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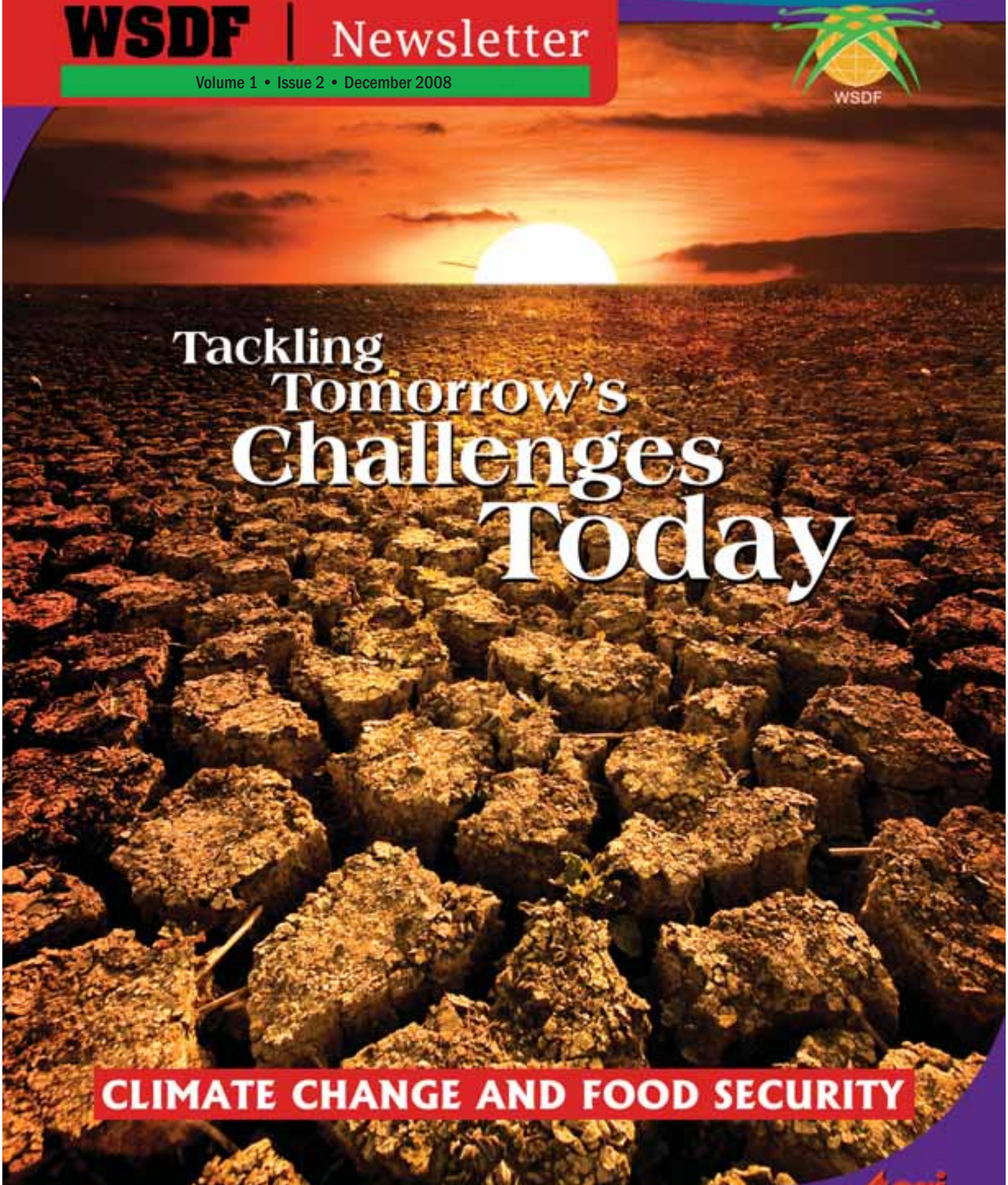

Tackling Tomorrow's Challenges Today

CLIMATE CHANGE AND FOOD SECURITY

teri

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Foreword

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The issue of food scarcity has come to the fore in various parts of the globe, since prices of agricultural produce increased sharply earlier this year. There are growing concerns on whether the expanding population of the world will be able to get adequate nutrition and avoid hunger in the future. The global demand for food has gone up substantially in recent years for a variety of reasons. The increasing number of human beings on this planet has clearly led to an increase in the demand for food. At the same time, with increases in income in several parts of the developing world, a distinct shift has taken place towards greater consumption of animal protein, the production of which requires a large input of foodgrains in keeping with the current trend of what one might call 'factory farming'. In addition, the response on the supply side has been inadequate, mainly because, arable land is just not available for expanding agriculture in several regions of the world. Even in terms of technology, the green revolution has reached its limits in several respects and, therefore, even with high prices, an adequate response in terms of increased output may not be possible. The tragedy of the current situation is that some of the poorest regions of the world would suffer from acute shortage of foodgrains, because there are over 50 countries in the world, which do not produce enough food to meet their own needs. With higher prices of foodgrains and other agricultural produce suitable for human consumption, some of the poorest communities in different parts of the world will find it very difficult to meet their own needs with the limitations of income that they are subjected to. As a result of the recent increase in food prices, it can be concluded that some of the decades-long successful efforts at wiping out poverty in some of the worst afflicted regions of the world have essentially been negated by recent developments. To bring about an improvement in the condition of the poorest countries and communities in the world may be very difficult in the short term, given the stagnation in economic development that exists in several regions.

To add to some of the existing problems of food scarcity and unaffordable prices of foodgrains is the threat of climate change, which has a negative impact on the productivity and yield of several crops in several locations. For instance, the IPCC (Intergovernmental Panel on Climate Change) has projected that, by 2020, some countries in Africa may suffer from a decline of 50% in agricultural yields as a result of climate change. Additionally, by 2020, 75–250 million people in Africa would be subjected to water stress as a result of climate change. The fact that the Norwegian Nobel Committee awarded the 2007 Nobel Peace Prize to the IPCC and the former Vice-president of the US, Al Gore, is a recognition of the fact that some of the impacts of climate change could lead to conflict in different parts of the world. It is logical to expect that when large numbers of people suffer from hunger and starvation or lack of access to adequate water supply, they are likely to move from their homes to other locations where similar scarcity conditions are not known to exist. This undoubtedly can lead to danger of conflict and disruption of peace. Similarly, if two groups have to compete for the same supply of water, whether from sources like a river or freshwater lake, tensions could lead to conflict if supply of water is not adequate for meeting everybody's needs. Climate change can, therefore, bring about an abandonment of agriculture if yields and productivity, and availability of water may get very difficult for communities to pursue farming.

Unfortunately, in some of the worst affected regions of the world, the extent of study and analysis of this problem is quite inadequate. Therefore, coping strategies and adaptation to the impacts of climate change do not receive adequate attention, which would adversely affect the welfare of large numbers of people. Food scarcity, both for global as well as local reasons, can therefore become a serious issue for the future of humanity.

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Focus

The face of hunger in a changing climate

TERI research team[1]

Introduction

The importance of stable access to adequate food supplies for sustainable human development was properly highlighted when the World Bank defined food security as 'access to adequate food to all people at all times for active and healthy life' (World Bank 1986). The World Food Summit in 1996 further emphasized the developmental implications of food security, with the heads of states pledging to eradicate hunger. Therefore, it established the target of reducing the number of undernourished people by half, no later than 2015. In addition, the MDGs (Millennium Development Goals) that were brought into being in 2000 had, among other targets, the objective to halve the proportion of people who suffer from hunger by 2015, relative to 1990 levels.

According to the FAO's *State of the Food Insecurity Report 2006*, ten years after the World Food Summit, the number of undernourished people in the world remains persistently high. In 2001–03, the FAO estimates that there were still 854 million undernourished people worldwide—96% in the developing countries, around 3% in transition countries, and the remaining 1% in industrialized countries. The report also emphasized that because of population growth, the very small decrease in the number of hungry people has nevertheless resulted in a reduction in the proportion of undernourished people in the developing countries by 3%—from 20% in 1990–92 to 17% in 2001–03. Figures 1a and 1b present the share of undernourished people for different regions of the world in 1990–2003. This implies that progress has continued towards the MDG 1 of halving the percentage of undernourished people by 2015. However, if one digs deeper, it is clear that the progress over this period was slower than over the previous two decades, when the prevalence of undernourishment declined by 9% (from 37% to 28%) between 1969–71 and 1979–81 and, further, by 8% between 1979–81 and 1990–92. These trends clearly highlight a daunting challenge ahead, in reducing the numbers of hungry and achieving the MDG. This challenge is likely to be further accentuated due to climate change and its likely impacts. There are growing concerns over the likely increase in the number of food insecure in the world due to climate change. This, however, will depend on the emission scenarios and the socioeconomic development pathways. Table 1 presents the number of people at risk of hunger in developing countries under reference scenarios and climate change scenarios of IPCC (2000). Table 1 clearly shows that, compared to the reference scenarios, climate change will lead to substantial increase in the number of the hungry in the future under both crop models and all-emissions scenarios (A1, A2, B1, and B2). Considering the positive effects of increased CO_2 on crops may alleviate the

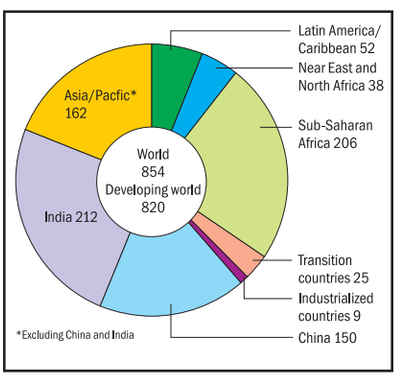

Figure 1a Distribution of undernourished people for different regions of the world (2001–03)
Source FAO (2006)

[1] The research for this article was undertaken at TERI by Ms Upasna Sharma and Ms Sreeja Nair, with inputs from Ms Prima Madan

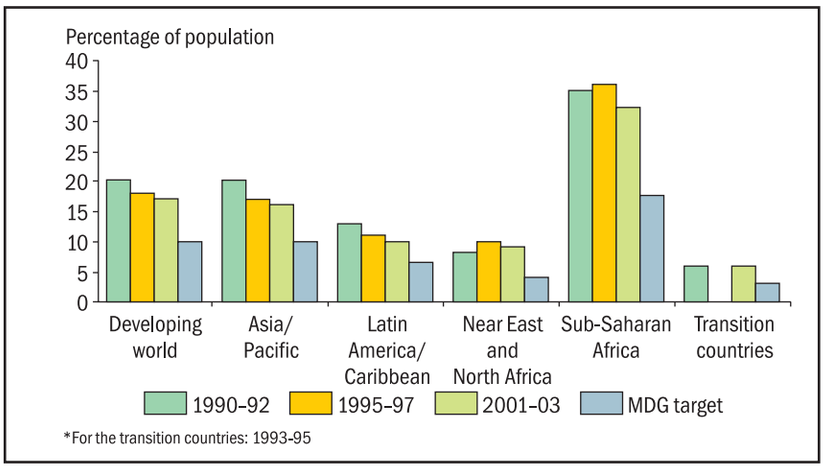

Figure 1b The proportion of undernourished people for different regions of the world.
Source FAO (2006)

Table 1 Impact of climate change and socioeconomic development pathways on the number of people at risk of hunger in developing countries, in millions

	2020		*2050*		*2080*	
Scenario	*AEZ-BLS*	*DSSAT-BLS*	*AEZ-BLS*	*DSSAT-BLS*	*AEZ-BLS*	*DSSAT-BLS*
Reference[a]						
A1	663	663	208	208	108	108
A2	782	782	721	721	768	769
B1	749	749	239	240	91	90
B2	630	630	348	348	233	233
CC, no CO_2[b]						
A1	NA	726	NA	308	NA	370
A2	794	845	788	933	950	1320
B1	NA	792	NA	275	NA	125
B2	652	685	356	415	257	384
CC[c]						
A1	666	687	219	210	136	136
A2	777	805	730	722	885	742
B1	739	771	242	242	99	102
B2	640	660	336	358	244	221

AEZ-BLS – Agro Ecological Zone-IIASA-Basic Linked System, DSSAT-BLS – Decision Support System for Agrotechnology Transfer-IIASA-Basic Linked System, NA – not available
[a] – projections under IPCC reference socioeconomic development pathways considered without any climate change.
[b] – projections under IPCC scenarios includes climate change, but assumes no effects of elevated CO_2 on crops.
[c] – projections under IPCC scenarios, which include climate change and positive effects of elevated CO_2 on crops.
A1, A2, B1, and B2 are emission scenarios based on different socioeconomic development pathways.
AEZ and DSSAT are the two crop modelling systems, each coupled to the same economic and food trade model, BLS.
Source Schmidhuber and Tubiello (2007)

problem a bit but even then the number of hungry is marginally higher compared to most reference scenarios.

Introduction

The concept of food security has gone through various transformations over the last several decades, as the understanding of the processes that lead to food insecure situations advanced over the years. Here, we briefly trace the different stages of the evolvement of the concept of food security. Food security concerns emerged as early as 1948, when the Universal Declaration on Human Rights recognized the right to food as a central element of an adequate standard of living.

In the 1960s and 1970s, food security was mostly concerned with national and global food supplies. Adequate food supply for the world's growing population was the principal concern. Therefore, the dominant belief was that if national governments could produce enough food to supply the demand in their countries, hunger would disappear without dependence on food-aid. Resources were directed towards improvements in agricultural production and the 'Green Revolution' increased the output dramatically.

The severe famine and food crisis, which plagued Africa in the mid-1980s, resulted in the deterioration of living standards in the Third World despite advances in production. In addition groundbreaking

publications (for example, Amartya Sen's *Poverty and famines: an essay on entitlement and deprivation* [1981]) brought to light the limitations of the food supply focus. Sen's theory on food entitlement, in which he questioned traditional assumptions on famine and argued that famine was a result of entitlement failure rather than a food deficiency, helped usher in the paradigm change (Sen 1981). It became clear that adequate food availability at the national level did not automatically translate into food security at the individual and household levels. Therefore, in the 1980s to 1990s the policy-makers began to explore individual and household food security and emphasized both the availability and stable access to food. Interest was centred on understanding food systems, production systems, and other factors that influence the composition of food supply and a household's access to the supply over time.

The famine in Africa also revealed another important aspect of food-insecure households, which gradually broadened the focus from household food security to household livelihoods security. It was understood that food security may not always be the first priority and is only one of the competing interests that the poor try to balance, while taking into account short- and long-term survival (Maxwell and Smith 1992). For example, people may intentionally suffer from hunger in the short-term rather than lose their assets. The household livelihood security model allows for a broader and more comprehensive understanding of the relationships between poverty, malnutrition, and dynamic and complex strategies that the poor use to survive. It also emphasizes household actions, perceptions, and choices.

The FAO defines food security as a 'situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO 2002). This definition encompasses the different paradigm shifts that occurred over the last few decades in conceptualizing food security. This definition was categorized into four main dimensions of food security, which are as follows.

- *Food availability* Sufficient quantities of food available on a consistent basis.
- *Food stability* Differing risks associated with temporarily or permanently losing access to resources needed to consume adequate food.
- *Food access* Sufficient resources to obtain appropriate food for a nutritious diet.
- *Food use* Appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

Within these definitions of food security, climate affects food systems in the broadest sense of the word. Key parameters that affect the physical, chemical, and biological processes that drive the productivity of agricultural, forestry, and fisheries systems include the inter-annual, monthly, and daily distribution of climate variables (Easterling, Aggarwal, Batima, *et al.* 2007). Changes in these variables can not only affect the physical availability of food, but also affect farm-based incomes, fish catch, and agricultural trade pattern and, thereby, affect all dimensions of food security by altering food availability, accessibility, utilization, and food system stability. The impacts are varied in nature, affecting some systems more than others. For example, vulnerable communities include low-income groups in arid and semi-arid areas, areas prone to floods and coastal disasters, and regions lacking financial, technical, and institutional resources to meet the food supply-demand gap (UNEP 2006). Furthermore, there could be geographically new sets of population vulnerable to food security by being exposed to climatic extremes. Rise in sea level and occurrence of extreme events pose new risks for assets and infrastructure along coastal zones, threatening livelihoods and increasing vulnerability to food insecurity (UN 2008).

Impacts of climate change on food security

The accentuating pressure exerted by climate change and its likely impacts is expected to affect all the four dimensions of food security-availability,

stability, use, and access. Climate drivers such as changes in temperature, precipitation, increased CO_2 levels, and extreme weather events and socioeconomic drivers, such as increase in population, act on physical conditions (for example, agro-ecological conditions) and socioeconomic conditions (for example, the baseline sanitation infrastructure or lack of it) to cause impacts that manifest as one or more of the four dimensions of food security. Moreover, the impacts can be direct such as effect of temperature on soil moisture or indirect such as climate change, which adversely affects water availability for irrigation. Figure 3 broadly depicts climate change and food security linkages.

Assessments of the impacts of climate change on food security have largely been focused on the 'availability' dimension and, up to a limited extent, on the 'access' dimension. Very few studies assess the impact of climate change on food 'use' and food 'stability'. Based on a review of literature, Schmidhuber and Tubeillo (2007) presented an overview of the impacts of climate change on different dimensions of food security. The key findings of this overview, supplemented with additional references, are presented below.

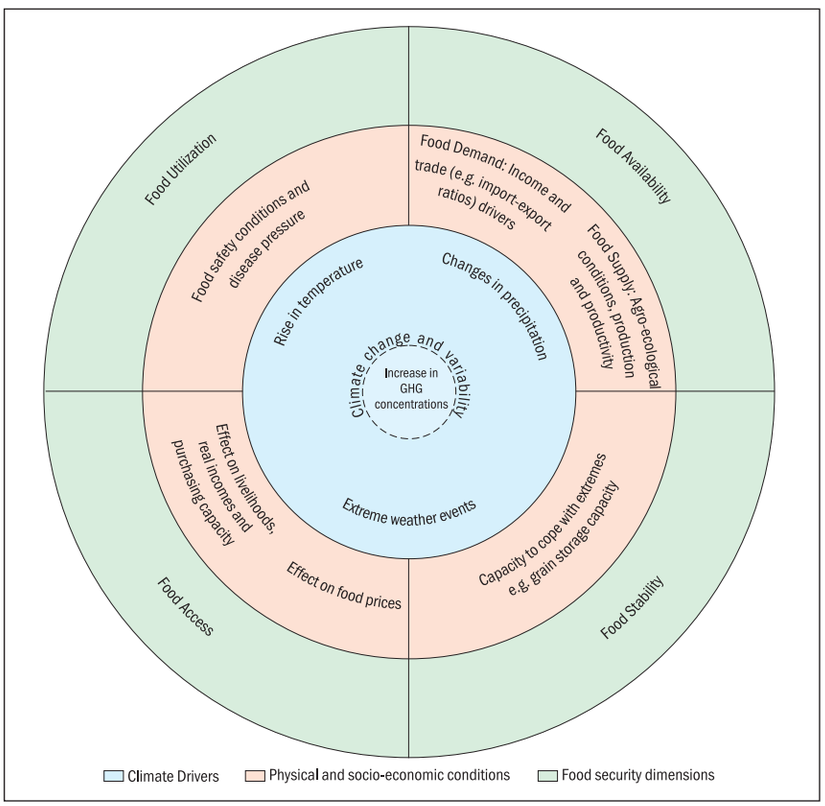

Figure 3 Climate change and food security linkages

Impacts on food availability (production)

Climate change is expected to affect food production through physical changes such as changes in agro-ecological conditions; for example, land suitability and length of growing season. Agriculture is an important source of income for many and not just a source of food. The impact of climate change on food production and crop yields would not only affect physical availability of food but also the incomes of people. Changes in growth and distribution of incomes may affect demand for agricultural produce, which in turn would again affect food production choices.

The Working Group II of the *Fourth Assessment Report* of the IPCC (Intergovernmental Panel on Climate Change) (IPCC 2007) provides a comprehensive overview of the likely impacts of climate change on agriculture based on an extensive review of literature. Impacts on food production and availability have been quantified in numerous studies and under various sets of assumptions. Majority of the studies have focused on physical impacts; that is, alterations in the agro-ecological environment that are associated with climate change. A brief summary of these alterations is presented below.

Land availability and suitability

Increasing temperatures and the change in precipitation[2] and sea level rise affect the availability of

[2] Changes in precipitation are not merely about increasing or decreasing rainfall. Rainy seasons that begin later or earlier than normal have a greater impact on crops failing than a wetter rainy season that starts on time.

total arable land for cultivation and the quality of available land. Loss of arable land may be caused as a result of declining groundwater levels and increased evapotranspiration, which lead to the aridity of soil; and rising sea levels, which lead to increasing levels of salinity. Changes in temperature would affect the length of growing season (the length of time that soil temperature and moisture conditions are suitable for crop growth) and, therefore, crop yields.

The impact on land availability and suitability for agriculture will not be uniform across regions of the world. For instance, in the pioneering work by the FAO / IIASA (International Institute for Applied Systems Analysis), Fischer, Shah, and van Velthuizen (2002) suggest that even though the total land and total prime land would remain virtually unchanged at the current levels of 2600 mha (million hectares) and 2000 mha, respectively, there would be significant regional shifts. Areas that will predominantly benefit in terms of increase in suitable cropland, length of growing period, and crop yields lie in temperate latitudes where most of the developed countries are located. Estimates by Fischer, Shah, and van Velthuizen (2002) suggest that there may be 160 mha increase in suitable crop area. This is, however, dependent on the local conditions including geomorphological characteristics in undertaking the same. A corresponding decline of 110 mha of potential cropland (135 mha of decline in agricultural prime land, which is offset by an increase in moderately suitable land of 20 mha) is predicted at lower latitudes where most of the developing countries are located. A pronounced shift within the quality of cropland is predicted in developing countries; for example, in sub-Saharan Africa alone, land for double cropping would decline by 10–20 mha, and land suitable for triple cropping would decline by 5–10 mha.

Disease outbreaks and pest infestations

Most agricultural pests are sensitive to temperature and humidity changes. Climate change is likely to create conducive environs for the expansion of the geographical range of many agricultural pests and growth of new pests.

Temperature thresholds for crops

Rise in temperatures can be beneficial to crop growth but only up to a certain point. Crops have certain temperature thresholds beyond which the rise in temperature leads to decline in yield.

CO_2 effects

Depending on different IPCC (2000) emission scenarios, the atmospheric CO_2 concentration is projected to increase from 379 PPM (parts per million) today to 800 PPM by 2100. Higher atmospheric concentrations of CO_2 will improve the water-use efficiency of all crops (by reducing evapotranspiration) and increase the rate of photosynthesis of most crops. Therefore, it will have a positive effect on many crops-enhancing biomass accumulation and final yield. However, the direct effects of CO_2 will be small in regions where fertilizer use is low or other factors inhibit crop growth (Darwin 2001). In India, the net effect is likely to be neutralized (Kalra, Aggarwal, Chander, *et al.* 2003). In addition, studies show that the nutritional quality of agricultural produce (for example, some cereals and forage crops) may not be proportionate with higher yields under elevated CO_2 conditions (McCarthy, Canziani, Leary, *et al.* 2001). Overall, there is substantial uncertainty associated with effects of CO_2 on crop yields and nutritional quality.

Impacts of climate change on the stability of food supplies

Stable access to food can be disrupted due to a number of factors, both climatic and non-climatic. Among the climatic factors, it is the extreme weather events and short-term variability that can bring about greater fluctuations in crop yields and local food supplies and, therefore, adversely affect the stability of food supplies, especially at a local and regional level. While short-term climate variability and associated adaptation are part and parcel of the agricultural sector, what is

new based on the scientific evidence summarized in the Working Group I of the Third (IPCC 2001) and *Fourth Assessment Report* of the IPCC (Solomon, Qin, Manning, *et al.* 2007) is that global and regional weather conditions are also expected to become more variable than at present, with increases in the frequency and severity of extreme events such as cyclones, floods, hailstorms, and droughts; some of these changes in certain regions may be unprecedented. The magnitude of disruptions in food supply will critically depend on the ability of the affected regions to cope with such disruptions through better storage facilities, higher food imports, and other such interventions.

Impacts of climate change on access to food

Access to food refers to the ability of individuals, communities, and countries to purchase sufficient quantities and qualities of food. The food prices and real incomes of the people become crucial in determining access to food. Where income levels are low and shares of food expenditures are high, higher prices for food may still create or exacerbate a possible food security problem. Over the last 30 years, falling real prices for food and rising real incomes have led to substantial improvements in access to food in many developing countries. In these regions, the economic output from agriculture itself (over and above subsistence food production) will be an important contributor to food security, Schmidhuber and Tubeillo (2007).

The FAO's long-term outlook to 2050 suggests that the regions that will see the strongest reductions in the prevalence of undernourishment are those that are expected to see the highest rates of income growth (FAO 2006).

The FAO projections do not take into account the effects of climate change. Some studies (Fischer, Shah, and van Velthuizen 2002) have attempted to assess the impact of climate change on income levels (agricultural gross domestic product) and prices by coupling agro-ecologic and economic models. Though Schmidhuber and Tubeillo (2007) discuss the findings from these coupled models in relative detail, the main messages can be summarized as follows.

- Though at the global level, the impacts of climate change are likely to be very small, at the regional level, the importance of agriculture as a source of income can be much more important.
- The strongest impact of climate change on the economic output of agriculture is expected for sub-Saharan Africa, which means that the poorest and already most food-insecure region is also expected to suffer the largest contraction of agricultural incomes.

The conceptual link between household livelihoods security (as that affects the real incomes) and access to food is quite clear here, but most of the quantitative impact assessment studies in the context of climate change and its effect on real incomes have been at the macro-level, whereas the assessments of household livelihoods security have usually been made at the micro-level. There is clearly a need to link the two scales.

There are a number of studies (Fischer, Shah, and van Velthuizen 2002; Reilly, Baethgen, Chege, *et al.* 1996; Darwin, Tsigas, Lewandrowski, *et al.* 1995) that have attempted to measure the likely impacts of climate change on food prices. The basic messages that Schmidhuber and Tubeillo (2007) extract from these studies are as follows.

First, on an average, prices for food are expected to rise moderately in line with moderate increases of temperature (until 2050), some studies even foresee a mild decline in real prices until 2050.

Second, after 2050 and with further increases in temperatures, prices are expected to increase more substantially.

Third, price changes expected from the effects of global warming are, on an average, much smaller than price changes from socio-economic development paths.

While these are long-term projections, short term

variability and weather patterns influence food production. For instance in 2006 wheat production was affected in India because of warm winters in northern India (NIDM 2006). This affected availability and there was reported shortage of wheat in that year. The country had to import huge quantities of wheat (India Together 2007) given that wheat is a staple diet in many parts of India and there is a huge demand. This was irrespective of the fact that wheat import prices were its peak (Business Line 2008).

Impacts of climate change on food utilization

Essentially, all manifestations of climate change (drought, higher temperatures or heavy rainfalls) have an impact on food safety and food security. For example, studies such as D'Souza, Becker, Hall, *et al.* (2004) have confirmed and quantified the effects of temperature on common forms of food poisoning, such as salmonellosis, and diarrhoea. It was found that rising temperatures were strongly associated with increased incidences of food poisoning and diarrhoea in adults and children. Extreme rainfall events can increase the risk of outbreaks of water-borne diseases (for example, cholera), especially where basic public infrastructure including sanitation and hygiene is lacking or inadequate.

The link between climate change and 'food utilization' dimension of food security emerges in the following way. Climate change may alter the conditions for food safety and may lead to change in 'disease pressure' from food and water-borne diseases, which may cause compound hunger, especially where people are already at the margins of poverty and do not have adequate resources to counter the disease. The result could be a substantial decline in labour productivity and an increase in poverty and even mortality. This, in turn, makes the affected populations more susceptible to infectious disease.

The above discussion clearly indicates that climate change is likely to affect all dimensions of food security. There is a clear-cut attribution on how climate change will impact food security but there are large uncertainties that are associated in the estimations, given the assumptions and need for specific studies that take into account the impacts holistically. However, a number of fairly robust policy relevant findings emerge from the studies that assess the impact of climate change on food systems. These are summarized in Box 1.

Way forward

That climate change will impact all four dimensions of food security has been clearly established. However, the intensity and extent of the overall impact will vary across regions and over time. It also depends on the socioeconomic status of the countries.

Climate change is expected to increase dependency of developing countries on food imports and further accentuate the existing food insecurity in certain regions including sub-Saharan Africa and, to an extent, South Asia. Needless to mention, climate change impacts (either through socioeconomic route or through biophysical changes) related to food security will fall disproportionately on the poor, making them most susceptible.

In the wake of posed threats, it is crucial to develop our capacities to cope effectively with the likely possible climatic changes in future. In this regard, it is important to select win-win measures, such as organic farming, which offer the possibility of sustained productivity, and crop diversification, which spreads the risk of climatic changes. These and other measures such as adjustments in crops and sowing dates, use of drought- and flood-tolerant varieties, pest disease and salinity resistant varieties, improvement in crops and livestock through breeding, mixed and intercropping, and low-cost harvest technologies, and eco-farm technology (to reduce the effects of high temperature on crops) are essential with the viewpoint of reduction of losses and strengthening adaptation in the agricultural sector. Examples of adaptation strategies for agricultural sector highlighted in IPCC AR4 (2007) are presented in Box 2.

Future environment policy and its role in promoting sustainable agricultural practices and fostering adaptation is well realized. This includes provision

Box 1 Key findings of the IPCC AR4

- Climate change is likely to increase the number of people at risk of hunger compared to reference scenarios with no climate change.
- The impact of chosen socioeconomic pathways (SRES [*Special Report on Emissions Scenarios*]) on the numbers of people at risk of hunger is significantly greater than the impact of climate change. Climate change alone is estimated to increase the number of undernourished people to 40–170 million. In comparison, the impacts of socioeconomic development paths can amount to several hundred million people at risk of hunger. These projections also indicate that, with or without climate change, MDGs of halving the proportion of people at risk of hunger by 2015 may not be realized until 2020–30 (Fischer, Shah, Tubiello, *et al.* 2005; Tubiello 2005).
- Climate change will further shift the focus of food insecurity to sub-Saharan Africa. By 2080, about 75% of all people at risk of hunger are estimated to live in this region and sub-Saharan Africa is likely to surpass Asia as the most food-insecure region. However, this is largely independent of climate change and is mostly the result of the projected socioeconomic developments for the different developing regions.
- While moderate warming benefits crop and pasture yields in mid- to high-latitude regions, even slight warming decreases yields in seasonally dry and low-latitude regions. On the whole, the results of the models project the potential for global food production to increase with increase in local average temperature over a range of 1– 3 °C, but the models project the potential to decrease above this range.
- Modelling studies suggest that increasing frequency of crop loss due to extreme events, such as droughts and heavy precipitation, may negate the positive effects of moderate temperature increase. As such, the projected changes in the frequency and severity of extreme climate events will have more serious consequences for food and forestry production, and food insecurity, than will changes in projected means of temperature and precipitation (high confidence). A change in frequency of extreme events is likely to disproportionately impact small-holder farmers and artisan fishers.
- Recent research suggests immense positive effects of climate mitigation on the agricultural sector, although benefits, in terms of avoided impacts, may be realized only in the second half of this century due to the inertia of global mean temperature and the easing of positive effects of elevated CO_2 in the mitigated scenarios. Even in the presence of robust global long-term benefits, regional and temporal patterns of winners are highly uncertain and critically dependent on GCM (Global Climate Model) projections.
- Food and forestry trade is projected to increase in response to climate change, with increased dependence of most developing countries on food imports.
- Simulations suggest rising relative benefits of adaptation with low to moderate warming, although adaptation may stress water and environmental resources as global warming increases. For example, climate changes may increase irrigation demand in the majority of the regions due to a combination of decreased rainfall and increased evaporation arising from increased temperatures, which, combined with expected reduced water availability, adds another challenge to future water and food security.

Source Easterling, Aggarwal, Batima, *et al.* 2007

Box 2 Adapting to climate change in the agriculture sector for food security

Choice of crop
- Use more heat/drought-tolerant crop varieties in areas under water stress
- Use more disease and pest tolerant crop varieties
- Use salt-tolerant crop varieties
- Introduce higher yielding, earlier maturing crop varieties in cold regions

Farm management
- Alter application of nutrients/fertilizer
- Alter application of insecticide/pesticide
- Change planting date to effectively use the prolonged growing season and irrigation
- Develop adaptive management strategy at farm level

Development of agricultural biotechnologies
- Develop and distribute more drought-, disease-, pest-, and salt-tolerant crop varieties

Improvement of agricultural infrastructure
- Improve pasture water supply
- Improve irrigation systems and their efficiency
- Improve use/store of rain and snow water
- Improve information exchange system on new technologies at national as well as regional and international level
- Improve sea defence and flood management
- Improve access of herders, fishermen, and farmers to timely weather forecasts

Source Cruz, Harasawa, Lal, *et al.* (2007)

for freer trade, improving access to international supplies, investment in transportation and communication infrastructure, irrigation, removal of barriers such as high financial costs for initial switch from non-organic to organic farming, and continued technological progress which are some critical factors that would define food security in a changing world.

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Feature

Climate change and food security

Lester R Brown*
President of the Earth Policy Institute

Climate change presents new risks to food security. Crop-withering heat waves, more destructive storms, and the melting of mountain glaciers, which sustain the dry season flow of major rivers, are combining to make harvest expansion more difficult. In the past, unusual weather events were temporary; things would return to normal within a year or two. But with climate influx, there is no norm to return to.

Agriculture, as it exists today, has been shaped by a climate system that has changed little over farming's 11 000-year history. Crops were developed to maximize yields in this long-standing climatic regime. As the temperature rises, agriculture will be increasingly out-of-sync with its natural environment. Nowhere is this more evident than in the relationship between temperature and crop yields.

Higher temperatures can reduce or even halt photosynthesis, prevent pollination, and lead to crop dehydration. This was observed in 2002, when record-high temperatures and drought reduced grain harvests in India, the US, and Canada, dropping the world harvest by 90 MT (million tonnes), or 5% below consumption. The record-setting 2003 European heat wave contributed to a world harvest that fell short of consumption by 90 MT. Intense heat and drought in the US Corn Belt, in 2005, contributed to a world grain shortfall of 34 MT.

On top of this, the world is now facing a climate-driven shrinkage of river-based irrigation water supplies. The affects, perhaps, will be most severe in Asia. Mountain glaciers in the Himalayas and on the Tibet-Qinghai Plateau are melting and could soon deprive major rivers of India and China of the ice melt required to sustain them during the dry season. In the Ganges, the Yellow River, and the Yangtze River basins, where irrigated agriculture depends heavily on rivers, this loss of dry-season flow will shrink harvests.

The world has never faced such a predictably massive threat to food production as that posed by the melting mountain glaciers of Asia. Two-thirds of the glaciers that feed the Yellow and Yangtze rivers of China will disappear by 2060, if even the current 7% annual rate of melting continues. Glaciologists report that the Gangotri glacier, which supplies 70% of the ice melt that feeds the Ganges River during the dry season, could disappear entirely in a matter of decades.

China and India are the world's leading producers of both wheat and rice—humanity's food staples. China's wheat harvest is nearly double that of the US, which ranks third after India. These two countries are also the leading producers of rice, together accounting for over half of the world harvest. The issue is not just the future of mountain glaciers, but also the future of the world's grain harvests.

In many ways, our poor energy choices are exacerbating an already_precarious food situation. The US, in a misguided effort to reduce its oil insecurity by converting grain into fuel for cars, is generating global food insecurity on a scale never seen before. In 2008, more than a quarter of its grain harvest will be turned into fuel ethanol. The line between the food and energy economies is becoming blurred as the two begin to merge. If the food value of grain is less than its fuel value,

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the market will move the grain into the energy economy. Thus, as the price of oil rises, the price of grain follows it upward.

As economic stresses translate into political stresses, the number of failing states, such as Afghanistan, Somalia, Sudan, the Democratic Republic of the Congo, and Haiti, which was already increasing before the rise in food prices began, could increase even faster. Political insecurity and food insecurity go hand-in-hand.

The alternative to this civilization-threatening scenario is to abandon business-as-usual energy policies and to cut carbon emissions by 80 %, not by 2050 as many political leaders suggest, because that will be too late, but by 2020, as outlined in the book *Plan B 3.0: mobilizing to save civilization*. The first step is to ban new coal-fired power plants, a move that is rapidly gaining momentum in the US. The main concern is whether we can mobilize to lower atmospheric CO_2 concentrations before higher temperatures dehydrate crops and melt the mountain glaciers that feed major rivers, which in turn irrigate our future grain harvests.

Food security will deteriorate further, unless leading countries collectively mobilize to stabilize population, restrict the use of grain to produce automotive fuel, stabilize climate, stabilize water tables and aquifers, protect cropland, and conserve soils. Stabilizing population is not simply a matter of providing reproductive health-care and family planning services. It requires a worldwide effort to eradicate poverty. Eliminating water shortages depends on the global attempt to raise water productivity, similar to the effort launched half a century ago to raise land productivity, an initiative that has nearly tripled the world grain yield per hectare. None of these goals can be achieved quickly, but progress toward all is essential in order to restore a semblance of food security.

Today's troubling food situation is unlike any the world has faced before. The challenge is not simply to deal with a temporary rise in grain prices, as in the past, but rather to quickly alter those trends whose cumulative effects collectively threaten the food security that is a hallmark of civilization. If food security cannot be restored quickly, social unrest and political instability will spread and the number of failing states will likely increase dramatically, threatening the very stability of civilization itself.

Global climate change and food security: role of adaptation and mitigation

Pramod Aggarwal
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The food security of several poor countries of the world, especially in Africa and Asia, is limited by frequent occurrence of climatic extremes such as droughts, floods, cyclones, and heat waves. The Fourth Assessment Report of the IPCC (Intergovernmental Panel on Climate Change), released in 2007, showed that these countries are likely to suffer significant additional consequences for food production and insecurity due to projected increase in climate variability and risks. Addressing climate change is central to ensure future food security and attainment of the Millennium Development Goals by these countries, especially on poverty alleviation. Urgent steps are, therefore, needed to increase their adaptive capacity to face current as well as future climatic risks. Action needs to be taken now, since it takes time for many adaptive practices to become effective. These adaptation strategies will need to simultaneously consider the background of changing demand due to globalization, population increase and income growth, as well as the socio-economic and environmental consequences of possible adaptation options.

There is considerable traditional knowledge in the

region for adapting to climatic risks that is valuable even today. This includes mixed cropping, changing crops / varieties and planting times, diversifying sources of income, and maintaining food-stocks for managing periods of scarcity. These management strategies would also help in the future climate change scenarios. However, it may not be enough in view of the increasing intensity of climatic risks and pressure on land to produce more food with much higher efficiency. Some additional adaptation options relevant for current as well as future climatic risks are effective dissemination of real-time weather information and required responses, insurance for climatic risk management, strengthened pest surveillance and forecasting mechanisms, and establishing community partnership based food, forage, and seed banks. Intensification of food production systems to bridge current yield gaps, improving land and water management, and strengthening research will further enhance adaptive capacity and, hence, food security.

The global share of average emissions of greenhouse gases from agriculture is 13.5%. This fraction is larger in developing countries due to the relatively large role of agriculture in their national economy. The emissions from agriculture are primarily due to methane emission from rice paddies, enteric fermentation in ruminant animals, and nitrous oxides from application of manures and fertilizers to agricultural soils. A variety of options exist for mitigation of these emissions. The most prominent options are improved crop and grazing land management (for example, improved agronomic practices, nutrient use, tillage, and residue management), restoration of organic soils that are drained for crop production and restoration of degraded lands. Significant mitigation is also possible with improved water and rice management, agro-forestry, and improved livestock and manure management.

The IPCC estimates that the mitigation options in agriculture are cost-competitive with non-agricultural options. If agricultural mitigation options could be included in future global agreements on climate change, it would lead to better soil fertility, increased production, and higher income for the farmers, in addition to the primary goal of reducing carbon emissions.

At present, the costs of adaptation and mitigation are not clearly known, although these are expected to be high. Strategies that maximize synergies between adaptation, mitigation, food production, and sustainable development would be the most appropriate. For example, increasing the efficiency of fertilizer and water use will lead to higher profits for the farmers as well as sequester more carbon, which will improve soil health and lead to higher production. Such practices would become more attractive if farmers are paid incentives for environmental services (for example, carbon sequestration) that agricultural practices provide. It is time that the society considers such incentives for farmers in the interest of global environment, food security, and poverty alleviation.

Climate change, food security, and poverty alleviation: National Rural Employment Guarantee Act, 2005

Rita Sharma, PhD
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Food security has three dimensions: (1) food availability – this is based on food production, (2) food accessibility – this depends upon purchasing power, employment or income, and (3) food utilization – this is contingent on clean drinking water, sanitation, health, and education. Climate change will adversely affect all three.

The vulnerability of poor households to the impacts of climate change on agriculture and livelihoods depends on access to land, water, and government support to enable adaptation. Climate change, food security, and poverty reduction are inter-related. Poverty eradication and development, including sustainable agriculture production, will promote adaptation to climate change and food security.

The impact of climate change falls differently on people. The brunt of the impact of climate change will be borne by the poor; those who have not contributed to the problem. The poor will have the least resources to cope. In this light, the response to climate change can become an action for poverty alleviation to reduce the vulnerabilities of the poor.

The IPCC (Intergovernmental Panel on Climate Change) projected that, as a result of an increase in anthropogenic emissions of greenhouse gases, the earth's temperature, which increased by 0.74 °C between 1906 and 2005, is likely to increase by 1.8–4.0 °C by the end of the century. This would lead to higher frequency of hot extremes, heavy precipitation events and floods, cyclones, more intense and longer droughts, and gradual recession of glaciers, which will reduce water availability for downstream populations.

South Asia has been identified as a hotspot for global warming and climate change. People living on the coasts, and floodplains, in hill tracts, and arid and semi-arid areas are most at risk. The poor and food-insecure will feel the impact first. Agriculture and natural resource based livelihoods will face immediate risk. As water tables decline, crop and livestock productivity will fall. New patterns of pests and diseases lack of appropriate seeds and planting material, and crop failure on account of drought will aggravate the situation. Traditional settlements will be threatened, leading to large-scale migration. Water-borne diseases will go up. There will be increasing instances of heat-related mortality.

In South Asia, two-thirds of the population derive their livelihood from agriculture and natural resource based activities. Agriculture still accounts for a significant share of the GDP of the countries in the region. The FAO (Food and Agriculture Organization) estimates that over one-third of the world's 830 million undernourished people live in South Asia.

India has good reasons to be concerned about climate change. The proportion of the country's population below poverty level, according to the Government of India definition (based on minimum level of dietary energy consumption), was 27.5% in 2004/05. This translates into 302 million people, of which 221 million (73%) reside in rural areas and are primarily dependent upon climate-sensitive sectors such as rain-fed agriculture, animal husbandry, forestry, herding, and fishing for livelihood.

Poverty eradication and development, including sustainable agriculture production, are the key instruments for addressing the challenges of climate change and safeguarding food security. The consistent efforts in mitigating poverty, in the past three decades, have resulted in the decline of the nation's poverty ratio from 54.9% in the mid-1970s to 27.5% in the mid-2000s (a reduction by 50%). The decline in absolute

numbers, however, has been a marginal 6%, down from 321 million to 302 million.

The Government of India's initiative in enacting a unique legislation, the NREGA (National Rural Employment Guarantee Act), 2005, is a major step in poverty alleviation and empowerment. This Act guarantees 100 days of employment to each rural household whose adult members volunteer to do unskilled manual work. The primary objective of the NREGA is to alleviate immediate deprivation by guaranteeing wage employment for a minimum of 100 days per household per annum at a prescribed minimum wage.

The auxiliary goal is to rejuvenate the natural resource base through the creation of durable rural assets, which can reduce poverty through growth effects and lead to sustainable livelihoods. Another expected outcome is the strengthening of grassroots, democratic, and participatory processes and developing a more robust regime of transparency and accountability in rural governance.

This historic legislation is unprecedented in its nature, scope, and extent. The employment entitlement applies to the entire country, covering over 600 districts and 600 000 villages. The macro-level performance indicators are impressive. In 2007/08, 33 million households were provided work. The expenditure was Rs 160 billion ($4 billion). Around 1.4 billion person-days of employment were generated, which is an average of 42 days per households. Seventy percent of the expenditure was paid as wages. 1.8 million jobs relating to soil and water conservation, drought proofing, flood protection, rural connectivity, afforestation and plantation, irrigation, and many others were undertaken. It is expected that in 2008/09, nearly 50 million households will be provided employment with an estimated expenditure of about Rs 320 billion ($8 billion).

The NREGA is the biggest legally guaranteed employment programme in human history. The power of the NREGA derives from the fact that it creates a right to work and is demand-driven. It targets the weak and vulnerable among the rural community. Small and marginal farmers, and landless labourers make up the bulk of the workforce. Scheduled Castes and Scheduled Tribes account for 57% of those who are provided work. Women constitute nearly 50% of the workers. Seasonal migrants, normally compelled to leave their villages, find employment under the NREGA.

While in operation for only about three years, early field reports point to the NREGA's positive impact on poverty reduction. Distress migration in several regions has subsided. Agricultural wages have risen and the bargaining power of agricultural labour has improved. Its major spatial impact has been in arid and drought prone regions, where groundwater recharge has improved, resulting in the rise of water tables, improved agricultural productivity, and increased cropping intensity.

The Indian experience is demonstrating that the NREGA, a poverty alleviation programme, is promoting adaptation to climate change. NREGA puts immediate purchasing power into the hands of the poor and enhances food security. However, the NREGA is not merely a safety net. It will lead to a long-run drought-proofing and flood-protection, making Indian agriculture better resilient to climate change by putting it on a more sustainable path. The potential of the NREGA as an instrument of adaptation lies in its ability to improve both food accessibility and availability.

Resources

Initiatives and agreement

Dhaka symposium declaration: international symposium on climate change and food security in South Asia

Dhaka, August 2008

The 'International symposium on climate change and food security in South Asia' was held at the University of Dhaka during 25–30 August 2008. It was jointly sponsored by the Ohio State University, the World Meteorological Organization, the Food and Agriculture Organization, the United Nations Economic and Social Commission for Asia and Pacific, the University of Dhaka, and the Government of Bangladesh. The Symposium resulted in a Dhaka Symposium Declaration, which highlighted the key issues, knowledge gaps, opportunities, and recommendations for all concerned stakeholders in order to work together in minimizing the short- and long-term vulnerability of the South Asian region to climate change and its impacts on food security in the region.

The link <http://www.wmo.int/pages/prog/wcp/agm/meetings/rsama08/documents/DhakaSymposiumDeclaration_new.pdf>

G8 leaders statement on global food security

G8 Summit, July 2008

The leaders of the world's eight wealthiest countries, the G8, discussed the ways to solve the global food crisis and global warming, among other issues, at the G8 Summit 2008. These discussions led to a release of a G8 Leaders Statement on Global Food Security. The statement clearly lays emphasis on the level of urgency with which the most immediate food, nutrition, and agricultural inputs needs of tens of millions of hungry people worldwide needs to be tackled.

Link to the statement <http://www.g8summit.go.jp/eng/doc/doc080709_04_en.html>

High-level conference on world food security: the challenges of climate change and bioenergy

FAO, 3–5 June 2008

The 'High-level conference on world food security: the challenges of climate change and bioenergy' opened at the Food and Agriculture Organization headquarters in Rome, Italy, on 3 June 2008. Throughout the three days of events, 42 heads of state and government, 100 high-level ministers, and 60 non-governmental and civil society organizations from 181 member countries discussed the challenges that climate change, bioenergy, and soaring food prices posed to world food security. Following significant discussion and negotiations, the conference concluded with the adoption by acclamation of a declaration calling on the international community to increase assistance for developing countries, in particular the least-developed countries and those that are most negatively affected by high food prices.

The declaration link <http://www.fao.org/fileadmin/user_upload/foodclimate/HLCdocs/declaration-E.pdf>

The meeting link <http://www.fao.org/foodclimate/hlc-home/en>

Forthcoming events

Sirte, Libyan Arab Jamahiriya
15–17 December 2008
Ministerial conference on water for agriculture and energy in Africa – the challenges of climate change
Websites <http://www.fao.org/nr/water/docs/sirteconceptnote.pdf>, <http://www.fao.org/nr/water/events.html>

Poznañ, Poland
1–12 December 2008
COP 14, CMP 4
Fourteenth session and Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP), Fourth Session
Website <http://unfccc.int/meetings/unfccc_calender/items/2655.php>

Delhi, India
5–7 February 2009
Delhi Sustainable Development Summit
Towards Copenhagen: an equitable and ethical approach
Email dsds@teri.res.in
Website <http://dsds.teriin.org/2009/index.htm>

Denmark, Aarhus
5–6 March 2009
Climate change, sustainability and the 'Post-2012 regime'
Faculty of Agricultural Sciences
Blichers Allé 20
Postboks 50, 8830 Tjele
Email anne.overgaard@biology.au.dk

Denmark, Copenhagen
10–12 March 2009
International scientific congress on 'Climate change: global risks, challenges and decisions'
Climate Office
University of Copenhagen
Noerregade 10, P O Box 2177
1017 Copenhagen K
Email jsha@adm.ku.dk
Website <http://climatecongress.ku.dk>

World Sustainable Development Forum

The WSDF (World Sustainable Development Forum), established by TERI, provides a platform to identify, analyse, and disseminate policy interventions to enhance human well-being in the present, and create conditions for a sustainable future. In its endeavours, the Forum is supported by highly distinguished patrons and advisory committee members who are global leaders in government, industry, and academia, as well as opinion-makers in a world characterized by locale specific socio-economic and environmental priorities. Given the diverse developmental imperatives across regions, WSDF activities and events seek to spread the key messages emerging from the annual DSDS (Delhi Sustainable Development Summit) and RSDS (Regional Sustainable Development Summit), collate information, monitor developments, and report on the progress of MDGs, apart from understanding and disseminating information on the issues of sustainable development in varied contexts.

Towards this end, a biannual newsletter series titled 'Tackling tomorrow's challenges today', which is published by the Forum, seeks to discuss development prerogatives, debates, and discourses with the aim of highlighting challenges to the attainment of development that is sustainable worldwide. Given overriding global concerns on the subject, this second issue brings to focus the key issues pertaining to climate change and food security.

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The WSDF (World Sustainable Development Forum) solicits support from governments, institutions, organizations, and corporate houses in bringing together the finest minds and leading thinkers of the world to focus on the global challenges of sustainable development.

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