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Agriculture and Food Systems

by

M.S. Swaminathan

President, World Conservation Union (IUCN)

National Academy of Sciences of India

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M.S. Swaminathan
President,
National
Academy of
Sciences of
India

1. The Changing Scenario

The unfavourable weather of 1972 and 1974 in the middle latitudes and the failure of monsoons in the sub-Saharan countries provided the backdrop to the discussions on the impact of climate on global food security during the decade of the seventies ~~at the first World Climate Conference in 1979~~. The eighties witnessed both uncomfortable food gluts in some parts of the world and acute food scarcity in others, particularly in the Sahelian region of Africa. According to the State of Food and Agriculture Survey of FAO (1989), the years 1987 and 1988 witnessed a marked turnaround in the world agricultural and food security situations. Some important agricultural commodity markets shifted from having a global surplus to a situation of relative scarcity, and international prices increased significantly, after having fallen to their lowest levels in many years. ~~FAO's March 1990 Food Outlook predicts that the cereal supply situation will remain tight in 1990/1991.~~ Even assuming normal weather, 1990 production is unlikely to be large enough to meet trend consumption in 1990/1991 and allow stock replenishment. With stocks at their lowest level for many years, adverse weather would have serious consequences. ~~(Figure 1)~~

The past 10 years have witnessed great progress in methods of both monsoon forecasting and climate impact assessment. In addition several basic shifts have occurred in our approach to the analysis of the inter-relationships between climate and food production systems.

First, while in the past the focus was on the impact of climate on human activity, the current concern is more on the impact of human activity on climate. Second, while studies on the possible impact of a cooling trend in the world's climate on crops like maize and soyabeans attracted interest in the seventies (Thompson, 1975), the interest now is more on interactions among CO2 concentration in the atmosphere, temperature, precipitation and biological productivity. The feed-back linkages among climate change, crop yields and spatial shifts of crop potential are being investigated in several countries and in several major crops (Parry, Contes and Konijn, 1989). There have been apprehensions about a possible increase in the warming of the El Nino current, thought to be a major contributory factor to droughts in Brazil, India, Australia and the Sahelian region of Africa during 1982-1983, in case of a rise in world temperature.

Third, with an increase in human population, precipitation patterns are assuming great significance not only for stability of crop production but also for drinking water security for human and animal populations. In spite of a growing awareness of the need to stabilise human population, a global annual population growth of 1.6 to 1.7% is still occurring. This would lead to a net increase of 90 million more people to feed each year. The course of fertility decline during the current decade will largely determine whether the world's ultimate population reaches 10 billion, 15 billion or some other plateau. Demographically the industrialised and developing countries will differ not only in the absolute size of the population but also in the age composition. For example, in India about 70% of the population will be below the age of 35 in the year 2000, while in the United States a similar percentage will be above the age of 50. In many developing countries, over 60% of the populations will be rural, depending for their livelihood security on crop husbandry, animal husbandry, fisheries, forestry and agro-industries.

Finally, an important development between 1979 and 1990 is the addition of the dimensions of ecological sustainability and equity to the goal of enhancing productivity and profitability in research and development programmes designed to improve major farming systems. Equity is now defined in two time dimensions: a) intra-generational equity safeguarding the interests of those living today, and b) inter-generational equity safeguarding the interests of the generations yet to be born, i.e. a time-dimension of infinity. Agricultural scientists are thus now faced with the task of combining ecological sustainability, economic viability and intra- and inter-generational equity in technology development and dissemination.

2. Nature of Food Security Challenge

During the seventies, the major food security challenge was quantitative adequacy or physical access to food supplies. During the eighties also, physical access continued to be an important problem in some years and in some regions. For example, the 1988 harvest worldwide was about 5% less than the 1985 harvest. The Sahelian food famine of the mid-eighties also underlined the precarious food situation in many African countries where per capita food production was declining steadily (~~Table 1~~)

On the other hand, the spread of modern technologies, particularly irrigation, fertiliser and high yielding seeds of cereals helped the densely populated countries of South and South-east Asia to keep growth rates in food production above that of the population. In such countries the food security challenge became one of economic access to food or one of lack of entitlements to use the terminology of Amartya Sen (1981). Sen (1987) has also emphasised that a public distribution system geared to the needs of the vulnerable sections of the Community can bring the essentials of livelihood within easy reach of people whose lives may remain otherwise relatively untouched by the progress of real national income (~~Table 2 and 3~~)

Swamiathan (1987) has stressed that while dealing with food systems the following three evolutionary steps should be recognised.

- a) Food Self-sufficiency which implies adequate supplies in the market;
- b) Food Security which involves both physical and economic access to food; and
- c) Nutrition Security which implies physical and economic access to a balanced diet and safe drinking water for all people at all times.

Many developing countries including India which have experienced a "green revolution" are still in the first stage of this evolutionary process.

Kates et al (1989) have calculated that the biosphere at current production level could support about 6 billion people, if the diet of all human beings is vegetarian. If 15% of calories were derived from animal products, planet earth could support about 4 billion people.. If 25 % of calories are derived from animal products, the total population which could be supported would fall to 3 billion. Fish production is the most efficient from the point of view of conversion of plant calories into animal protein. In this context, FAO's (1989) report that the world fish catch levelled off in 1987, after ten years of steady growth is a matter for concern. The world harvest of fish in 1987 was 92.7 million tons, as compared to 92.4 million tons in 1986. El Niño warm currents in the Southeastern Pacific substantially reduced catches of some pelagic species in South America. In contrast to this trend, consumer demand for fish is likely to increase by 28.4 million tons by the year 2000. Therefore, an integrated approach to coastal and inland aquaculture and capture fisheries will be important.

3. Challenges ahead:

Sustainable advances in biological productivity are essential for meeting the needs of both enhanced agricultural production and greater agricultural diversification. For this purpose we need new agricultural technologies capable of raising the population carrying capacity of land and water. Such techniques will have to be tailored to the following major land use systems:

a) Mountain eco-systems, where damage upstream would have serious repercussions on downstream agriculture (e.g. Himalayas and the Indo-Gangetic agricultural region),

b) Coastal eco-systems, where it will be necessary to promote the integrated management of land and sea surface,

c) Sustainable intensification areas (could also be referred to as "green revolution" areas) which, with appropriate support from maintenance and anticipatory research, can sustain intensive output of crops and livestock at high and rising levels of productivity,

d) Semi-arid areas, where inadequate or unreliable rainfall coupled with over-exploitation leads to chronic land degradation,

e) Arid areas, belonging to both the hot and cold desert categories, where sylvi-pastoral and sylvi-horticultural systems of land use are ideal, and

and f) Island eco-systems where changes in sea-levels could have important implications.

Unsustainable management of the resource and environmental systems associated with such regions is having serious repercussions, as is ~~event~~ evident from the following visible signs in many developing countries.

- Precipitous drying of drinking water resources.
- Vanishing forests, flora and fauna.
- Intensifying drought and floods.
- Loss of grazing lands and growing degradation of land.
- Deterioration of the quality of air and water.
- Explosive growth of rural and urban unemployment.
- Mushrooming of Urban slums.

It is the poor and the marginalised who suffer most from such environmental breakdown.

The nexus among people, resources, environment, technology and agricultural development is thus a close one. ~~FAO's estimates of total harvested land of different potentials is given in Fig. 2.~~ FAO's study, World Agriculture: Toward 2000, concluded from an analysis of 93 developing countries, excluding China, that nearly 60% of harvested land in 1982-84 belonged to the high potential category. Non-irrigated arid and semi-arid areas of developing countries accounted in 1983-83 for only about 9% of total cereal production and 6% of root and tuber production. Thus for achieving the production goals of the future, it will be essential to maintain and further enhance the production potential of "sustainable intensification areas" and upgrade degraded land. In this context, it will be useful to consider briefly the present state of global land and water management.

- i) Land: It is estimated that 30 to 50% of the earth's land area is degraded due to improper management. In particular, both the conversion of forest land for agriculture and exploitative agricultural practices have led to an increase in soil erosion over the past 25 years. The rate of soil erosion is almost imperceptible (1mm of soil loss in a storm amounts to 15 tonnes per hectare) and significantly exceeds its floor renewal rate (2.5cm/500 years and at best 1 tonne per hectare per year). The rate of soil erosion in temperate countries is 10 to 20 times the soil renewal rate, while in the tropics it is almost 20 to 40 times.

FAO's estimates suggest that approximately 6 million ha/year are becoming unfit for agriculture. In some areas, the productivity of eroded soils cannot be restored even at enormous costs (equivalent to the application of 2000 tonnes of quality soil per hectare, or 50 tonnes dry rotted cattle manure per hectare).

Soil loss also leads to nutrient depletion. One tonne of good agricultural soil may contain a total of 4 kg. of nitrogen, 1kg of phosphorous, 20 kg of potassium and 2kg of calcium. Further, soil erosion results in a loss of organic matter which plays a pivotal role in improving infiltration, water retention, soil structure and cation exchange capacity.

Organic matter and soil micro-flora and micro-fauna (including earthworms) are interdependent in maintaining soil quality and in promoting recycling of nutrients and degradation of wastes.

- ii) Water: The World Commission on Environment and development in its report, "Our Common Future" (1987) has drawn attention to the serious state of global water resources.

Global water use has doubled between 1940 and 1980 and it is expected to double again by 2000, with two thirds of the projected water use going to agriculture (WCED, 1987). Yet 80 countries, with 40 percent of the world's population experience serious water shortage even now. There will be growing competition for water for irrigation, industry and domestic use. River water disputes will multiply between nations and within nations. No easy solution is in sight unless solar desalination of sea water becomes an economic proposition.

In areas of intensive agriculture, problems of salinity, sodicity and water logging as well as the incidence of malaria, schistosomiasis and other waterborne diseases are becoming important. Ground water resources are being adversely affected ^{bi} qualitatively by the excessive use of mineral fertilizers and pesticides. Most countries are yet to develop policies for regulating ground water use in accordance with the recharge capacity of the aquifer.

iii) Biological diversity

Biological diversity is the only foundation upon which the edifice of sustainable advances in biological productivity can be built. Recent advances in molecular biology and genetic engineering, which render the transfer of genes across sexual barriers possible, have further enhanced the economic and ecological value of our biological wealth. Unfortunately, serious losses are now occurring at all the three levels in which biological diversity manifests itself, namely intra-specific, inter-specific and ecosystem levels, due largely to the destruction of habitats rich in genetic resources, such as tropical rain forests. The disappearance of forests also reduces the extent of carbon absorption on the earth. The carbon emission-absorption balance is thus upset.

Unfortunately, many plant and animal species are now under threat of extinction (~~Table 17~~). Some scientists predict that if present trends in habitat destruction continue, at least 25 percent of the world's species will be lost in the next several decades. Such a loss of biodiversity has profound implications for development. Biological resources are renewable; forests, fisheries, wildlife and crops reproduce themselves and even increase when managed properly. Further, the highly diverse natural ecosystems which support this wealth of species also maintain hydrological cycles, regulate climate, build soils, cycle essential nutrients, absorb and break down pollutants and provide for recreation, research and a richer quality of life.

Marine protected areas are yet to receive the same attention as their counterparts on land. The area of sea and seabed is more than two and a half times as great as the total area of land masses of the world but less than one percent of that marine area is currently within established protected areas. This compares with about 3 percent of area which is protected in the terrestrial environment. Conservation of biological diversity under aquatic conditions should receive greater support.

Conserving biological diversity, therefore, is urgent. because diversity provides the raw material for human communities to adapt to change. The loss of each additional gene, species or habitat reduces the available options.

Loss of the biological potential of the soil, adverse changes in water availability and quality, increasing biotic and abiotic stresses and the biological impoverishment of the earth are all occurring at a time when human population is expanding and the pathways of economic and industrial development chosen so far have built-in ~~seeds~~ ^{potential for} of climatic alterations.

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on the other,

4. Energy and Fuelwood:

~~FAO's (1989) estimate of fuelwood shortages is given in Fig. 3.~~
In India, it has been calculated that a minimum of 1.4 percent growth rate in energy availability will be needed for achieving a 1 % growth rate in GNP. However, the energy-^{mix} ~~wise~~ made available is itself often the cause of both short term and long term environmental damage. The deficit of firewood is growing day by day. At the present level of consumption of forest produce and on the current productivity of forests, India needs a minimum of 0.47 ha of forest land for every individual. The existing forest area on this basis would be adequate only for a population of 150 million (in contrast to the present population of 850 million). The task of improving the productivity of forests and mobilising alternative sources of energy is thus urgent. A similar situation obtains with regard to fodder for animals.

Mix

The population of domesticated animals is increasing, while the area under grasslands and pastures is shrinking. Thus, we will need land-saving agricultural technologies, grain-saving animal rearing methods and energy and cost saving methods of enhancing biological productivity, if we are to face the challenges on the food production and distribution front.

5. Challenges on the Economic Scene:

The financial and technical resources needed to promote ecologically sustainable agricultural and food production systems and to meet possible future changes in temperature, precipitation and sea levels are enormous. For example, the participants of the Keystone Dialogue on Plant Genetic Resources held at Madras, India, in January 1990, concluded that a minimum of US\$ 500 million per year of new money will be needed to undertake the tasks essential for conserving for posterity a sample of the genetic variability existing in crop plants through ex situ conservation techniques. ~~while~~ The tasks associated with sustainable agriculture such as upgrading degraded land, ~~and~~ conserving water and biological diversity need considerable additional resources. there is today a net outflow of resources from developing to developed countries. (WCED, 1987) P

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It is hence unfortunate

Even the slogan "trade and not aid" is losing its meaning. Trade barriers are growing. The scope of intellectual property rights is expanding, while there is little effort to give economic recognition to the informal innovation system which is the very foundation of agricultural evolution and of the conservation of biological diversity. The GATT-TRIPS (Trade related intellectual property rights) negotiations should give serious attention to methods of recognising informal innovations. A better common future for all will not be possible without a better common present.

negotiations (Keystone Dialogue, 1990)

For developing countries as a whole, external debt increased 4 percent in real terms in 1987, reaching US\$ 1,218,000 Million by the end of the year. High debt-servicing payments coupled with low level of commercial lending and new investment, resulted in growing net transfers of resources from the poor nations to the rich (by World Bank estimates, no less than US\$ 43,000 million in 1988, compared to US\$ 38,100 million in 1987)

6. Implication of Potential Changes in Climate

a) Spatial Impact:

North America continues to be the principal grain surplus area today. The heavy dependence on North America for world grain reserves has increased the sensitivity of world food supply to the weather and climate of that region. If unfavourable growing conditions occur simultaneously in the major mid-latitude regions of North America, the USSR and Australia, the global food security system will be under severe stress.

ORAM (1985) has drawn attention to four vulnerable producer groups who may be affected severely by adverse changes in temperature and precipitation. The first is located in humid tropics, in lowland areas of Asia and in the Pacific and Caribbean. These areas, normally prone to excessive rains and flooding, may be less severely affected by climatic change. The second group located in the arid and semi-arid areas of the tropics in Africa and South Asia and in the Mediterranean climate of West Asia and North Africa will be extremely vulnerable. A third group comprising farmers at high altitudes may experience both favourable and unfavourable effects. The fourth group consisting of farms located at the cold margins at higher latitudes may also experience diverse effects. However, being mostly located in developed countries they will be less vulnerable to destitution or starvation because of the social security systems in operation in such areas.

During the last 10 years, special attention has been given to the agriculture of countries in sub-Saharan Africa. This region is ecologically diverse and covers an area of 22,245 sq. kms. An estimated 30% of the area can sustain production of rainfed crops. The World Bank in a long-term perspective study titled "Sub-Saharan Africa: From Crisis to Sustainable Growth" (World Bank, 1990) has proposed a series of measures which can enhance productivity and reduce vulnerability to ecological and economic factors. An important recommendation relates to arresting soil erosion. Soil erosion, widespread in all areas of sub-Saharan Africa, is perhaps most serious in Ethiopia, where top soil losses of up to 290 metric tons a hectare have been reported for steep slopes. The report lays specific stress on developing farmer's associations and recognising the role of women.

The impacts on agriculture could be of two major types. First, by altering production in the main food-producing areas, climate change

could enhance food scarcities. The location of main food-producing regions could change. Second, there could be profound impacts on the physiological mechanisms regulating plant and animal productivity. The greatest impact will come from changes in precipitation patterns.

b) Physiological impact

Predictions by global climate modelers that additional atmospheric carbon dioxide will warm the planet are subject to considerable uncertainty. The Goddard Institute of Space Studies (GISS) and the University of Birmingham, UK., initiated in 1989 a three year study of the impacts of climate change on global agricultural output and food trade. To date, only three comprehensive regional or national assessments of the consequences of climate change for agriculture have been completed. The International Institute for Applied Systems Analysis has conducted several case studies with support from the United Nations Environment Programme (see World Resources, 1990-91 published in 1990)

Generally, it is assumed that increased atmospheric CO_2 would enhance growth rates of certain types of crop plants and that changes in temperature and precipitation would affect livestock, crops, pests and soils. They will also affect ground water replenishment patterns and evapo-transpiration rates.

Normally, increased CO_2 in the atmosphere can help to increase the rate of photosynthesis, if water and nutrients do not become limiting factors. C_3 and C_4 plants (i.e., those which have 3-carbon or 4-carbon path for photosynthesis) will ~~not~~ show differential response.

C_3 crops like wheat, barley, rice and potatoes could respond positively to CO_2 enrichment.

Sinha and Swaminathan (1990)

examined the ~~is~~ integrated impact of a rise in temperature and in CO_2 concentration on the yield of rice and wheat. The study showed that increasing mean daily temperature results in decreasing the period from transplantation to maturity. Such a reduction in duration is often accompanied by decreasing crop yield. There are however genotypic differences in per-day yield potential.

Breeders can consciously select strains with a high per day productivity. Increasing levels of CO_2 increases photosynthetic rate and hence dry matter production. However, this is coupled with the

Conclusions

It is clear we must regulate the impact of human activity on climate in a manner that sustainable advances in biological productivity are possible. We must achieve as soon as possible a balance between carbon emissions and absorption. We must intensify our ~~our~~ work on coastal aquaculture in order to take advantage of the vast quantities of carbon fixed in the oceans. For this we should begin an ocean capability classification, on the model of land capability studies. Above all, we should initiate anticipatory research ~~or~~ in areas vital to both the food and livelihood security of our people.

induction of early flowering. An increase in CO_2 might increase dry matter production but an increase in temperature reduces crop duration and ^{thereby} ~~hence~~ yield.

In the case of wheat, there will be an adverse impact on yield if ^{mean} temperatures rise by 1 to 2°C . For each 0.5°C increase in temperature there would be a ~~crop~~ reduction of crop duration by 7 days, which in turn would reduce yield by 0.45 t ha^{-1} .

For India as a whole, rice may become even more important than now in the national food security system, since rice ^{give high yields} can ~~grow~~ ^h under a wider range of growing conditions than wheat.