Climate change and food security

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Abstract
Food security in the twenty-first century has three major components: the availability of food on the market; adequate purchasing power to acquire food; and human ability to digest and absorb nutrients. As we enter the new millennium, the global population continues to grow and apprehensions arise about a potential imbalance between human numbers and food needs – especially in largely populous countries such as India and China.

Added to the concern over population growth trends is the possible impact of climate change on agriculture. Global models predict that the overall impact in this particular sector should be minimal. However, regionally, the repercussions are potentially devastating. South and Southeast Asia are particularly vulnerable to the climate change-induced conditions. Climate change will have a direct impact on crop yields and soil fertility. It will likely also force agricultural migration in many areas.

While industrialised countries are largely responsible for the human-induced damage to the atmosphere, poor nations and the poor in all nations are those who will suffer the worst consequences. The global community – industrialised and developing countries alike – should work in concert to address the issues of climate change and its mitigation, and to ensure that all members of the human family have the opportunity to live productive lives.

Introduction
The concept of food security has been evolving over the last 50 years. Immediately following World War II, the principal food security concern was increasing food production to meet the needs of an expanding population. Later, economic access to food became a matter of concern, since millions were going to bed hungry, not necessarily because food was not available, but because they did not have adequate purchasing power to achieve balanced diets. In recent years, the human ability to absorb and digest food has become an important focus because of poor environmental hygiene and unclean drinking water. Thus, today food security has three major components:

- availability in the market;
- adequate purchasing power;
- absorption facilitated by clean drinking water and environmental hygiene.
Based on these considerations, the Science Academies Summit held at the M.S. Swaminathan Research Foundation (MSSRF) in Madras, India in 1996 recommended the following definition of food security:

- that every individual has physical, economic, social, and environmental access to a balanced diet that includes the necessary macro- and micro-nutrients, safe drinking water, sanitation, environmental hygiene, primary health care, and education so as to lead a healthy and productive life.
- that food originates from efficient and environmentally benign production technologies that conserve and enhance the natural resource base of crops, animal husbandry, forestry, and inland and marine fisheries.

There is evidence that children with low birth weight are handicapped in brain development. This may be the cruelest form of inequity, since the new millennium is to be the “knowledge millennium” – wherein information, knowledge, and intellectual property will determine the pace and direction of economic growth and human wellbeing.

‘About 50% of the deaths of small children are associated with malnutrition’ (WHO 1998). The Food and Agriculture Office’s (FAO) 1996 World Summit set a target for reducing the number of persons going to bed hungry by half by 2015. Several experts have expressed doubts as to whether even this extremely modest target can be achieved. In addition to protein-calorie under-nutrition, the FAO estimates that nearly two billion people suffer from iron deficiency. It has also determined that deficiencies of iodine, vitamin A, and other micronutrients are widespread. Such “hidden hunger” affects health and productivity. Further, one third of the children in South Asia and the Sahelian region of Africa are born with low birth weights, due to nutritional anaemia in pregnant women. There is evidence that children with low birth weight are handicapped in brain development. This may be the cruelest form of inequity, since the new millennium is to be the “knowledge millennium” – wherein information, knowledge, and intellectual property will determine the pace and direction of economic growth and human wellbeing.

What has been the Indian experience with hunger and how does this impact future hunger management?

In 1798 Thomas Malthus published his Essay on the Principle of Population, in which he concluded that poverty and famine were natural outcomes of population growth, as human populations increase faster than the resources used for subsistence can support. About one hundred and fifty years later, in the twenty year period following the Second World War, India began fulfilling Mathus’s predictions. The country had suffered tragic losses in 1943 when an estimated four million people starved to death in the Bengal famine, the worst food disaster in recorded history. Starting in 1947, the newly independent Indian government made......
assertive, but largely unsuccessful efforts to assuage starvation through expansion of farming areas. It was not until 1968, with the advent of the Green Revolution—which included continued efforts to expand farm areas, double-cropping on existing farmlands, and the use of genetically modified seeds—that the problem was alleviated. (The precepts of the Green Revolution were applied at that time in developing countries around the world, but India was particularly successful in its implementation.) As we enter the new millennium, however, the global population continues to grow, and apprehensions are arising once again that there may be an imbalance between human numbers and food needs. The population growth rate in Asia from 1995 to 2000 averaged 1.4% per annum (UN Population Information Network). There are concerns that large scale famines in developing countries may require highly populous countries like China and India to resort to extensive food imports (Brown 1995). Some of the major factors underlying such concerns include:

- a steady decline in per capita availability of irrigation water and arable land as a result of continuing population growth, as well as the diversion of prime farm land for non-farm uses;
- increases in food demand to meet the needs of the growing population, which includes close to 800 million undernourished children, women, and men;
- increases in proportional food demand and higher demand for animal products stemming from greater purchasing power and increased urbanisation;
- stagnation or decline in marine fish production;
- slackening of technological change;
- fatigue of the Green Revolution due to environmental, economic, and social factors;
- climate change resulting in potential alterations of precipitation, temperature, and sea level, and possibly of increased ultraviolet-ß radiation.

These factors represent real challenges for both scientists and policymakers and there is no room for complacency. The Green Revolution, which has saved millions of lives, was made possible through a collaboration of agricultural scientists from around the world who can legitimately claim credit for converting an atmosphere of despair to one of hope by transforming the untapped agricultural potential of developing countries into production. Looking back over the past 30 years, it is clear that organised national and international agricultural research, devoted to public good and supported largely by public funds and by multilateral and bilateral donors, can contribute significantly to achieving a balance between the demand and supply of food despite rapid population growth.

Learning from industrialised country practices
The major potential impacts of climate change generally are assumed to include temperature rise, increased and decreased precipitation, sea level rise, intensification of ultraviolet-ß radiation, and increased frequency and force of extreme weather events. While it is undeniable that industrialised countries are responsible for the overwhelming majority of greenhouse gas emissions, developing countries are among those most vulnerable to these effects. Specifically, developing
island nations and semiarid regions will bear the burden of the predicted impacts – regardless of their proportional emissions culpability. As developing economies continue to grow, the associated demands for increased access to electricity and transportation that accompany expanding infrastructure will give rise to steep increases in CO$_2$ emissions.

In 1992, the Climate Change Institute spearheaded a study of eight developing countries which, together, comprise about 25% of the global population – India, Sri Lanka, Bangladesh, Pakistan, Indonesia, Vietnam, Malaysia, and the Philippines. Funding was provided by the Asian Development Bank and the governments of Australia, Japan, and Norway. A compelling component of the country studies was the development of emissions profiles. While over half of the greenhouse gasses emitted from the eight participating countries were attributable to fossil fuels, agriculture proved to be the largest source for Bangladesh, Sri Lanka, and Vietnam, and land-use change was the most problematic in Indonesia (Topping 1997).

### Table 2: Emissions Inventory Summary

<table>
<thead>
<tr>
<th>Country</th>
<th>Current Emissions (Gg CO$_2$-equivalent)</th>
<th>Per Capita Emissions (t/person/yr)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>51.389–88.048</td>
<td>0.46–0.78</td>
<td>Agriculture accounts for about 76% of emissions. Fossil fuel combustion accounts for about 79% of emissions.</td>
</tr>
<tr>
<td>India</td>
<td>809.432</td>
<td>0.93</td>
<td>Land use accounts for 72% of emissions.</td>
</tr>
<tr>
<td>Indonesia</td>
<td>708.582</td>
<td>3.7</td>
<td>Emissions from fossil fuel combustion only.</td>
</tr>
<tr>
<td>Malaysia</td>
<td>123.367</td>
<td>7.1</td>
<td>Fossil fuel combustion accounts for about 55% of emissions.</td>
</tr>
<tr>
<td>Pakistan</td>
<td>114.557–128.637</td>
<td>0.95–1.1</td>
<td>Fossil fuel combustion accounts for about 45% of emissions.</td>
</tr>
<tr>
<td>Philippines</td>
<td>75.196–88.638</td>
<td>1.3–1.5</td>
<td>Fossil fuel combustion accounts for about 38% of emissions.</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>17.677</td>
<td>1.0</td>
<td>Agriculture accounts for about 44% of emissions.</td>
</tr>
<tr>
<td>Vietnam</td>
<td>84.938–112.438</td>
<td>1.3–1.7</td>
<td>Agriculture accounts for about 44% of emissions.</td>
</tr>
<tr>
<td>Total</td>
<td>1,941.823–2,033.504</td>
<td>1.1–1.2</td>
<td>Fossil fuel combustion accounts for about 52% of emissions.</td>
</tr>
</tbody>
</table>

Source: Country Study Reports, as cited by Topping, 1997 (Prepared by Gibbs). The Malaysia study only analyzed fossil fuel use.

**What is the significance of climate change for food security?**

As detailed by Qureshi and Richards in their contribution to the 1997 M.S.R.F. publication, Impact of Climate Change on Food and Livelihood Security: An Agenda for Action, the major potential consequences of climate change for agriculture fall into three categories: direct effects on crop yields, effects on soil fertility, and large-scale effects on agricultural zones.

**Direct effects on crop yields**
- increased soil fertilisation from elevated CO$_2$ levels;
- variation in temperature and water availability to levels beyond optimal for cultivation of some crops;
- loss of crops due to elevated force, frequency, and duration of extreme weather events such as droughts and monsoons;
- increased threat from pests as warmer winters and increased moisture provide improved breeding conditions.

**Effects on soil fertility**

While elevated CO$_2$ levels may improve soil fertility to an extent, factors such as higher temperatures, dramatically altered hydrological cycles, and weather extremes are likely to outweigh the potential advantages of this effect. In addition, rising sea levels pose the threat of soil salinisation and possibly cropland erosion.

**Large-scale effects on agricultural zones**

As temperatures rise and coasts flood, agriculture will be pushed pole-ward and inland. It has not been conclusively determined whether climate change will actually decrease the amount of cultivatable land because shifts in temperatures and hydrological patterns may improve potential productivity for some areas. However, agricultural migration may represent competition for land currently being used for cattle, and will most likely have a deleterious effect on natural habitats. In addition, such shifts would bring about tremendous social and cultural upheavals.

South and Southeast Asia are particularly vulnerable to the impacts of climate change on agriculture. Specifically, those countries where agriculture is responsible for a significant proportion of the Gross Domestic Product (GDP) are likely to feel the consequences.

In most developing countries, the contribution of agriculture to Gross National Product (GNP) is going down, but there is no commensurate drop in the role of agriculture in providing opportunities for jobs and livelihoods. As such, much of the onus of providing more food, jobs, and income falls on the farm sector. Job-led economic growth is the need of the hour. While the challenges are great, progress in science and technology has opened up uncommon opportunities for a food secure world. Advances in the fields of biotechnology and information, space, renewable energy, and management technologies have been spectacular in recent years. At the same time, there is a growing realisation that sustainable development endeavours must be rooted in the principles of ecology, economics, gender equity, and ethics. This involves blending traditional technologies and ecological prudence with frontier science, leading to the development of eco-technologies. Given the circumstances, it is also important to promote anticipatory research for developing technologies and public policies that can help to mitigate the adverse consequences of droughts and floods and at the same time maximise the benefits of favourable temperature and rainfall.
What is the role of computer models?

Computer simulation models can provide guidelines for such anticipatory research. General Circulation Models (GCMs) have been developed to demonstrate the current global weather system, and to simulate the consequences of atmospheric alterations – the results of which can then be compared to observed events and historical trends. In general, GCMs do not have a high degree of accuracy in predicting changes in precipitation and they are limited when it comes to extreme weather anomalies. However, there is an overall consensus between GCMs that rainfall in South Asia will increase in the coming years. In fact, there is agreement that doubling of CO\textsubscript{2} levels in the atmosphere will result in higher temperatures, which will give rise to higher humidity and consequently increased precipitation [(Parry 1990), as sited in Qureshi and Richards, 1997].

Extreme rainfall and flooding in Florida and California in 1998 resulted in extensive crop-loss as well as in global media attention to the effects of the El Niño Southern Oscillation (ENSO) phenomenon in the United States. At the same time, areas like Indonesia, Australia, South and Central America, and South-eastern Africa were experiencing uncommonly warm, dry weather. ENSO is a disturbance of the ocean-atmosphere system in tropical Pacific Ocean that is sparked by a periodic warming of the ocean. The consequences of El Niño include droughts, flooding and temperature fluctuations, and can be felt around the globe. It is expected that with atmospheric deterioration, ENSO will happen more frequently, and with greater force.

In the 1980s, El Niño storms caused about $8 billion worth of damage. Subsequently, at least $800 million has been invested globally in El Niño predictions, about half of which is attributable to the United States (CNN 1997). El Niño 1998 was probably the worst of the 20th century. However, it was not entirely unexpected. Models and satellites were used to forecast the probable extremes of the weather phenomenon. At that time, it proved difficult to translate predictions into preventative actions. However, there is now discussion of using analyses of previous ENSOs in conjunction with computer modelling in order to determine the best damage prevention practices in advance. These include reinforcing dams and levies in flood-prone areas, ensuring that fire prevention supplies are on-hand in areas likely to experience drought, and planting more plants, or crops that are less susceptible to extreme conditions.

In 1991 Bangladesh was hit by a storm that killed about 138,000 people. Three years later, a comparable storm hit the same area, and only claimed a few hundred lives because of a warning system that had been established with support from the World Meteorological Organisation (Qureshi and Richards 1997). Computer simulation models of the potential impact of changes in temperature, precipitation, and sea level are now available in many industrialised countries. Data on enhanced ultraviolet-β radiation on crop and farm animal productivity are also becoming available. The mandate of national and international agricultural research centres includes attention to the stability of crop and animal production. Many such centres also hold large ex situ collections of germplasm,
which means that they are in comparatively advantageous positions to help initiate anticipatory research for avoiding and mitigating potential adverse changes in weather and sea level. Several International Agricultural Research Centres (IARCS) like the International Rice Research Institute (IRRI) also have a good deal of experience studying the relationship between climate and crop yields.

**Climate management and sustainable food security:**

**How can we build on the Indian experience?**

In 1979 there was a severe drought in India. The reaction of the government of India was to develop a detailed strategy for monsoon management. The three major components of this strategy follow:

First, in each district, the government established a Crop/Weather Watch Group that consisted of climatologists, agricultural scientists, representatives of farmers' and women's organisations, concerned officers of government, representatives of financial institutions, and members of the media. The tasks to be addressed by each group included monitoring monsoon progression, developing contingency plans and alternative cropping strategies to suit different weather probabilities, building seed reserves of alternate crops, and intensifying efforts in the area of water harvesting and minor irrigation. The aim was to maximise the beneficial impact of a good monsoon on agricultural productivity while minimising the adverse impact of aberrant rainfall through efficient water saving and use, crop life-saving practices, and contingency land use plans.

Second, the most favourable areas (MFAs) were demarcated in each district, with the idea of intensifying agricultural production through appropriate public policies and investment, particularly using minor irrigation and water management. MFAs were those areas where the moisture retention capacity of the soil was high and where irrigation facilities were either available or could be created. Compensatory production programmes were designed to offset, to the extent possible, crop losses in the drought or flood affected areas.

Third, strategies were developed for introducing effective relief and rehabilitation measures in the areas most seriously affected (MSA) either by drought or floods. In chronically drought prone areas, such measures included earmarking community land for establishing cattle camps to save the lives of farm animals, and identifying aquifers which could be conserved as “ground water sanctuaries” to be tapped for drinking water supply only when absolutely essential.

The above three-pronged strategy has helped to minimise both human suffering and crop losses when monsoon behaviour has been abnormal and resulted in drought or floods. Also introduced in 1979 was a Rural Godown Scheme, which was designed to promote the decentralised storage of harvested produce in order to prevent distress sales by farmers when the harvest is good and panic purchase by consumers when crop losses are high. This strategy is especially important today, because globally, hunger is a result of inadequate purchasing power rather than food scarcity.
What is and should be done in anticipation of the impact of climate change on food security?

The need for micro-level understanding and management of temperature and precipitation is evident from the fact that although rainfall may often be normal in national terms, total food grain production may go down due to climatic variations at the local level. Micro-level management promotes the use of precision farming techniques, which involves specific, plant-scale agronomy rather than area-based methodologies. Plant-scale agronomy is knowledge and information-intensive, and it affords opportunities for making farming intellectually stimulating, in addition to being economically rewarding. These methods will be very helpful in facing the challenges arising from climate change in that they are designed to anticipate and adjust to localised ambient changes as they occur, and do not require activity that originates at the national scale.

Thanks to rapid progress in genome mapping and molecular breeding, we can now design crops to suit different growing conditions. The M.S. Swaminathan Research Foundation has established a Genetic Resources Centre for Adaptation to Sea Level Rise in a mangrove forest near Chidambaram in Tamil Nadu, India. The Centre is focussed on assembling a gene pool for the purpose of breeding crop varieties that are tolerant to seawater intrusion. This sort of designer crop development should receive high priority in meeting the challenge of climate change. Genetic research shows great promise for both agricultural productivity and nutritional improvement. For example:

- In the United States there have been successful field trials of transgenic cotton – altered to carry the bacterium Bacillus thuringiensiis (Bt), which is lethal to certain insect pests. This method of pest control is proving to be relatively successful without the deleterious side effects of insecticide sprays.
- According to IRRI, one third of the global population depends on rice for more than half of their staple diet. The fact that the milling process for most of the rice being consumed removes beta-carotene, a precursor to vitamin A, with the hull is therefore something to be seriously considered. In January 2000, a group of European scientists announced that they had begun to address this problem by genetically modifying rice to carry beta-carotene in its endosperm.
- The Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), which is a project of the Consultative Group on International Agricultural Research (CGIAR), has also been conducting regional research around the world in an effort to develop wheat and corn seeds that are more resistant to the elements; diseases; and extreme fluctuations in weather, such as prolonged droughts.

It is likely that genetically modified crops will be widely grown in the coming decades in both developed and developing countries. It would therefore be useful to organise an international network for fostering anticipatory research to meet the potential impact of climate change on food security. This network would be serviced by a co-ordinating unit, which would advise on priorities for screening germplasm for tolerance to climatic changes. Genotypes, which can be used in breeding strains for tolerance to heat, coastal salinity, floods, etc, can then be identified.

CGIAR has already established a facilitating entity for International Agricultural Research Centres (IARCS), interested National Agricultural Research Systems (NARSS), called the IARC/NARS Training Group (INTG). This group has
existed since 1991 (formerly known as the Inter-Center Training Group), with the purpose of strengthening agricultural research and research management training. Using INTG as a foundation, an international network, comprised of IARCS, NARS, and advanced research institutes, could be established within the CGIAR system, and serviced by a co-ordinating unit. This action would be an important step in helping NARS to optimise the benefits of favourable growing conditions and to minimise the adverse impact of unfavourable climatic changes. The cost of servicing the network could be kept low through electronic information linkages with appropriate advanced research institutions and meteorological departments.

The Co-ordinating Centre could also advise IARCS on the progress being made in short and medium term weather forecasting, and on the implications for scientific management of farming systems. Weather forecasting is an area where considerable progress is being made, and IARCS should take the lead in developing strategies to enhance the stability of crop production based on the effective use of weather forecasts. In this way, a small initiative in this area could provide multiple benefits towards achieving the goal of coupling productivity advance with production stability.

In addition to tapping frontier science such as genetic engineering, there is an equal need to preserve and use traditional wisdom. For example, the traditional water harvesting and saving techniques adopted in the past in India were very effective in insulating human and animal populations from acute water scarcity. Anil Agarwal and Sunita Narain (1996) point out that in the desert region of Jaisalmer in India, there is an annual rainfall of 100 mm, but there is enough drinking water for the people even in severe drought years because of their habit of storing water in traditional rainwater harvesting structures called Kunds. In contrast, Cherrapunji, a village in north-eastern India, has an average annual rainfall of 15,000 mm and suffers from water shortages during summer months because the surrounding forests have been denuded and the local population has no tradition of water harvesting and conservation.

**Local Action:** Governments should sponsor the training of at least one male and one female volunteer in every village in the science and art of climate management. These trained villagers could be designated “Climate Managers.” Wherever possible, an appropriate technical institution should provide such village-level Climate Managers with information derived from computer simulation models, so as to help them to be prepared to handle both adequate and aberrant rainfall.

**Conclusion**

While industrialised countries are largely responsible for the present situation where human activities are beginning to influence climate, poor nations and the poor in all nations are the ones who will suffer the most.

Balanced diet and safe drinking water are the first among the hierarchical needs of human beings. In the past, food production was described as a “gamble in rainfall” in many countries. Today, we are in the fortunate position of being able to harness new scientific tools to minimise the “gamble” component of agriculture. A marriage between modern science and traditional wisdom will help to ensure that
food security is sustained under varying climatic scenarios. The impact of climate change on agriculture is likely to be harder on tropical countries than on nations in temperate zones, and, as such, will likely increase the nutritional disparity between developed and developing countries.

Successful strategies to address climate change must involve the efforts of both developed and developing countries. Both avoidance and mitigation strategies should be developed at the local, national, regional, and global levels, in order to lay the foundation for a common happy future.

Developing countries should formulate nationally designed and accepted plans for achieving a balance between carbon emissions and absorption. Effective action at home and emphasis abroad on a “polluter pays” principle should be the two-pronged strategy of developing nations in dealing with climate change issues. Prevention of deforestation and promotion of greening will help to increase carbon sequestration.

The global community should work in a concerted manner to avoid large human-induced changes in climate and to address the consequences already being felt. The international community and national governments must make every effort to ensure that all members of the human family have an opportunity for productive and healthy lives.

References and suggested resources


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**News articles**


**Web sites**

Consultative Group on International Agriculture Research  
www.cgiar.org

Food and Agriculture Organization of the United Nations  
www.fao.org

IARC/NARS Training Group  
www.cgiar.org/ntag

International Rice Research Institute  
www.cgiar.org/irri
M. S. Swaminathan is the Chairman of the M.S. Swaminathan Research Foundation (MSSRF). Dr. Swaminathan has received the World Food Prize, the Tyler Prize, the Honda Prize and UNEP-Sasakawa Environment Prize for his work in crop genetics and sustainable agricultural development in India and the Third World. He used the funds from these awards to establish MSSRF in 1988. MSSRF is a non-profit, non-political trust committed to a mission of harnessing science and technology for environmentally sustainable and socially equitable development. From 1984 to 1990, Dr Swaminathan was President of the International Union for the Conservation of Nature and Natural Resources. He served as Director General of the International Rice Research Institute from 1982 to 1988. From 1972 to 1985 he was the Independent Chairman of the Food and Agriculture Office Council, and from 1972 to 1978 Director General of the Indian Council of Agricultural Research.

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