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The Effects of Global Climate Change on Agriculture

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Abstract: Climate is the primary important factor for agricultural production. Concerning the potential effects of climatic change on agriculture has motivated important change of research during the last decade. The research topics concentrate possible physical effects of climatic change on agriculture, such as changes in crop and livestock yields as well as the economic consequences of these potential yield changes. This study reviews the effects of climate change on agriculture. The main interests are findings concerning the role of human adaptations in responding to climate change, possible regional impacts to agricultural systems and potential changes in patterns of food production and prices.

Key words: Climate change · Agriculture · Regional effects · Adaptations

INTRODUCTION

Climate is an important factor of agricultural productivity. The fundamental role of agriculture in human welfare, concern has been expressed by many organizations and others regarding the potential effects of climate change on agricultural productivity. Interest of this matter has motivated a substantial body of research on climate change and agriculture over the past decade. Climate change is expected to agricultural and livestock production, hydrologic balances, input supplies and other components of agricultural systems.

Climate change is caused by the release of 'greenhouse' gases into the atmosphere. These gases accumulate in the atmosphere, which result global warming. The changes in global climate related parameters such as temperature, precipitation, soil moisture and sea level. However, the reliability of the predictions on 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, which 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.

Agriculture and climate: Agricultural facilities contribute approximately 20 % of the annual increase in anthropogenic greenhouse gas emissions [2]. This sector contributes to global warming through carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) gase emissions.

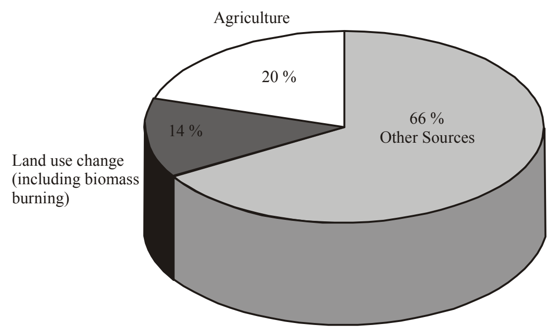

Fig. 1: Contribution to global warming [2]

The greenhouse gases 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, which is about 300 times the potential of CO_2 and about 20 times that of N_2O. The main gase sources are nitrogen fertilizers, flooded rice fields, soil management, land conversion, biomass burning and livestock production and associated manure management. The livestock industry accounts approximately from 5% to 10% of the overall contribution to global warming [2].

Carbon dioxide (CO_2): Primarily, deforestation due to agricultural expansion and land speculation was caused

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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 event contributes approximately a third of the total CO_2 emissions globally. Therefore, CO_2 is also released during the burning of agricultural crop waste, for example, during the burning of cereal straw, sugar cane stubble and rice straw. In many countries, it is a common practice to burn large quantities of crop residue, which results killing of insects and other pests as well as disease-causing organisms and neutralizes soil acidity. To less extent, CO_2 is released from the fossil fuels used in agricultural production and from livestock production. Nowadays, high-intensity animal production has become the biggest consumer of fossil energy in modern agriculture [2].

Methane (CH_4): Methane (CH_4) is the most significant greenhouse gas released within the agriculture sector. Most of the methane releases come from paddy fields (91%) and less significantly from animal husbandry (7%) and the burning of agricultural wastes (2%). The quantification of rice paddy emissions has proven difficult as the emissions vary with the amount of land in cultivation, fertilizer use, water management, density of rice plants and other agricultural practices. Among to many Asian countries, China is a very large source of CH_4 emissions. Livestock and associated manure management causes 16% of the total annual production of CH_4. These emissions are a direct result of the ability of buffalo and cattle to utilize large amounts of fibrous grasses that cannot be used as human food, or as feed for pigs and poultry.

Buffalo and cattle contribute about 80% of the global CH_4 emissions from domestic livestock annually.

Nitrous Oxide (N_2O): Most of the agriculture-based N_2O emissions come from nitrogen fertilizer usage, legume cropping and animal waste. Some N_2O emissions are also released during biomass burning. Many farmers use nitrogen fertilizers on their fields to enhance crop growth. The crop takes up most of the nitrogen, but some of them leach into surrounding surface and ground waters and some of it enters the atmosphere. The nitrogen flux 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 of nitrogen is denitrified and diffused into the atmosphere, which is contributing to global warming. However, the amount of N_2O emitted is much lower in volume than the amount of CH_4 (Table 1).

Table 1: Methane emissions from agricultural and other sources in selected Asian countries, 1990 ('000' tons) [5].

Country	Livestock	Other agriculture[a]	Waste	Total	Nitrous oxide
Bangladesh	520	473	74	1335	3
China	8940	18400	790	33830	1100
Indonesia	864	2039	--	3746	2769
Japan [b]	520	276	400	1316	54
Kazakhstan	939	--	1763	3555	7
Mongolia	301	--	15	329	0
Nepal	370	542	--	996	1
Philippines	315	559	138	1290	8

[a]Including flooded rice fields

Reduction of greenhouse gas emissions: Improved land use applications may work toward the reduction of greenhouse gas emissions. For instance, significant decreases of CH_4 emissions from agriculture could be achieved through better management of rice paddies. Additionally, irrigated rice fields have been found to produce more CH_4 than deepwater rice. The intermittent soil drying and reduced land disturbances such as zero tillage and mulching will also help reduce emissions for these agricultural lands. Changes of cultivation practices, such as a shift from transplanting to direct seeding and appropriate water management can also contribute decreasing of CH_4 emissions. The reduction of organic material and mineral fertilizer use will help decrease emissions, together with the appropriate fertilizers application. Some changes in agriculture production could be beneficial and can 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. However, rice is an important crop in Asia [1].

The intensively managed monogastric animals such as poultry and pigs have stabilized the level of emissions generated from the livestock industry, as these animals produce less emission than the large ruminants in the Asian countries. The reduction of CH_4 emissions from 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. Therefore, additional CH_4 decreases are possible by improving nutrition of traditionally managed ruminant animals. Improving treatment and management of animal wastes and by reducing biomass burning could also reduce CH4 emissions. These practices could reduce CH_4 emissions by 15-56 percent from agriculture. However, this problem is that these options usually involve a tradeoff between productivity and CH_4 reduction. N_2O emissions could also be decreased with better application of nitrogen fertilizers and with better treatment and management of animal wastes.

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

The role of forests and vegetation is important as sources and sinks of greenhouse gases. The CO_2 emission is only one part of the carbon cycle. Assimilation of CO_2 also occurs where vegetation binds carbon into biomass. Carbon storage is important and dependent on the vegetation type in the soil. Vegetation and soils of unmanaged forests hold 20-100 times more carbon per unit area than agricultural lands. The land use changes and deforestation 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. The amount of nitrogen is lost from the soil also depends on agricultural practices such as irrigation and plowing and on temperature, soil type and weather conditions. Another agriculture-based N_2O release is during the breaking of new land when nitrogen bound in the soil and vegetation escapes to the atmosphere.

Impact of climate change on agriculture: The climate change effects on agriculture will differ across the world. Determining how climate change will affect agriculture is complex; varieties 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 crop productivity will alter due to these changes in climate and due to weather events and changes in patterns of pests and diseases. The suitable land areas for cultivation of key staple crops could undergo geographic shifts in response to climate change.

Modeling of climate change impacts for regional food supplies are difficult for a number of reasons, including:

- Uncertainties in regional climate change predictions;
- 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
- Uncertainty regarding the potential for adaptation of agricultural practices.

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

Vulnerability of climate change depends on physical, biological and socioeconomic characteristics. Low-income populations dependent on isolated agricultural systems are particularly vulnerable to hunger and severe hardship. These populations are already barely food-sufficient, even the slightest decline in yields could be very harmful in these areas. 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, Southeast Asia and Africa.

There is also a strong indication that marginal agriculture and farmers may be most vulnerable both to short term variations of weather and longer term changes of climate whether or not they are located in resource-poor countries. This may be compounded when farming is practiced at or near the edge of its appropriate climatic region. Relatively small climate changes could substantially alter the potential for agriculture, thus creating a mismatch between existing farming systems and prevailing climatic resources for agriculture in these areas [3, 4].

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.

The possible negative effects

Climate change could influence agricultural 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.

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

The changes in soil properties such as the loss of soil organic matter, leaching of soil nutrients, 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 change or expand and new combinations of diseases and pests 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 [5].

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

The possible positive effects: The some changes in soil moisture, increases in temperature and shifts in patterns of plant diseases and pests could lead to decreases in agriculture productivity. However, 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 C3, C4 or CAM, depending on the photosynthetic pathways they employ. C3 plants such as potato, rice, soybean, wheat and vegetables, including most trees are likely to benefit from extra CO_2. The results of many 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 [2].

C4 plants are mainly tropical origin and include grasses and agriculturally important crops such maize, millet, sorghum and sugarcane. C4 plants are expected to benefit less from increasing of CO_2. CAM plants are a variant of C4 plants and these plants are not likely to be affected.

Increasing of temperature may also bring beneficial effects in some areas of the world. An important effect of an increase in temperature, particularly where agricultural production is currently limited due to low 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 livestock and dairy production. The pattern of animal husbandry may be affected by alterations in climate, cropping patterns, as well as ranges of disease vectors. The higher temperatures would likely result in a decline in dairy production, reduced animal weight gain and reproduction and lower feed-conversion efficiency in warm regions. More mixed impacts are predicted for cooler regions. If the intensity and length 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 could also affect livestock by 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. Cattle, goat, horse and sheep 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: Population growth will mean more land must be used for rice cultivation and other crop production and an increase in the number of farm animals without significant improvements in yield rates in the future. These factors will lead to increase of 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 levels and types of technological and socioeconomic adaptations to climate change are possible. The extent of these adaptations depends on the affordability of such measures, particularly in developing countries in the world. Recent studies show that the increase 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 soil characteristics, crop genetics and water availability [6].

The biggest problem occurs 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.

CONCLUSIONS

There will be both winners and losers, with some areas benefiting from increases in agricultural production as a result of climate change while other areas suffer decreases in the world. Climate change could also affect the welfare of economic groups differently.

The regional increases and decreases associated with climate change are not expected to result in large changes in food production over the next century on a global scale. Therefore, impacts on regional and local food supplies in some low latitude regions could amount to large percentage changes in current production. Climate change may impose significant costs for these areas. In addition, warming beyond that reflected in current studies may impose greater costs in terms of total food supply. Projections from most economic studies show substantial economic losses as temperature increases beyond the equivalent of a CO_2 doubling. This reinforces the need to determine the magnitude of warming which may accompany the CO_2 buildup currently under way in the atmosphere.

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