Chapter 16
Global Climate Change and Food Security in South Asia: An Adaptation and Mitigation Framework

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Contents

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Abstract South Asia is home to nearly 22% of the world's population, including 40% of the world's poor. Agriculture plays a critical role in terms of employment and livelihood security for a large majority of people in all countries of the region. The region is prone to climatic extremes, which regularly impact agricultural production and farmers' livelihood. Himalayan glaciers, a major source of water for the rivers in the Indo-Gangetic plains, are projected to significantly recede in future that could affect food and livelihood security of millions of people in Pakistan, Nepal, Bhutan, India and Bangladesh. Climate change is further projected to cause a 10–40% loss in crop production in the region by the end of the century. The increased climatic variability in future would further increase production variability. Producing enough food for the increasing population in a background of reducing resources in a changing climate scenario, while minimizing environmental degradation is a challenging task. Simple adaptation strategies such as changes in planting dates and varieties could help in reducing impacts of climate change to a limited extent. A Regional Adaptation and Mitigation Framework for South Asia is proposed that could assist the region in increasing its adaptive capacity to climate change. This includes assisting farmers in coping with current climatic risks, intensifying food production systems, improving land, water and forests management, enabling policies and regional cooperation, and strengthening research in critical areas. South Asian agriculture is a significant source of greenhouse gases (GHG) emissions, primarily due to methane emission from rice paddies, enteric fermentation in ruminant animals, and nitrous oxides from application of manures and fertilizers to soils. While a considerable fraction of this is inevitable, some reduction in emissions could be obtained by midseason drainage or alternate drying in irrigated rice, increasing nitrogen use efficiency and soil carbon, and improvements in livestock diet. Clear inclusion of agricultural GHG mitigation options in future international agreements would lead to improved soil fertility, higher income for the farmers, and food security.

Keywords Climate change • South Asia • Food security • Adaptation • Mitigation

Abbreviations

CDM	Clean development mechanisms
COP	Conference of parties
GDP	Gross domestic product

GHG	Greenhouse gas
MDG	Millennium development goals
SAARC	South Asian Association in Regional Cooperation
UNFCCC	U.N. Framework Convention on Climate Change

16.1 Introduction

A large human population, continuing high rate of population growth, and poverty characterize South Asia. The region has nearly 1.4 billion people (22% of the world's population), including 40% of the world's poor. Agriculture continues to play a critical role in terms of employment and livelihood security in all countries of the region, although its share has now considerably declined to 20–25% of GDP. More than half of the population of the region is still engaged in agriculture. Most farms in the region are small (less than 1 ha). In addition to the marginal and small farmers there are a large number of landless households. There are more than 300 million hungry and malnourished people in the region.

South Asia is very prone to climatic extremes. Droughts and floods are common in the whole region whereas heat waves and cyclones occur regularly in some parts. Degradation of natural resources due to intensive human activities is also common in the region. There is evidence of gradual deterioration in natural resources, particularly in areas that benefited from the Green Revolution technologies. The introduction of canal irrigation in India, for example, has resulted in almost seven million ha of cultivated land becoming effected by soil salinity and waterlogging (Joshi and Tyagi 1994) while the rapid increase in the number of tubewells during the last three decades in north-western India, eastern Pakistan and other regions has resulted in overexploitation of groundwater, leading to a rapid fall in water-tables. There is now growing concern about the decline in soil fertility, changes in water-table depth, deterioration in the quality of irrigation water, and rising salinity (Sinha et al. 1998).

Despite impressive development of irrigation potential, food production and consequently economy of the region is still considerably dependent on monsoon. There have been several droughts and floods in all countries of the region, which have affected their food security.

During last few decades, however, the region as a whole has shown progress on several fronts at the macro level. The population growth rate has shown some decline, although there are significant differences among countries. The region has generally achieved food self-sufficiency and the per capita availability of food is rising. In general, there has also been an increase in per capita income, which has led to increasing demand of superior grains, and animal and horticultural products (Bhalla et al. 1999).

South Asian population is predicted to increase by almost 700 million people in the next 40 years. This, and the rising income of people is expected to result in a large demand for food. It is estimated that the food grain requirement by 2020 in the region will be almost 50% more than in 2000 (Paroda and Kumar 2000). The additional quantities will have to be produced from the same land resource, or less, due to the increase in competition for land and other resources by non-agricultural sectors. The situation may be further complicated by global climatic change that directly affects agriculture and hence food supply.

The global mean annual surface air temperature increase by the end of this century is likely to be in the range of 1.8–4.0°C (IPCC 2007a). For South Asia, the projections for increases in mean annual temperature are 0.5–1.2°C by 2020, 0.88–3.16°C by 2050 and 1.56–5.44°C by 2080 depending upon the scenario of future development (Table 16.1; IPCC 2007a). Overall, the temperature increases are likely to be much higher in the *rabi* (winter) season than in the *kharif* (monsoon) season. It is very likely that hot extremes, heat waves, and heavy precipitation events will become more frequent. The projected sea level rise by the end of this century is likely to be 0.18–0.59 m. Rupa Kumar et al. (2006) have shown similar results for the region using a regional climate model.

The absolute amount of precipitation is likely to increase in South Asia in future in all months except in the period December–February when this is likely to decrease (Table 16.1). This increase may, however, be associated by heavier precipitation events and fewer rainy days leading to increased frequency of floods and droughts in the region.

The IPCC (2007b) showed that densely populated megadeltas of the region such as those in India and Bangladesh, and islands and coastal areas such as those in Sri Lanka and Maldives, India and Bangladesh are more vulnerable to global climate change. Enhanced glacier melt in the Himalayas is projected to reduce availability of water resources in agriculturally important Indo-Gangetic plains of Pakistan, India, Nepal and Bangladesh.

The Thirteenth Conference of Parties to the UNFCCC Conference in Bali (COP-13) in 2007 saw some progress in cooperative action by all countries for meeting these challenges. Bali Action Plan calls for enhanced action on mitigation and adaptation by nationally appropriate commitments and actions, technology development and transfer, and provision of financial investments and resources to support these.

FAO organized in June 2008 a conference entitled ‘World Food Security: the Challenges of Climate Change and Bioenergy’. It urged governments to explore how farmers, smallholders in particular, could adapt and assist in mitigation through the global financial mechanisms and investment flows, and technology development and transfer (FAO 2008).

Producing enough food to meet the increasing demand against the background of reducing resources in a changing climate scenario, while also minimizing further environmental degradation in South Asia, will be a challenging task. Addressing climate change is central for the region’s future food security and attainment of Millennium Development Goals (MDGs), especially on poverty alleviation. The region will need to implement strategies, linked with its development plans, to enhance its adaptive capacity, mitigate emissions of greenhouse gases (GHG) and sequester more carbon.

Table 16.1 Projected changes in surface air temperature and precipitation for South Asia under SRES A1FI (highest future emission trajectory) and B1 (lowest future emission trajectory) pathways for 2020s, 2050s and 2080s (From IPCC 2007a)

	2020				2050				2080			
	Temperature (°C)		Precipitation (%)		Temperature (°C)		Precipitation (°C)		Temperature (°C)		Precipitation (%)	
Season	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1
Dec.–Feb.	1.17	1.11	−3	4	3.16	1.97	0	0	5.44	2.93	−16	−6
Mar.–May	1.18	1.07	7	8	2.97	1.81	26	24	5.22	2.71	31	20
June–Aug.	0.54	0.55	5	7	1.71	0.88	13	11	3.14	1.56	26	15
Sept.–Nov.	0.78	0.83	1	3	2.41	1.49	8	6	4.19	2.17	26	10

The Fifteenth South Asian Association for Regional Cooperation (SAARC) Summit held in Colombo on 2 and 3 August 2008 reiterated the need for increased regional cooperation in assessing and managing risks and impacts of climate change, and to develop a people-centered short to medium term strategy to ensure region-wide food security (http://www.saarc-sec.org/data/summit15/colombostatementonfoodsecurity.htm).

Some Governments of the region have developed their *National Action Plans on Climate Change* detailing strategies they will follow for increasing their adaptive capacity and for mitigation (Government of India 2008; MOEF 2008).

In the light of these developments, a Regional Adaptation and Mitigation Framework for South Asia is being proposed in this paper which articulates the vision on technological and policy options for enhancing adaptive capacity, mitigating GHG emissions, and sequestering carbon in agricultural systems of South Asia, while keeping focus on meeting increased food production and other developmental targets.

16.2 Impacts of Climate Change on South Asian Agriculture

IPCC (2007b) indicates that crop yields could decrease up to 30% in South Asia by the end of the century even if the direct positive physiological effects of CO_2 are taken into account. Several global studies indicate a probability of 10–40% loss in crop production in India with increases in temperature by 2080–2100 (Rosenzweig and Parry 1994; Fischer et al. 2002; Parry et al. 2004; Cline 2007; Stern 2007). These long-time horizon estimates generally assume the business as usual scenario, no new technology development, and no or limited adaptation by all stakeholders. Recent studies in India and Pakistan suggest a 5–7% decline in wheat for every degree Celsius increase in temperature provided irrigation remains available in future at today's levels. In Sri Lanka, initial estimates indicate a loss of 6% rice output with an increase of 0.5°C temperature (Government of Sri Lanka 2000).

The projected negative impacts of increased temperatures on cereal yields in the low latitude regions (see Box 16.1) imply that food security of most developing countries, including the South Asian countries, is likely to become vulnerable in near future. At the same time, differential impacts of climate change on food production in different parts of the world is likely to have consequences on international food prices and trade (Easterling et al. 2007).

Analysis of the historical trends in yields of crops in the Indo-Gangetic plains using regional statistics, long-term fertility experiments, other conventional field experiments and crop simulation models has shown that rice yields during last three decades are showing a declining trend and this may be partly related to the gradual change in weather conditions during last two decades (Aggarwal et al. 2000a; Pathak et al. 2003).

All countries of South Asia frequently experience natural climatic disasters. Bangladesh, parts of India and Sri Lanka are low-lying coastal areas prone to cyclones, sea level rise, and floods. Bhutan, Nepal, India and Pakistan have several mountain ecosystems that are vulnerable to glacier melt. Semi-arid and arid areas of India, Afghanistan, Pakistan and Bangladesh frequently experience heat and drought stress. Such climatic extremes are known to negatively impact agricultural production, and farmers' livelihood. The projected increase in these events could result in greater instability in food production and threaten livelihood security of farmers. Increased production variability could be perhaps the most significant impact of global climate change on South Asian economies.

Rise in sea level can significantly affect the livelihood of coastal communities due to salinization of cultivated areas and water bodies, and associated change in land use.

Cold waves cause significant losses to crops such as mustard, mango, guava, papaya, brinjal, tomato, and potato in northern India, Nepal, Afghanistan and Pakistan. There are indications that such cold waves and frost events could decrease in future due to global warming and hence yield losses in these crops associated with frost damage are likely to decrease.

The IPCC has indicated a significant increase in runoff in many parts of the world including South Asia due to global warming (IPCC 2007b). This, however, may not be very beneficial because the increase is largely in the wet season and the extra water may not be available in the dry season, when it is most needed, unless storage infrastructure is vastly expanded. This extra water in the wet season, on the other hand, may lead to increase in frequency and duration of floods. The increased melting and recession of glaciers associated with global climate change could further change the runoff scenario. In recent decades, Himalayan glaciers have receded between 2.6 and 28 m/year (Kulkarni and Bahuguna 2002). These glaciers are a major source of water for the rivers such as the Indus, Ganga and Brahmaputra in the Indo-Gangetic plains, which are crucial to millions of people in Pakistan, Nepal, Bhutan, India and Bangladesh. Such increases in glacier melt in Himalayas could affect availability of water for irrigation especially in the Indo-Gangetic plains, and thus affect food and livelihood security of millions.

The nutritional quality of cereals may be moderately affected by climatic changes, which in turn, may have consequences for nutritional security of several developing countries where cereals are the primary diet. Research has indeed shown that the increasing CO_2 concentrations and temperature lead to a decline in grain protein content in cereals (Hocking and Meyer 1991; Ziska et al. 1997).

Crop–pest interactions will change significantly with climate change leading to impact on pest distribution and crop losses (Easterling et al. 2007). Diseases and insect populations are strongly dependent upon the temperature and humidity. Any increase in them, depending upon their base value, can significantly alter their population, which ultimately results in yield loss. With small changes, the virulence of different pests changes. The swarms of locusts produced in the Middle East usually fly eastward into Pakistan and India during summer season and they lay eggs during monsoon period. Changes in rainfall, temperature and wind speed pattern may influence the migratory behavior of locusts and other similar pests, thus threatening food and livelihood security.

Heat stress associated with global warming directly impacts forage quality, ingestion of food and feed, declines in physical activity, and ultimately reduces dairy milk yield (St-Pierre et al. 2003). Increases in air temperature and/or humidity have the potential to affect the reproductive behavior of domestic animals. Global warming would further increase water, shelter, and energy requirement of livestock for meeting the projected increased milk demands.

Increasing sea and river water temperature is likely to affect fish breeding, migration, and harvests (Sharp 2003; Easterling et al. 2007). A rise in temperature as small as 1°C could have important and rapid effects on the mortality of fish and their geographical distributions. Corals are affected by warm surface waters leading to bleaching due to losses of associated symbiotic algae. Heat stress in 1998 and 2002 caused considerable bleaching of corals in the Indian Ocean (Wilkinson et al. 1999; Kumaraguru et al. 2002). Such events are likely to become more frequent in future due to global climate change.

Box 16.1 IPCC's key observations on vulnerability of agriculture to global climate change (IPCC 2007b)

In mid- to high-latitude regions, moderate to medium local increases in temperature (1–3°C), along with associated carbon dioxide (CO_2) increase and rainfall changes can have small beneficial impacts on crop yields. In low-latitude regions, even moderate temperature increases (1–2°C) are likely to have negative yield impacts for major cereals. Further warming has increasingly negative impacts in all regions (medium to low confidence).

About 2.5–10% decrease in crop yield is projected for parts of Asia in 2020s and 5–30% decrease in 2050s compared with 1990 levels without CO_2 effects (medium confidence).

Projected changes in the frequency and severity of extreme climate events have significant consequences for food production, and food insecurity, in addition to impacts of projected mean climate (high confidence).

Smallholder and subsistence farmers, pastoralists and artisanal fisherfolk will suffer complex, localised impacts of climate change (high confidence).

Food trade is projected to increase in response to climate change, with increased dependence on food imports for most developing countries (medium to low confidence).

The marginal increase in the number of people at risk of hunger due to climate change must be viewed within the overall large reductions due to socio-economic development (medium confidence).

Projected changes in the frequency and severity of extreme climate events have significant consequences for food production, and food insecurity, in addition to impacts of projected mean climate (high confidence).

Simulations suggest rising relative benefits of adaptation with low to moderate warming (medium confidence), although adaptation stresses water

(continued)

Box 16.1 (continued)

and environmental resources as warming increases (low confidence). On average, in cereal cropping systems worldwide, adaptations such as changing varieties and planting times enable avoidance of a 10–15% reduction in yield corresponding to 1–2°C local temperature increase. Adaptive capacity in low latitudes is exceeded at 3°C local temperature increase.

16.3 A Regional Framework for Adapting Agriculture to Climate Change

In view of the projected large-scale adverse effects of global warming on food production in South Asia, we need to analyze the possible options that could assist in increasing the regions adaptive capacity. There is considerable traditional wisdom in the region for adapting to climatic risks and it is valuable even today. Sharing such experiences accumulated over centuries across South Asia could be useful at the household, community as well as regional level. The region has earlier adapted to climatic stresses by resorting to mixed cropping, changing varieties and planting times, by diversifying sources of income for farmers, and maintaining buffer stocks of food for managing periods of scarcity. These management strategies would also help in the future climate change scenarios but may not be enough in view of the increasing intensity of climatic risks and pressure on land to produce more food and also with much higher efficiency. Some of the possible adaptation options, which are relevant for adapting to current climatic risks as well as to climate change, are discussed below (see Box 16.2). These include options available with farmers (often referred to as autonomous adaptations) as well as with communities and governments (often referred to as planned adaptation). The latter are generally policy options that facilitate increases in the adaptive capacity of the agricultural systems.

Box 16.2 Key elements of the adaptation framework for South Asia

1. Assisting farmers in coping with current climatic risks
   - Improving collection and dissemination of weather related information
   - Establishing a regional early warning systems for climatic risks
   - Promoting insurance for climatic risk management
   - Facilitating establishment of community partnership in food, forage and seed banks
2. Intensifying food production systems
   - Bridging yield gaps in crops
   - Enhancing livestock productivity
   - Enhancing fisheries

(continued)

Box 16.2 (continued)

3. Improving land, water, and forests management
   - Implementing strategies for water conservation and use efficiency
   - Managing coastal ecosystems
   - Increasing the dissemination of resource conserving technologies
   - Exploiting the irrigation and nutrient supply potential of treated wastewaters
   - Improving management of forests
4. Enabling policies and regional cooperation
   - Integrating adaptation perspectives in current policy considerations
   - Providing incentives for resource conservation
   - Establishing regional food security programs
   - Securing finances and technologies for adaptation
   - Raising capacity in regional climate change assessments
5. Strengthening research for enhancing adaptive capacity
   - Assessing regional impacts on crops, livestock, fisheries, pests, and microbes
   - Evolving 'adverse climate tolerant' genotypes
   - Evaluating the biophysical and economic potential of various adaptation strategies

16.4 Assisting Farmers in Coping with Current Climatic Risks

16.4.1 Improving Collection and Dissemination of Weather Related Information

South Asia experiences considerable number of climatic extremes even today. A prerequisite for managing climatic risks, and thus increasing adaptive capacity, is timely knowledge of their spatial and temporal magnitude. A dense network of Weather Stations for standardized, real-time monitoring of rainfall and temperatures needs to be established in the whole region. The *SAARC* Meteorogical Research Centre (SMRC) could be very effective for this purpose. The weather data, together with short- and medium-range weather forecasts, will enable scientists and extension workers to quickly translate the information into region-specific, value-added agricultural services for farmers such as time of crop planting, applying inputs, and timing the farm operations. Development of decision support tools for translating weather information into operational management practices will further facilitate this.

16.4.2 Establishing a Regional Early Warning System for Climatic Risks

A reliable and timely early warning system of impeding climatic risks could help in determining the potential food insecure areas and communities given the type of risk. Success of such a system is also dependent upon community preparedness to quickly use such warnings. To enable this, contingency plans should be developed for different types and durations of risks for various agro-ecological regions with due consideration to the required response time and available resources. Cooperation in developing such an early warning system, especially using modern tools of information and space technologies will be mutually beneficial for all countries of the region. This is especially critical for monitoring movements of insects and pathogens within South Asia. As climatic features, agricultural profiles, and pests are similar across large parts of the region, countries may not be able to address the issues related to transboundary movement of pests individually. Mechanisms do exist in some countries of the region to keep track of the movements of few pests such as locusts and avian bird flu. These early warning mechanisms, including regional cooperation for risk analysis, exchange of information and coordinated action, need considerable strengthening for a variety of key pests.

16.4.3 Promoting Insurance for Climatic Risk Management

The increasing probability of floods and droughts and other uncertainties in climate may seriously increase the vulnerability of resource-poor farmers of South Asia to global climate change. Policies that encourage crop/livestock insurance spread the risk and thus provide protection to the farmers if their farm production is reduced due to natural calamities. Weather insurance, coupled with standardized weather data collection, can greatly help in providing an alternate option for adapting agriculture to increased climatic risks. South Asian countries, in cooperation with other vulnerable regions such as in Africa, should endeavor to secure global adaptation and mitigation funds for improving climatic services and for implementation of weather related risk management programs.

16.4.4 Facilitating Establishment of Community Partnership in Food, Forage and Seed Banks

Climatic risks such as drought, cyclones and floods, often result in destruction of standing crops and loss of livestock. In such events, farmers need food for themselves, forage for their surviving livestock, and seeds to replant. Since such activities cost money and individual farmers may not be able to manage them on their own, communities of farmers could group together and establish their own stocks of food, forage and seeds. Such self-help groups will require technical and financial support from the government and other development partners, at least in the initial stages.

16.5 Intensifying Food Production Systems

16.5.1 Bridging Yield Gaps in Crops

Recent years have witnessed stagnation in food production in South Asia. The national average yields of rice and wheat crops are less than 4 t/ha today, whereas climatic factors in the region allow reasonably high yield potential of most crops. For example, in the productive Indo-Gangetic plains, potential rice and wheat yields are estimated to be 10 and 8 t/ha, respectively (Aggarwal et al. 2000b) indicating large yield gaps. Such yield gaps exist in all crops and across all ecosystems and bridging them could ensure meeting increased food demands of the future (Singh et al. 2001). Even if a fraction of these yield gaps could be bridged, food security in the region could be strengthened and the vulnerability of the food sector to climate change could be reduced. Fragile seed sector, poor technology dissemination mechanisms, lack of adequate capital for inputs, and poor markets and infrastructure are the key reasons for yield gaps (Aggarwal et al. 2004). A mission-oriented approach for key crops focusing on eliminating these constraints will enhance food security. Considering increasing competition for land and water among agriculture, urban settlements, industry, and recently biofuel plantations, such a mission approach must also ensure more yields per unit of land, water, and nutrients.

16.5.2 Enhancing Livestock Productivity

In recent past, livestock productivity has increased in South Asia due to intensification and industrialization. This will need to be further augmented to meet rapidly growing demands for milk and meat. Most livestock in the region feed primarily on crop by-products, household waste, and open grazing areas. Since productivity is the key to growth, livestock productivity will have to be raised through scientific breeding, feeding and management (Nin et al. 2007; Staal et al. 2008). Climate change is likely to impact availability of feed, water and energy for livestock. Livestock species with higher adaptation to harsher environments are available but they often have low productivity. Heat tolerance of the key livestock species needs to be enhanced by allele mining. Livestock based industry will also need to adapt to provide cooler housing for animals for alleviating their heat related distress and decline in reproduction.

This will require formulation of long-term policies by the governments and significant investments in the industry. In view of large number of low productive livestock in the region, South Asia must assess the size of the sustainable livestock population with a perspective on carbon emissions, water use, milk production and social values.

16.5.3 Enhancing Fisheries

Fisheries are a major source of nutrition and livelihood security to millions of fishers and others in South Asia (FAO 1997). This sector has seen phenomenal growth in last few decades. To meet future demands of fish, there is a need to utilize scientific and sustainable fishing practices, enhancing fish productivity, strengthening the whole chain from fish production to consumption, and imparting skills in community management and training in different aspects of fisheries and aquaculture. Climate change is likely to impact fish breeding, migration and harvest in marine as well as inland ecosystems (Nellemann et al. 2008). Being a highly perishable commodity, the quality of fish and fish products may erode due to rise in atmospheric temperature. Increase in extreme events will also have considerable impact on fisheries and aquaculture. Alternate fish species and fishing practices will need to be studied that could meet the demands for fish in the face of climate change. A comprehensive assessment of the fisheries potential of the increasing waterlogged and inundated areas as a result of higher precipitation caused by global warming should be made. Similarly, the scope for enhancing mariculture may be explored for the areas affected by sea level rise and incursion of seawater into the coastal areas.

16.6 Improving Land, Water, and Forests Management

16.6.1 Implementing Strategies for Water Conservation and Use Efficiency

Agriculture sector uses the largest amount of water in South Asia, yet a large fraction of arable land remains rainfed. There is an urgent need to develop technologies and policies for integrated storage and distribution of surface, ground, and rainwater. Technical standards, design and operation of irrigation systems should take note of the changing climatic variability. Scientific watershed management programs can assist in this endeavor and at the same time yield multiple benefits such as sustainable production, resource conservation, ground water recharge, drought moderation, employment generation and social equity (Dhyani et al. 1997).

In South Asia, there are several transboundary river basins such as Indus, Ganges and Brahmaputra and Tista. Comprehensive planning and regional collaboration from the perspective of glacier melt and water availability, its appropriate storage and integrated use could help in conserving water resources and utilizing them for alleviating droughts during periods of water stress. Appropriate measures should be put in place to manage increased silting of the irrigation systems caused by increased runoff and soil erosion associated with projected higher frequency of the intense rainfall events in the future.

16.6.2 Managing Coastal Ecosystems

Sea level rise is likely to inundate heavily populated, large coastal lands in India, Bangladesh, Maldives and Sri Lanka. This may lead to salinization of land and water bodies, and drainage congestion. Coastal lands are also vulnerable to frequent cyclones and other climatic extremes (Alam and Laurel 2005). There has been a significant increasing trend in the cyclone frequency over the Bay of Bengal during November and May, the main months for cyclone in the Bay of Bengal (SMRC 2003). Due to their limited financial resources, expensive adaptation mechanisms to prevent inundation of coastal lands may not be feasible. Salinity management, alternate land/resource use systems including salt tolerant crops, fish and fisheries, and diversification of livelihood strategies acceptable to local communities will, however, enhance their adaptive capacity.

16.6.3 Increasing the Dissemination of Resource Conserving Technologies

Recent researches have shown that surface seeding or zero-tillage establishment of upland crops after rice gives similar yields to those planted under normal conventional tillage over a diverse set of soil conditions. This reduces costs of production, allows earlier planting and thus higher yields, results in less weed growth, and above all reduces the use of fuel, and shows improvements in efficiency of water and fertilizers. Such technologies have become quite popular in eastern Pakistan and northwestern India (RWC 2007). Studies should be made to analyze and eliminate the key limitations for its accelerated diffusion in other parts of South Asia.

16.6.4 Exploiting the Irrigation and Nutrient Supply Potential of Treated Wastewaters

In the future, irrigation water availability in South Asia is likely to be less due to glacier retreat, increased variability in precipitation, and competition from rapidly growing industrial and urban sectors. In order to meet the increasing food demands in such a scenario of increasing water deficits there is a need to improve water productivity at all scales. Additionally, industrial and sewage wastewater could be evaluated as a potential irrigation source. Such effluents, once properly treated, can also be a source of nutrients for crops and potentially for fish culture. Since water serves multiple uses and users, effective inter-departmental coordination in the government is needed to develop the location specific framework of sustainable water management and cost-effective recycling of wastewater.

16.6.5 Improving Management of Forests

Forests account for about 20% of the arable land use in south Asia and are a large reserve of biodiversity and provide many services to local communities and national economy apart from protection against floods, cyclones and sea level rise. IPCC (2007b) has shown that the net primary productivity of forest ecosystems is likely to increase due to CO_2 fertilization, at least in the initial decades, and may decline in the later periods. Studies by Ravindranath et al. (2006) on forest ecosystems of India have shown that nearly 75% area is likely to experience changes in forest or vegetation type. Since forests are highly vulnerable even at moderate warming, there is a need for developing effective adaptation practices and policies. These strategies include planting of tolerant species, mixed species forestry, implementation of fire protection practices, conservation of biodiversity, halting of forests fragmentation, and promoting community forestry (Ravindranath et al. 2006).

16.7 Enabling Policies and Regional Cooperation

16.7.1 Integrating Adaptation Perspectives in Current Policy Considerations

South Asian countries have limited resources, which are targeted towards attaining food security and poverty alleviation, and other developmental targets. Addressing future climate change concerns at the cost of current priority of development cannot be an option. However, integrating perspectives on climatic risks in their current policies and programs in different sectors such as disaster management, water resources management, land use, biodiversity conservation, and agricultural development will lead to increased adaptive capacity to current as well as future climatic variability.

16.7.2 Providing Incentives for Resource Conservation

Adaptation to environmental change could be in the form of a policy where positive incentives are provided to farmers and industry for increasing the resilience of food production systems. Necessary provisions need to be included in the development plans to address the issues of attaining twin objectives of containing environmental changes and improving resource use productivity. For example, policies and incentives for appropriate organic matter management in rural areas would encourage farmers to sequester carbon in the soil and thus improve soil health, and use water and energy more efficiently. Rational pricing of surface and groundwater and incentives for their conjunctive use can arrest its injudicious use.

16.7.3 Establishing Regional Food Security Programmes

History has shown that climatic extremes do not impact the entire South Asian region at the same time. Despite being land and food scarce, several countries in the region have evolved a policy of storing food in good years to manage food scarcity in bad years as well as for providing support to relatively poor population. Assuming that climate change associated extremes are not likely to occur all over South Asia at the same time in the future as well, and considering the huge costs of storing food, SAARC countries should establish a Food Security Fund or a Food Bank to augment the regional food security that will mutually benefit countries in reducing supply fluctuations during adverse weather. Such emergency reserves should be specifically meant for supporting only the poor and needy.

16.7.4 Securing Finances and Technologies for Adaptation

Implementing various strategies for enhancing adaptive capacity would require considerable financial resources. Several global funds for adaptation are now available and some more are likely to be established in future. South Asia should attempt to secure these funds for 'climate proofing' food supplies in its vulnerable regions. Some specific programs where such funds could be used are developing and strengthening adaptation related infrastructure, implementation of weather related risk insurance programs, enhancing research capacity, and for securing 'patented' knowledge/technologies related to adaptation, including germplasm/genes from various sources.

16.7.5 Raising Capacity in Regional Climate Change Assessments

Effective handling of environmental issues in agriculture needs a close interaction between scientists, development partners, policy makers, administrators, trade and industry, farmer organizations and other stakeholders. Different types of capacity building programs need to be developed at various levels to ensure efficient management of natural resources for sustainable agricultural development. A network could be established to facilitate continuous dialogue, share experiences, and to develop strategies for implementation of desired changes. Enhancing capacities of SAARC regional centers on agriculture, disaster management, coastal zones, meteorology, and forestry, will strengthen regional cooperation and enhance adaptive capacity.

16.8 Strengthening Research for Enhancing Adaptive Capacity

16.8.1 Assessing Regional Impacts on Crops, Livestock, Fisheries, Pests, and Microbes

Developing an effective adaptation response requires a comprehensive understanding of the impacts and vulnerabilities of different agricultural commodities, and microbes and pests. A large part of current understanding of impacts on South Asia is based on generic global scale assessments since there are relatively few regional studies. Indigenous research is needed to understand the probable impacts especially on native crops such as legumes, oilseeds, and plantations. This requires special facilities such as carbon dioxide enrichment and temperature enhancement in open fields, controlled environment chambers, and validated simulation models. Regional and international cooperation for capacity enhancement in this should be sought. Special attention is needed in the region in short-term to assess the impacts of enhanced climatic variability at critical stages of crop growth and its management.

16.8.2 Evolving 'Adverse Climate Tolerant' Genotypes

Future breeding efforts will need to address multiple stresses – droughts, floods, heat, salinity, and pest load – imposed by changing global climate. There will be a need to stack several adaptive traits in a suitable agronomic background. This requires substantial breeding efforts, including collection, conservation and distribution of appropriate genetic material among breeders and other researchers. There is a need for a better understanding of wild relatives and landraces, and their distributions and sensitivity to climatic variables. In view of large biodiversity for stress tolerance in South Asia, regional cooperation in development of adapted genotypes should be encouraged.

16.8.3 Evaluating the Biophysical and Economic Potential of Various Adaptation Strategies

There are several strategies available with farmers such as using alternate crops/varieties, livestock and fish species, and modified input management that can be employed to manage small changes in climatic parameters. Larger changes in climatic parameters may require consideration of alternate land use systems. Since the socio-economic scenario is rapidly changing, and there is considerable uncertainty in the magnitude of global climate change, a thorough quantitative assessment of the potentials and constraints of land is needed, in which scientific knowledge, socio-economic conditions and the conflicting interests of various stakeholders can be harmonized and most efficient and sustainable land use systems identified. Current availability of simulation models and other systems research tools provides an opportunity for an interdisciplinary approach for this (Roetter et al. 2007). Capacity for such research in the region could be enhanced through international collaboration.

16.9 A Framework for Mitigation of Emissions from Agriculture

The global share of average emissions of GHG from agriculture is 13.5% (IPCC 2007c). This fraction is much larger in South Asian countries due to relatively large role of agriculture in national GDP. The IPCC concluded that there has been a large growth in emissions from agriculture in South Asia in last few decades relative to the developed world due to expanding use of nitrogen fertilizers and manure to meet demands for food resulting from rapid population growth (IPCC 2007c). In the future, the percentage of emissions from agriculture in the region is likely to be smaller, and closer to the global average, due to relatively much higher growth in energy use (and hence emissions) in transport and industrial sectors.

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 (Fig. 16.1). IPCC has identified various strategies for enhancing carbon sequestration in soils and for mitigating emissions of GHG from agricultural systems (see Box 16.3). The key ones in the context of South Asia are discussed below.

16.10 Sequestering Soil Carbon and Mitigating GHGs

Soil carbon sequestration is considered the main mechanism responsible for mitigation potential (Smith et al. 2007). There are several approaches to increase carbon sequestration in soils of South Asia (Lal 2004). These include addition of organic manures, minimal tillage, residue management, agroforestry, scientific water and nutrient management, and restoration of degraded soils. Lal (2004) estimates that such practices can lead to carbon sequestration of 25–50 Tg C/year in soils of South Asia for several decades, including 11–22 Tg C/year on croplands.

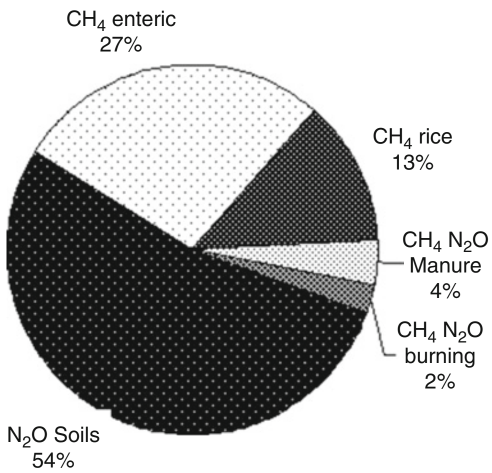

Fig. 16.1 Contribution of various agricultural sectors to GHG emissions in South Asia (Smith et al. 2007)

Box 16.3 IPCC's key observations for mitigation of GHGs and carbon sequestration in agricultural systems (IPCC 2007c)

A variety of options exist for mitigation of GHG emissions in agriculture. The most prominent options are improved crop and grazing land management (e.g., improved agronomic practices, nutrient use, tillage, and residue management), restoration of organic soils that are drained for crop production and restoration of degraded lands. Lower but still significant mitigation is possible with improved water and rice management; set-asides, land use change (e.g., conversion of cropland to grassland) and agro-forestry; as well as improved livestock and manure management.

Soil carbon sequestration (enhanced sinks) is the mechanism responsible for most of the mitigation potential (high agreement/much evidence), with an estimated 89% contribution.

Current GHG emission rates may escalate in the future due to population growth and changing diets (high agreement/medium evidence). Deployment of new mitigation practices for livestock systems and fertilizer applications will be essential to prevent an increase in emissions from agriculture after 2030.

Organic soil restoration has a host of biodiversity/environmental co-benefits but opportunity cost of crop production lost from this land; economic impact depends upon whether farmers receive payment for the GHG emission reduction.

Controlling emission of methane from paddies by midseason drainage or alternate drying instead of continuous flooding in irrigated areas has reasonable mitigation potential. Improved management of livestock diet through use of feed additives, substitution of low digestibility feeds with high digestibility ones, concentrate feeding, and changing microflora of rumen also leads to a reduction in methane emission.

Appropriate crop management practices, which lead to increase nitrogen use efficiency and yield, hold the key to reduce nitrous oxide emission. Curtailing the nitrification process by the use of nitrification inhibitors, particularly the cheap, locally available, plant-derived materials, such as neem cake, will be useful to mitigate nitrous oxide emission from soil.

Improving the efficiency of energy use in agriculture by using better designs of machinery, increasing fuel efficiency in agricultural machinery, commercialization of wind/solar power potential, and use of laser levelers also lead to mitigation.

Changing land use by increasing area under biofuels or agro-forestry could also mitigate GHG emissions (Smith et al. 2007). This, however, may have trade-offs with goal of increasing food production. South Asian countries that are short of land resources need to examine the consequences of diverting land to biofuels on their food security (Aggarwal et al. 2007).

16.11 Facilitating Mechanisms for Payments to Farmers for Carbon Sequestration

A Clean Development Mechanism (CDM) is being implemented under the UNFCCC to mitigate GHG emissions. This allows for carbon credits to be traded primarily in the energy and forestry sectors. It does not at this time specifically include carbon sequestration and mitigation in agriculture. The IPCC (2007c) estimates that the agricultural GHG mitigation options are cost-competitive with non-agricultural options. If these mitigation options could be included in future agreements on climate change, it would lead to better soil fertility and higher income for the farmers in addition to the primary goal of carbon sequestration. To facilitate this, methodologies are needed to upscale the carbon sequestered/mitigated in individual farms to a large regional scale in order to keep the transaction costs at a low level.

16.12 Conclusions

Global climate change is likely to affect food and livelihood security of the millions of poor farmers and landless in South Asia and other developing countries. Climatic changes could limit the future capacity of South Asia to remain agriculturally self-sufficient. Urgent steps are needed to increase its adaptive capacity to face current as well as the future climatic risks. Action needs to be taken now since it takes time for 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. This would require increased adaptation research, capacity building, development activities, changes in policies, and support of global adaptation and mitigation funds and other resources.

The costs of adaptation and mitigation are not clearly known today but these are expected to be high (Stern 2007; Cline 2007). A universally preferable solution is to start with such adaptation strategies that are anyway needed for sustainable development. Strategies that maximize synergies between adaptation, mitigation, food production and sustainable development would be 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 could be paid incentives for environmental services that agriculture provides. It is time that the society considers such incentives to farmers in the interest of global environment, food security, and poverty alleviation. Development partners should consider the adaptation and mitigation strategies outlined in this paper to help in poverty alleviation and enhancing food security of the vulnerable South Asia.

International climate change negotiations revolve primarily around mitigation of GHG emissions from industrial and other sources, and other related activities. Such discussions must simultaneously address poverty alleviation and the vulnerability of poor farmers of developing countries.

South Asia has a history of regional cooperation through SAARC and other mechanisms. Climate change makes the need for such cooperation even more important. Regional collaboration in many proposed areas of adaptation and mitigation would be useful due to large areas across borders with similar agro-ecological features. For example, Punjab in India and Pakistan, Bengal state of India and Bangladesh, Tarai region of Nepal and Uttar Pradesh and Bihar in India, have similar agro-ecological features. Having agreements on agriculture related trans-boundary issues such as water and pests movement would help in managing climatic risks as and when they occur. Also, such collaboration and cooperation would be necessary to raise the voice of South Asian farmers in global negotiations.

References

Aggarwal PK, Bandyopadhyay SK, Pathak H, Kalra N, Chander S, Sujith Kumar S (2000a) Analysis of the yield trends of rice-wheat system in north-western India. Outlook Agric 29:259–268

Aggarwal PK, Talukdar KK, Mall RK (2000b) Potential yields of rice-wheat system in the Indo-Gangetic plains of India. Rice-Wheat Consortium Paper Series 10. New Delhi, India. RWCIGP, CIMMYT, p 16

Aggarwal PK, Joshi PK, Ingram JS, Gupta RK (2004) Adapting food systems of the Indo-Gangetic plains to global environmental change: key information needs to improve policy formulation. Environ Sci Policy 7:487–498
Aggarwal PK, Joshi HC, Kumar S, Gupta N, Kumar S (2007) Fuel ethanol production from Indian agriculture: opportunities and constraints. Outlook Agric 36:167–174
Alam M, Laurel AM (2005) Facing up to climate change in South Asia, Gatekeeper Series, 118. International Institute for Environment and Development, London, UK
Bhalla GS, Hazell P, Kerr J (1999) Prospects for India's cereal supply and demand to 2020. International Food Policy Research Institute, USA, p 34
Cline W (2007) Global warming and agriculture: impact estimates by country. Peterson Institute for International Economics, p 250
Dhyani BL, Samra JS, Juyal GP, Ram B, Katiyar VS (1997) Socio-Economic analysis of a participatory integrated watershed management in Garhwal Himalaya (Fakot Watershed). Central Soil and Water Conservation Research and Training Institute, Dehradun
Easterling WE, Aggarwal PK, Batima P, Brander KM, Erda L, Howden SM, Kirilenko A, Morton J, Soussana J-F, Schmidhuber J, Tubiello FN (2007) Food, fibre and forest products. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp 273–313
FAO (1997) Review of the state of world aquaculture. FAO Inland Water Resources and Aquaculture Service, Fishery Resources Division. FAO Fisheries Circular. No. 886, Rev. 1. Rome, FAO, p 163
FAO (2008) High-level conference on world food security: the challenges of climate change and bioenergy. Food and Agriculture Organization, Rome, p 51
Fischer G, Shah M, van Velthuizen H (2002) Climate change and agricultural vulnerability. International Institute for Applied Systems Analysis, Austria
Hocking PJ, Meyer CP (1991) Carbon dioxide enrichment decreases critical nitrate and nitrogen concentrations in wheat. J Plant Nutr 14:571–584
Government of India (2008) National action plan on climate change. Prime Minister's Council on Climate Change, p 49
IPCC (2007a) Climate Change 2007: the physical science basis. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Avery KB, Tignor M, Miller HL (eds) Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, p 996
IPCC (2007b) Climate Change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, p 976
IPCC (2007c) Climate Change 2007: mitigation. In: Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA (eds) Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, p 851
Joshi PK, Tyagi NK (1994) Salt affected and water logged soils in India: a review. In: Svendsen M, Gulati A (eds) Strategic change in Indian irrigation. ICAR, New Delhi, India, and IFPRI, Washington, DC, pp 237–252
Kulkarni AV, Bahuguna IM (2002) Glacial retreat in the Baspa basin, Himalaya, monitored with 17 satellite stereo data (Correspondence). J Glaciol 48:171–172
Kumaraguru AK, Jayakumar K, Ramakritinan CM (2002) Coral bleaching 2002 in the Palk Bay, southeast coast of India. Curr Sci 85:1787–1793
Lal R (2004) The potential of carbon sequestration in soils of South Asia. Paper presented at the 13th International Soil Conservation Organization Conference, Brisbane
MoEF (2008) Bangladesh Climate Change Strategy and Action Plan 2008. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, xvi + p 68

Nellemann C, Hain S, Alder J (eds) (2008) In Dead water – merging of climate change with pollution, over-harvest, and infestations in the world's fishing grounds. United Nations Environment Programme, p 64

Nin A, Ehui S, Benin S (2007) Livestock productivity in developing countries: an assessment. Handbook Agric Econ 3:2461–2532

Paroda RS, Kumar P (2000) Food production and demand in South Asia. Agric Econ Res Rev 13:1–24

Parry ML, Rosenzweig C, Iglesias A, Livermore M, Fischer G (2004) Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Glob Environ Change 14:53–67

Pathak JK, Ladha PK, Aggarwal S, Peng S, Singh Y, Singh B, Kamra SK, Mishra B, Sastri ASRAS, Aggarwal HP, Das DK, Gupta RA (2003) Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. Field Crops Res 80:223–234

Ravindranath NH, Joshi NV, Sukumar R, Saxena A (2006) Impact of climate change on forest in India. Curr Sci 90:557–560

Roetter RP, van den Berg M, Laborte AJ, Hengsdijk H, Wolf J, van Ittersum M, van Keulen H, Agustin EO, Nguyen TS, Lai X (2007) Combining farm and regional level modelling for integrated resource management in East and South-East Asia. Environ Model Software 22:149–157

Rosenzweig C, Parry ML (1994) Potential impact of climate change on world food supply. Nature 367:133–138

Rupa Kumar K, Sahai AK, Krishna Kumar K, Patwardhan SK, Mishra PK, Revadekar JV, Kamala K, Pant GB (2006) High-resolution climate change scenarios for India for the 21st century. Curr Sci 90:334–345

RWC (2007) RCT induced impacts in Indo-Gangetic Plains. In: RWC Research Highlights 2006. Rice-Wheat Consortium, New Delhi, p 10

Sharp GD (2003) Future climate change and regional fisheries: a collaborative analysis. FAO Fisheries Technical Paper. No. 452. Rome, FAO, p 75

Singh P, Vijaya D, Chinh NT, Pongkanjana A, Prasad KS, Srinivas K, Wani SP (2001) Potential productivity and yield gap of selected crops in the rainfed regions of India, Thailand, and Vietnam. Natural Resource Management Program Report No. 5. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, p 50

Sinha SK, Singh GB, Rai M (1998) In decline in crop productivity in Haryana and Punjab: myth or reality? Indian Council of Agricultural Research, New Delhi, p 89

Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, O'Mara F, Rice C, Scholes B, Sirotenko O, Howden M, McAllister T, Ogle S, Pan G, Romanenkov V, Schneider U, Towprayoon S, Wattenbach M, Smith J (2007) Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agric Ecosyst Environ 118:6–28

SMRC (2003) The vulnerability assessment of the SAARC coastal region due to sea level rise: Bangladesh case, SMRC-No. 3. SMRC Publication, Dhaka, Bangladesh

Government of Sri Lanka (2000) Initial national communication under the United Nations Framework Convention on Climate Change, UNFCCC, p 122

Staal SJ, Nin Pratt A, Jabbar M (2008) Dairy development for the resource poor. Part 3: Pakistan and India dairy development case studies. PPLPI Working Paper No. 44–3. ILRI, Kenya, p 78

Stern N (2007) Stern review on the economics of climate change. Cambridge University Press, Cambridge, p 692

St-Pierre NR, Cobanov B, Schnitkey G (2003) Economic losses from heat-stress by US livestock industries. J Dairy Sci 86(E. Suppl):E52–E77

Wilkinson CR, Linden O, Cesar H, Hodgson G, Rubens J, Strong AE (1999) Ecological and socioeconomic impacts of 1998 coral mortality in the Indian Ocean: an ENSO impact and a warning of future change. Ambio 28:188–196

Ziska LH, Namuco O, Moya T, Quiland J (1997) Growth and yield response of field grown tropical rice to increasing carbon dioxide and air temperature. Agron J 89:45–53