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CLIMATE CHANGE AND AGRICULTURAL PRODUCTION

E. E. OFFIONG AND P. B. ITA

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ABSTRACT

The threat of global environmental change has tended to focus on the possible impacts of a changing environment on agriculture and the implications for global food security. From a policy viewpoint, however, it is also difficult to understand the level to which agriculturally related activities may contribute to global-scale environmental change and the extent to which policies to prevent, mitigate, or adapt to environmental change may affect agriculture and hunger. These issues are likely to become especially important in making decisions not only about how to reduce the magnitude of human perturbations to the environment but also about how to improve both food security and environmental quality in the more crowded world of today and the future. This paper highlights the close linkages between agriculture, environment, and hunger in the past, reviews some of the ways in which the global food system interacts with the global environment in the present, and raises some questions regarding agriculture, environment, and hunger in the future. The primary focus of the paper is on global-scale changes in the environment, including possible changes in the earth's climate to enhance environmental sustainability of agricultural products in our society.

INTRODUCTION

Man relied solely on hunting, fishing, and gathering for food for most of its two million years of existence. Agriculture the domestication of plants and animals appeared only about 10,000 years ago, roughly coincident both with a period of widespread climatic and ecological fluctuations (Matthews et al. 1990) and with an acceleration of population growth. Whether the spread of agriculture was a trigger for more rapid population growth or was itself a response to increasing population or environmental pressures remains a controversial question. For instance, anthropologic evidence, including indicators of nutritional status derived from skeletal remains, suggests that the health of hunters and gatherers tended to be better than that of subsequent farmers in the same region (Cohen, 1990).One explanation for this observation is that agriculture and related technological and social innovations may have emerged initially as a way to compensate for an unreliable or declining resource base arising from population pressures, environmental fluctuations, or both. In a sense, such "stress" models of the origins of agriculture suggest that hunger and a changing environment may have helped motivate the development and adoption of agriculture, even though in the short term agriculture apparently provided less output per unit of labor input than hunting and gatherings (Matthews et al. 1990). Environmental and other stresses leading to hunger, therefore, would have been an impediment to the development of agriculture. As in the stress models, hunger and malnutrition should still have decreased with increasing success in agriculture. These alternative models of the origins of agriculture are instructive because they highlight the intimate links that may have persisted for many millennia among environmental fluctuations, agriculture, and human welfare. In the long term, agriculture has clearly brought the potential for larger populations, expanded exploitation of climatic and other natural resources, and reduced vulnerability to many forms of environmental fluctuation, such as drought and other extremes of weather and climate. At the same time, however, agriculture and the increasing globalization of food systems may have increased vulnerability to other problems, such as market failures and the unequal distribution of food. For example, nutritional levels as indicated by estimates of human height have been marked by variations of comparable magnitude on time scales of 50-l0,000 years (Kates and Millman, 1990). Although it seems likely that environmental factors are now relatively less important contributors to such variations than they were in past millennia, human history provides no guarantee that new forms of environmental change might not emerge as dominant influences on human nutrition and well-being.

The Global Food System, the Environment, and Hunger

Growth in food production in recent decades has resulted primarily from increased crop yields per unit of land and to a lesser extent from expansion of cropland.. These improvements in yield stemmed from a combination of increased agricultural inputs, more intensive use of land, and the spread of improved crop varieties Concurrent with these production and yield increases has been significant growth of world trade in food and agriculture. Food imports grew from 8 percent of total world production to 12 percent in the recent times. Imports of nitrogenous and phosphate fertilizers grew by more than 27 percent in tonnage between 1982-1983 and 1985-86 and constituted 20-25 percent of world consumption(FAO,1987). One consequence of this "emerging" global food system may be a decrease in local vulnerability to famine in developing countries through increased reliance on food imports including food aid, but an increase in vulnerability to problems stemming from international trade and integration into the global economy (Millman et al. 1990).

E. E. Offiong, Department of Forestry and Wildlife Resources Management, University of Calabar, Calabar, Nigeria
P. B. Ita, Department of Forestry and Wildlife Resources Management, University of Calabar, Calabar, Nigeria

Crop Production and Fertilizer Application

Various forms of agricultural production may lead to significant trace gas emissions. Tilling of soils permits oxidation of organic matter and producing CO2. Even with no application of nitrogen fertilizers, cultivated soils may emit large amounts of N2O, perhaps as much in the aggregate as that released from fertilized fields. Application of fertilizers increases N2O release by plants, although emission rates vary greatly with soil conditions (Harriss, 1989). As noted previously, world fertilizer consumption is growing rapidly, and its use is widespread in a variety of different socioeconomic and technologic settings (Kates et al, 1990). Some 20-30 percent of CH4 emissions result from anaerobic production in the paddy fields used in wet rice production. Rapid expansion of paddy area and increasing cropping intensities have helped accelerate growth in CH4 emissions to some 1 percent per year (UNEP, 1989). Measured atmospheric concentrations are increasing at or near this rate, or about 0.8-1.0 percent per year as of the mid-1980s (UNEP, 1989; WRI ,1990).

Use of Water

Agriculture is the largest single consumer of fresh water, although its share of total use has declined significantly during the past century and is expected to continue to decline through the year 2000. On a global basis, total water withdrawals for all purposes constitute less than one tenth of total river runoff, and consumptive uses only one twentieth of this total. Withdrawal rates are much higher in some river basins, leading to significant regional-scale impacts on water level and quality in rivers, lakes, and enclosed seas such as the Aral (WRI, 1990). Irrigation has led to high salinity and water logging in millions of hectares of irrigated land in arid and semiarid areas of South Asia, the Middle East, the United States, and the U.S.S.R. Water quality and quantity problems are critical from the viewpoint of human health and environmental quality on local and regional scales, and they undoubtedly have global-scale implications for food production and food security especially if projected hydrologic and sea level changes do occur. However, they do not as yet appear to have significant influences on the likelihood or timing of global environmental change. This conclusion could change if various proposed mechanisms for biogeochemical feedback prove significant. Other aspects of the food system expected to have relatively limited impacts on the global environment. In developing countries, fertilizers require the highest commercial energy inputs, followed by machinery and irrigation. The Agriculture: Toward 2000 study (FAO, 1981) assumed that significant increases in commercial energy application will be needed to boost agricultural yields and farm earnings. Its two scenarios for the year 2000 project an average increase of 7.5 percent per year in commercial energy use in agriculture in 90 developing countries, resulting in more than a quadrupling of energy use between 1980 and 2000. Growth rates in fertilizer consumption in the early 1980s were somewhat below this rate of increase, averaging 6.2 percent per year between 1981-1982 and 1985 -1986 (FAO, 1988). Given the high costs of importing fertilizers and fossil fuels, it seems likely that developing countries may increasingly turn to alternatives such as biogas and animal power (Goldemberg et al. 1988; Sinha, 1986). Biogas consists mostly of methane and hydrogen gases produced by anaerobic fermentation of crop and animal wastes. Usable nitrogen, phosphorus, and potassium are byproducts. Of course, widespread use of biogas would presumably lead to significant methane and N2O emissions.

Existing Production Be More Efficiently Use

The present global food system entails a high degree of waste of potentially usable food products. Estimates of "postharvest" losses that is lost between harvest and delivery of food at the retail level range from 10 to 30 percent or more (BOSTID,1078). However, large losses also occur both before harvest and after food distribution to retail outlets. Poor utilization of food calories after food has been consumed may also result in the effective waste of food. For example, even a mild episode of diarrhea in adults may lead to a loss of food calories equivalent to 1-2 percent of annual food requirements, and diarrhea and associated infections among infants and small children can result in weight loss equivalent to 5-10 percent of annual food requirements. Estimates that small children in the developing world average on the order of three episodes of diarrhea per year or more than 1.4 billion episodes annually is around 1980. Intestinal parasites such as Schistosoma, Giardia lamblia, Ascaris lumbricoides, Trichuris trichiura, Strongyloides stercoralis, and hookworm may also cause or enhance malnutrition through a combination of reduced food intake, malabsorption, anemia, and other nutrient loss (TromkinsandWatson,1989).

Table1: Shares and Trends in Energy Consumption in the Food and Fibre Sector

Activity	Shares of Total Energy Consumption (%)		Change in Consumption (%)
	C. 1970	1980	1970 -1980
Farm Production	22.5	21.1	4.2
Farm family living	11.9	9.6	10.0
Processing of Food and related Products	27.9	29.8	19.8
Marketing and distribution	17.9	19.0	18.8
Input manufacturing (six industries)	19.8	20.5	11.3
Total	100	100	

Source:Dancan and Webb (1980)

Large effective losses of food calories also occur because of inefficiencies in converting raw animal feed into edible animal food products. Net conversion efficiencies observed in breeding populations of farm animals range from 3 to 6 percent for sheep and beef cattle to 11-12 percent for pig meat, milk and eggs (Holmes, 1980). Overall efficiencies are at best about 17 percent, that is, about 600 calories of feed are needed to produce 100 calories of animal products. Of course, animal production may produce foods with higher contents of protein, minerals, and fats than the raw feed could have provided and may also generate other benefits such as the work performed by animals and a mechanism for storing food and household assets. Nevertheless, these estimates of losses and inefficiencies suggest that there may be substantial room for improvement in the delivery of nutrition, which is presumably one of the primary objectives of the global food system. As recognized in the energy field in recent decades, it is important to focus on the end use efficiency of production in this case, the level of food production and associated inputs needed to provide a desired set of "services," such as a minimum number of calories per person each day and some degree of dietary quality and diversity. The most practical and cost effective way to increase delivered nutrition may not be to increase gross production but to reduce pre- and post-harvest losses, find lower-input methods for producing high-protein and other desired food products, and improve the capability of households and individuals to process and utilize food efficiently. A major benefit of such, a "food conservation" strategy akin to present-day energy conservation efforts--should be the overall reduction of the environmental stresses stemming from use of agricultural inputs, disposal of agricultural wastes, and other food-system activities. Some of the stages in the food system where improvements in the end use efficiency of agriculture may be possible. More effective utilization of agricultural inputs and reduction of "on-farm" losses a major focus of traditional agricultural research--constitute one area for efficiency improvements. This includes methods for more precise and timely application of fertilizers, pesticides, herbicides, and irrigation water and reductions in crop damage and loss caused by pests, diseases, weather, and harvesting method. Improvements in the efficiency of "secondary" production, that is, production of more desirable food products using primary foodstuffs as inputs are also possible through more efficient breeds of animals, reduced exposure of animals to adverse environmental conditions, diseases, and parasites, and use of feed substitutes that could not otherwise be used for human foods. In the long run, it may well be possible to eliminate the animals and to produce desired foodsor nutritionally and aesthetically equivalent substitutes through sophisticated food processing or even direct culturing of animal cells. The former is essentially what Buddhist vegetarians have done for centuries in creating meat like foods from soy and other plant products. Other opportunities for improving the efficiency of food use include improvement in postharvest food storage, more efficient food preparation at the household level, and improvements in the health of individuals to minimize losses caused by diarrhea, parasites, and incomplete digestion. For example, new storage methods such as a hermetically sealed "cube" developed by the Volcani Institute in Israel promise reduced grain losses caused by pests and moisture while at the same time lowering pesticide use (Donahaye, 1990). In the United States, a number of organizations utilize volunteer labor to "glean" crops missed by mechanical harvesters; thereby salvaging foodstuffs that would other wise go to waste. More widespread use of oral rehydration therapy, promotion of breastfeeding, and other efforts to combat diarrheal-related disease help reduce nutritional losses even after food consumption (Grant, 1990). Improving overall end use efficiency will not only require recognition of opportunities of this kind, but also-as evident from ongoing efforts to promote energy conservation around the world-restructuring of market and regulatory incentives, for example, to reflect more realistically the environmental "externalities" of agricultural production and to remove explicit and implicit subsidies of limited resources and entrenched technologies (NRC, 1989). Resulting changes in markets and food prices would undoubtedly have significant distributional effects, both between and within countries but how levels and patterns of hunger might change is difficult to predict.

Can Production Be Increased Without Increasing Impacts on the Global Environment?

As noted earlier, efforts to improve the efficiency of agricultural production and the utilization of food products may themselves lead to reduced levels of pollutants and resource use. However, significant increases in total food production are still likely to be needed in the future, in part because efficiency improvements could easily take decades to implement. An important issue, therefore, is whether future increases in production are possible with lower levels of impact on the global environment. From this perspective, expansion of cropland appears to have a relatively high level of impact. Much of the untapped reserve of available land is covered with tropical forest, so that agricultural development would likely lead to net reductions in biomass. Soil quality is generally poor, so that large amounts of fertilizer, energy, and other inputs would probably be necessary to maintain yields and prevent soil erosion. Some of these lands are in areas of poor or erratic rainfall, so that irrigation may be required but even with irrigation, production in these areas may be especially sensitive to any environmental changes that do occur. Similarly, expansion of rangeland for livestock production is also likely to have high levels of impact, especially to the extent that tropical forests are replaced and overgrazing occurs, contributing to land degradation, soil erosion, and desertification. Increased livestock numbers may of course increase methane emissions; unless new breeds of animals with lower emission rates are introduced. Increased production on existing cropland has in the past been achieved primarily through more intensive application of fertilizer, expansion of irrigation, and improved crop varieties. As noted previously, the first option may entail releases of N_2O and the second, especially for wet rice production, releases of methane. Clearly, new methods for providing nitrogen such as intercropping with nitrogen-fixing plants or genetic manipulation to add nitrogen-fixing abilities to crops could significantly reduce the use of nitrogen fertilizers. Reducing methane emissions from wet rice production is more problematic, since present methods for dry rice production have significantly lower yields (Sanchez, 1989); however, new strains of rice may reduce the need for flooding and therefore lower emissions of methane (WRI ,1990). The third option, improved crop varieties, will depend greatly on the pace and direction of agricultural research, the availability and diversity of genetic resources, advances in genetic manipulation, success in disseminating new varieties, and other factors. Concern is growing over recent trends towards more modest yield gains or even small declines-in areas such as the United States and Pakistan (Ruttan, 1989). On the other hand, (Pimentel et al, 1989) pointed out, present-day agriculture relies on only 15 species of plants and 8 species of livestock for 90 percent of world food production, out of millions of plant and animal species and at least 75,000 edible plants. Both improved forms of existing foods and entirely new foods are possible Triticale, for example, is a hybrid of wheat and rye that performs significantly better than wheat in areas of marginal soils and climate (WRI,1990). Alternative agricultural methods that deserve more attention from the viewpoint of potentially lower environmental impacts include various forms of low-input and rotational cropping methods such as agroforestry and alley cropping, trickle or drip irrigation methods, integrated pest management, perennial grain crops, low-intensity animal production systems, higher-yield forage crops, and aquaculture (Crosson and Rosenberg1989;NRC1989;Pimentel1989;WRI,1990).

Low-input alternatives for corn production are estimated to produce roughly twice the food-energy output from a given energy input as conventional corn production, primarily because of lower fertilizer requirements. Trickle irrigation reduccs percolation and evaporative water losses, helps to prevent salinization, and can save energy used in lifting and delivering water (Crosson and Rosenberg ,1989). Possibilities exist to improve the quality and yield of forage crops, including reduction in cellulose content, which would presumably lower methane emissions by ruminants (NRC, 1989). Further assessments of the potential environmental benefits and tradeoffs---of techniques of this kind are clearly warranted.

Food System Adapt to Environmental Change

The potential impacts of environmental change on the global food system and the responses and adaptations that could mitigate such impacts are not well understood. Research to date has focused largely on a small set of environmental changes (e.g., in atmospheric CO2 and in temperature and precipitation patterns), a narrow range of agricultural impacts (on grain yields), a limited repetoire of technologic and socioeconomic adjustments (increased irrigation), a sprinkling of countries and regions (the United States or climatically "marginal" regions), and a relatively short time frame (impacts on present-day agricultural technologies and food systems). Many important issues have been addressed only in qualitative terms. For example, little is known about the combined impact of climatic changes, higher levels of atmospheric CO2, increased ultraviolet radiation, and increasing acid deposition and air pollution on crops, animals, and plant and animal pests and diseases (Chen 1989; Oppenheimer, 1989). Only limited attention has been given to potential changes in international agricultural competitive advantage, differential vulnerability to environmental change, implications for food access and hunger within countries, and the full range of technologic, economic, and social responses available to farmers and other socioeconomic units (Chen 1990; Crosson 1989; Liverman 1990; Mabbutt, 1989). Not much is known about the potential impacts of changing atmospheric and oceanic conditions on marine ecosystems and fisheries, including possible effects of increased ultraviolet radiation on krill and other Antarctic species (Bakun 1990; Chen and WRI, 1990). Even more poorly understood are the many complex links and feedbacks that are likely to exist between (a) food system activities that contribute significantly to environmental change, (b) food system activities that would be directly or indirectly affected by environmental change, (c) impacts in related activities such as energy production and transportation, and (d) actions taken to reduce or modify the effects of any of these activities. For example, a traditional response to climatic variability has been to increase irrigation but the latter often requires large amounts of energy to move irrigation water and may lead to increased methane emissions. Irrigation also competes for water supplies with municipal and industrial water demands and evaporative losses all of which could grow even faster than expected in a warming climate. Without enough water, both the effectiveness of other agricultural inputs, such as fertilizers, and the yield benefits from CO2 enrichment may be reduced (Schneider and Rosenberg, 1989). Complex linkages of this kind may exist throughout the food system. Higher air temperature and humidities imply increased refrigeration loads at the same time that potentially less energy-efficient refrigerants may be in widespread use to limit emissions of CFCs thought to damage the stratospheric O3 layer. Increased prices for fossil fuels or restrictions on fossil fuel use would increase input costs throughout the food system but should, among other things, lower crop damage caused by air pollution and acid deposition. Efforts to promote production of biomass fuels as a substitute for fossil fuels and reforestation to sequester atmospheric CO2 could lead to displacement of food production, reduced income and standards of living on the part of farmers and laborers, and increased levels of environmental stress and resource degradation. Biogas production, which may make sense in terms of reduced fossil fuel and fuel wood. Demands and increased fertilizer availability could increase CH4 and N2O emissions. In developing new crop varieties, complex trade offs will be necessary to deal with changes in climatic variability and stresses, altered patterns of plant pests and diseases, changing availability of various agricultural inputs, and evolving food production, harvesting, storage, and processing methods. However, the genetic diversity upon which new varieties depend may itself be threatened by deforestation and other land use changes and by local, regional, and global environmental change. Thus, it is clear that the problem of providing more food to more people during the next several decades is greatly complicated by the threat of global environmental change. Measures to prevent such change or to improve adaptive capabilities could conceivably have effects on the global food system as profound as some of the expected effects of global environmental change itself and whether larger or smaller numbers of people would end up hungry is difficult to predict. For example, efforts to protect forests and species diversity might well limit access to important common resources on the part of landless and land--short population in developing countries. Limits on livestock and irrigation and increases in energy prices could affect the livelihood and food security of billions of people in both rural and urban areas. Moreover, since preventive measures may not succeed in preventing environmental change immediately and completely, it is certainly plausible that the global food system might have to adapt not only to significant changes in energy and fertilizer consumption, land use, and production methods, but also to some degree of local, regional, and global environmental change. Developing robust alternatives that simultaneously (a) stabilize or reduce contributions on the part of the global food system to global environmental change and (b) permit increased levels of delivered nutrition to the growing world population in the face of substantial environmental and other uncertainties will not be an easy task. However, failure to develop such alternatives could have dire consequences for hunger and world food security. To draw a lesson from the origins of agriculture, increased hunger could be inevitable if human society is only able to adapt under conditions of stress or evolutionary pressure. Instead, it may well be necessary to respond now to the perceived threat of global environmental change and to find and implement solutions before any changes or their adverse impacts become too damaging or irreversible. This is likely to be the best hope for reducing hunger and maintaining a livable environment in the more crowded world of the future.

CONCLUSION

The global change is real judging from the decrease in the rainfall and number of rainy days, increase in temperature and irregular relative humidity as collected over three decades. It is attracting concerns as a result of its perceived threat to the earth's environment and food security. Human activities through deforestation, logging, farming, urbanization, and construction and population explosions are some of the factors contributing to climate change. Forest/ land use have tremendous potentials to serve as tools in combating climate change, create sustainable economic and social development and protect people's livelihood through food supply and environmental protection. This is possible through forest conservation, afforestation, reforestation and sustainable forest management.

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