, soil type and weather conditions. Another mode of agriculture-based N_2O release is during the breaking of new land when nitrogen bound in the soil and vegetation escapes to the atmosphere.

OPTIONS FOR REDUCTION OF GREENHOUSE GAS EMISSIONS

Improved land use practices may work toward the reduction of greenhouse gas emissions. For instance, significant decreases in CH_4 emissions from agriculture could be achieved through better management of rice paddies. Additionally, irrigated rice has been found to produce more CH_4 than deepwater rice (Charoensilp et al. 1998). The intermittent drying of soils, and reduced land disturbances such as zero tillage and mulching will also help reduce emissions. Changes in cultivation practices, such as a shift from transplanting to direct seeding, and appropriate water management can also contribute toward a decrease in CH_4 emissions. A reduction in the use of organic materials, or a shift to the use of mineral fertilizers will help decrease emissions, together with the appropriate application of these fertilizers.

Some structural changes in agriculture production could also be beneficial and may reduce the necessity for soil disturbances, e.g., a shift from traditional to high yielding varieties, or switching from rice to some other field crops, especially cassava. However, rice is an important crop in Asia.

The recent growth in Asia of intensively managed monogastric animals such as poultry and pigs has stabilized the level of emissions generated from the livestock industry, as these animals produce less emissions than the large ruminants. Opportunities for reducing CH_4 emissions from already intensively managed cattle are somewhat limited because the CH_4 production per unit of cattle feed is small and the animals are for the most part already given a high-quality diet. However, additional CH_4 decreases are possible by improved nutrition of traditionally managed ruminant animals.

CH_4 emissions could also be reduced by improved treatment and management of animal wastes and by reducing biomass burning. These combined practices could reduce CH_4 emissions from agriculture by 15-56 percent. However, the problem is that these options usually involve a tradeoff between productivity and CH_4 reduction.

N_2O emissions could also be decreased with better treatment and management of animal wastes, and with better application of nitrogen fertilizers.

Energy use by the agriculture sector has decreased greatly since the 1970s. However, fossil fuel use in agriculture, and thus CO_2 emissions could be further reduced by, for example, minimum tillage, irrigation scheduling, solar drying of crops and improved fertilizer management.

Finally, it is important to note the role of forests and vegetation as sources and sinks of greenhouse gases. The emission of CO_2 is only one part of the carbon cycle. Assimilation of CO_2 also occurs where vegetation binds carbon into biomass. Carbon storage in the soil is important and dependent on the vegetation type. Vegetation and soils from unmanaged forests hold 20-100 times more carbon per unit area than agricultural land. Deforestation and land use changes have diminished the global storage of carbon as well as the capacity to bind CO_2, with the result that more CO_2 is being released into the atmosphere.

IMPACT OF CLIMATE CHANGE ON AGRICULTURE

The effects of climate change on agriculture will differ across Asia. Determining how climate change will affect agriculture is complex; a variety of effects are likely to occur. Changes in temperature as well as changes in rainfall patterns and the increase in CO_2 levels projected to accompany climate change will have important effects on global agriculture, especially in the tropical regions. It is expected that food productivity (especially crop productivity) will alter due to these changes in climate, and due to weather events and changes in patterns of pests and diseases. Land areas suitable for cultivation of key staple crops could undergo geographic shifts in response to climate change.

Modeling climate change impacts on regional food supplies is difficult for a number of reasons, including: 1) uncertainties in regional climate change predictions; 2) the fact that our understanding of certain agricultural processes, in particular the ‘fertilization’ response of different crops to increased levels of atmospheric CO_2, and the likelihood of altered patterns and distributions of plant diseases, weeds, insects and pests, remains incomplete; and 3) uncertainty regarding the potential for adaptation of agricultural practices.

The global aggregate effect of climate change on agricultural production is likely to be small to moderate. However, regional impacts could be significant. Crop yields and changes in productivity will vary considerably across regions. These regional variations in gains and losses will probably result in a slight overall decrease in world cereal grain productivity.

Vulnerability to climate change depends not only on physical and biological response but also on socioeconomic characteristics. Low-income populations dependent on isolated agricultural systems are particularly vulnerable to hunger and severe hardship. In these areas where populations are already barely food-sufficient, even the slightest decline in yields could be very harmful. The most negative effects are foreseen in dryland areas at lower latitudes, and in arid and semi-arid areas, especially for those reliant on rainfed, non-irrigated agriculture. Many of these at-risk populations are located in South and Southeast Asia.

Whether or not they are located in resource-poor countries, there is also a strong indication that marginal agriculture and marginal farmers may be most vulnerable both to short term variations of weather and longer term changes of climate. This may be compounded when farming is practiced at or near the edge of its appropriate climatic region. Relatively small changes in climate in these areas could substantially alter the potential for agriculture, thus creating a mismatch between existing farming systems and prevailing climatic resources for agriculture.

Impacts on rice yields in South and Southeast Asia are likely to vary greatly (Matthews et al. 1994a, 1994b). Several major studies have been conducted for countries in East Asia, including China (mainland and Taiwan), North and South Korea, and Japan (IPCC 1996). Possible climatic impacts span a wide range depending on the climate scenario, geographic scope, and study. While large changes were predicted for China, the studies conclude that to a certain extent, warming would be beneficial, with yield increasing due to diversification of cropping systems. Studies for Japan have shown that positive effects of CO_2 on rice yields would generally more than offset any negative climatic effects.

Likely Negative Effects

Climate change could influence food production adversely due to resulting:

- geographical shifts and yield changes in agriculture,

- reduction in the quantity of water available for irrigation, and
- loss of land through sea level rise and associated salinization.

Geographic limits and yields of different crops may be altered by changes in precipitation, temperature, cloud cover and soil moisture as well as increases in CO_2 concentrations. High temperatures and diminished rainfall could reduce soil moisture in many areas, particularly in some tropical and mid-continental regions, reducing the water available for irrigation and impairing crop growth in non-irrigated regions.

Changes in soils, for example, the loss of soil organic matter, leaching of soil nutrients, and salinization and erosion are a likely consequence of climate change for some soils in some climatic zones.

The risk of losses due to weeds, insects and diseases is likely to increase. The range of many insects will expand or change, and new combinations of pests and diseases may emerge as natural ecosystems respond to shifts in temperature and precipitation profiles. The effect of climate on pests may add to the effect of other factors such as the overuse of pesticides and the loss of biodiversity which already contribute to plant pest and disease outbreaks.

Agriculture in low-lying coastal areas or adjacent to river deltas may be affected by a rise in sea level. Flooding will probably become a significant problem in some already flood-prone regions of Asia such as China and further south in Eastern Asia. Decreases in productivity are most likely in these regions which are already flood-insecure. The summer monsoon is predicted to become stronger and move north-westward. However, this increased rain could be beneficial to some areas.

In addition to changes in temperature and rainfall, changes in the frequency of extreme climatic events could be damaging and costly to agriculture.

Likely Positive Effects

While increases in temperature, changes in soil moisture, and shifts in patterns of plant pests and diseases, could lead to decreases in agriculture productivity, CO_2 fertilization could lead to some increases in agricultural productivity. Atmospheric CO_2 levels are expected to have a positive effect on some plants, increasing their growth rate, and cutting transpiration rates. Crop plants may also be able to use water more efficiently under higher CO_2 levels.

Plants can be classified as C_3, C_4 or CAM, depending on the photosynthetic pathways they employ. C_3 plants, including most trees and agricultural plants such as rice, wheat, soybeans, potatoes and vegetables, are likely to benefit from extra CO_2. The results of a large number of experiments have confirmed that elevated CO_2 concentrations generally have beneficial effect on most crops. Factors known to affect the response include the availability of plant nutrients, the crop species, temperature, precipitation and other environmental factors (IPCC 1996).

C_4 plants are mainly of tropical origin and include grasses and agriculturally important crops such as maize, sorghum, millet and sugarcane. The C_4 plants are expected to benefit less from increases in CO_2. CAM plants are a variant of C_4 plants, and these plants are not likely to be affected.

Increases in temperature may also bring beneficial effects. An important effect of an increase in temperature, particularly in regions where agriculture production is currently limited due to lower average temperatures, would be the extension of the growing season available for plants, and the reduction of the growing period required by these crops for maturation. This would benefit not only high altitude farming, where increases in yields and the variety of crops grown can be achieved, but also high latitude regions, where the poleward shift of the thermal limits of agriculture would increase the productive potential. However, soils and other factors may not enable much of this potential to be realized. Higher rainfall in some areas might also enable higher production, and provide more water for irrigation.

Effects on Livestock

Climate change could affect both livestock itself and dairy production. The pattern of animal husbandry may be affected by alterations in climate, cropping patterns, as well as ranges of disease vectors. In warm regions, higher temperatures would likely result in a decline in dairy production, reduced animal weight gain and reproduction, and lower feed-conversion efficiency. More mixed impacts are predicted for cooler regions. If the length and intensity of cold periods in temperate areas are reduced by warming, feed requirements may be reduced, survival of young animals enhanced and energy costs for heating of animal quarters reduced.

Climate change would also affect livestock through its impact on disease. Incidence of diseases of livestock and other animals are likely to be affected by climate change, since most diseases are transmitted by vectors such as ticks and flies, the development stages of which are often heavily dependent on temperature. Sheep, goat, cattle and horses are also vulnerable to an extensive range of nematode worm infections, most of which have their development stages influenced by climatic conditions.

In general, intensely managed livestock systems have more potential for adaptation than mixed livestock-cropping systems. Adaptation may be more problematic in pastoral systems where production is very sensitive to climate change, technology changes introduce new risks, and the rate of technology adoption is slow. Livestock production may also be affected by potential changes in grain prices brought on by changing yields in some areas, or by changes in rangeland and pasture productivity.

For developing countries, livestock are better able to survive severe weather events such as drought than are crops, and therefore a better option in terms of income protection and food security.

PREPARING FOR CLIMATE CHANGE

In the future, population growth without significant improvements in yield rates will mean more land must be used for rice cultivation and other crop production, and an increase in the number of farm animals. These factors will lead to an increase in CH_4 and other greenhouse gases released to the atmosphere.

Adjustments will be necessary in order to counterbalance any negative impacts of a changing climate. Farmers must have the ability to adjust to changes by adapting farming practices. Adaptation, such as changes in crops and crop varieties, improved water management and irrigation systems, and changes in planting schedules and tillage practices will be important in limiting the negative effects and taking advantage of the beneficial effects of changes in climate. More efficient use of mineral fertilizers and other adjustments in agricultural practices could also act to counteract the effects of climate change.

Various types and levels of technological and socioeconomic adaptations to climate change are possible. The extent of adaptation depends on the affordability of such measures, particularly in developing countries. Recent national studies show that the increased costs of agricultural production under climate change scenarios would be a serious economic burden for some developing countries. Other important factors will be access to know-how and technology, the rate of climate change, and biophysical constraints such as water availability, soil characteristics and crop genetics.

The biggest problem arises with the uncertainty surrounding the effects of climate change and the unknown time frames. It is still uncertain who will be most impacted by the changes, and this fosters a lack of initiative for taking action now to mitigate the effects of climate change. Thus, education will be a necessary factor in the preparation for climate change.

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