WP-2011-014

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August 2011
http://www.igidr.ac.in/pdf/publication/WP-2011-014.pdf

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Abstract

Climate change is a major challenge for agriculture, food security and rural livelihoods for billions of people including the poor in the Asia-Pacific region. Agriculture is the sector most vulnerable to climate change due to its high dependence on climate and weather and because people involved in agriculture tend to be poorer compared with urban residents. More than 60 per cent of the population is directly or indirectly relying on agriculture as a source of livelihood in this region. Agriculture is part of the problem and part of the solution. Asian agriculture sector is already facing many problems relating to sustainability. To those already daunting challenges, climate change adds further pressure on agriculture adversely affecting the poor. The climate change is already making adversely impact on the lives of the population particularly the poor. It is already evident in a number of ways. Consistent warming trends and more frequent and intense extreme weather events such as droughts, cyclones, floods, and hailstorms have been observed across Asia and the Pacific in recent decades.

The objective of this paper is to identify climate change related threats and vulnerabilities associated with agriculture as a sector and agriculture as people's livelihoods (exposure, sensitivity, adaptive capacity). The paper analyses the connections between the nature of human action as drivers of threats as well as opportunities for sustainable agriculture and better human development outcomes. Broadly, it examines the impact of climate change on rural livelihoods, agriculture, food security. It discusses the options for adaptation and mitigation and requirements for implementation at local, national and international level of these measures.

Keywords:

climate change, adaptation, mitigation, Asia-Pacific region, agriculture

JEL Code:

Q10, Q54, R11

Acknowledgements:

Climate Change, Rural Livelihoods and Agriculture (focus on Food Security) in Asia-Pacific Region[1]

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1. INTRODUCTION

Climate change is a major challenge for agriculture, food security and rural livelihoods for billions of people including the poor in the Asia-Pacific region. Agriculture is the sector most vulnerable to climate change due to its high dependence on climate and weather and because people involved in agriculture tend to be poorer compared with urban residents. More than 60 per cent of the population is directly or indirectly relying on agriculture as a source of livelihood in this region. Agriculture is part of the problem and part of the solution. Food security and livelihoods depends on sustainable agriculture. Achieving food security requires adequate food availability, access and absorption. Agriculture plays a vital role in contributing to all the three components of food security.

As part of the problem, human actions on production, exchange and consumption relating to agriculture and rural development would have impact on climate change. It is important to know that why agriculture is part of the problem for adverse impact of climate change. Intensification due to green revolution, diversification and increase in rural non-farm activities are responsible for increase in green house gases (GHGs).

There has been intensification of agriculture due to green revolution. Over time, the nature of agriculture has been changing in Asia. There has been diversification in cropping patterns from traditional cereals towards high value products such as vegetables, fruits, flowers. Rural Asia is more diverse now. There has been rapid growth in rural non-farm economy including manufacturing in rural towns particularly in countries like China[2].

The above developments have led to negative consequences on environment. Intensification of agricultural production in irrigated and favourable rainfed environments combined with sometimes flawed incentives due to inappropriate policies has caused substantial environmental degradation. Expansion in cropped area into forested and woodland areas and onto steeper slopes increased soil erosion. Intensive livestock production also added water and land quality problems (see Rosegrant and Hazell, 2000).

Thus, Asian agriculture sector is already facing many problems relating to sustainability. Stagnant yields, water logging, soil erosion, volatility in prices, natural calamities, and small size of the farms. Population is going to increase further and with rising incomes in hitherto poor countries, there will be increase in demand which in turn puts additional

[1] Final version Technical Background Paper prepared for UNDP Regional Centre, Bangkok
The author is grateful to HDRU team and peer reviewers for very useful comments on the earlier drafts.
[2] See Gulati and Fan (2006)

pressure on sustainable food production. The Asian economies along with the world economy experienced one of the worst food crises with prices of major grains and other food products rising sharply and pushing more people toward poverty and extreme hunger. To those already daunting challenges, climate change adds further pressure on agriculture adversely affecting the poor. For example, the adverse effects of climate change on future food and agricultural production may further exacerbate high prices. **Thus, the impact of climate change on Asia –Pacific region's agriculture will pose a significant challenge for the 21st Century.**

The climate change is already making impact on the lives of the population particularly the poor. It is already evident in a number of ways. Consistent warming trends and more frequent and intense extreme weather events such as droughts, cyclones, floods, and hailstorms have been observed across Asia and the Pacific in recent decades. This region has the highest number of poor people in the world. In many of these countries, poverty is intimately related to repeated exposure to climate risks. The lives of the poor are punctuated by the risks and vulnerabilities that come with an uncertain climate. Climate change will gradually further increase these risks and vulnerabilities, putting pressure on already over-stretched coping strategies and magnifying inequalities based on gender and other disadvantages (UNDP, 2007).

The short term losses in the form of reduction in livelihoods and incomes due to impact of climate change on agriculture are well known. However, the scale of the potential adverse impact on human development is less understood and underestimated. The short term costs of extreme climate events such as droughts, floods and cyclones can have devastating and highly visible consequences for human development. The long-term impacts are less visible but no less devastating[3]. For the population in Asia, majority of them who live on less than US$2 a day climate shocks can trigger powerful downward spirals in human development. Climate shocks affect livelihoods in many ways. They wipe out crops, reduce opportunities for employment, push up food prices and destroy property, confronting people with limited choices. The rich can cope with shocks through private insurance, by selling off assets or by drawing on their savings. On the other hand, the poor may have no alternative but to reduce consumption, cut nutrition, take children out of school, or sell the productive assets on which their recovery depends. These are choices that limit human capabilities and reinforce inequalities (UNDP, 2007).

According to UNDP (2007), there are four broad channels or 'risk multipliers' through which climate shocks can undermine human development. These are: (a)'before the-event' losses in productivity; (b)early coping costs; (c) asset erosion of physical capital and (d) asset erosion of human opportunities. The risk of costs for human development can happen even before the event for the vulnerable people staying in the areas of climate variability. For example, the uninsured risk for the vulnerable population could lead to avoidance of risky investments and reduction in productivity of crops. Similarly, the adverse effects of second channel viz., human costs of coping are well known. These costs can have long terms impact on human development. The third channel is asset erosion. Climate shocks can have devastating effects on household assets and savings.

[3] On long run costs of climate change on human development, see UNDP (2007)

For example, loss of livestock assets which provide the people with a productive resource, nutrition, collateral for credit, a source of income for expenditures on health and education and, buffer against crop failure would have adverse impact on human development. Lastly, asset erosion of human opportunities can have long term costs in areas of nutrition, education, health and hamper human development prospects.

Although agriculture has remained a prime source of livelihoods, income from different off-farm activities and remittances through migration has been increasing significantly. There is a need to consider the impact of climate change on non-agricultural activities also in rural areas.

Against the above background, the objective of this paper is to identify climate change related threats and vulnerabilities associated with agriculture as a sector and agriculture as people's livelihoods (exposure, sensitivity, adaptive capacity). The paper analyses the connections between the *nature* of human action as drivers of threats as well as opportunities for sustainable agriculture and better human development outcomes. Broadly, it examines the impact of climate change on rural livelihoods, agriculture, food security and the measures needed for adoption and mitigation of climate change impact in the Asia-Pacific region.

While recognizing and identifying the big drivers of agriculture and food security in the region (e.g., urbanization, population growth, economic development and global trade, etc.) it is important to have a better understanding of the effects of climate change on people's lives, in the context of a framework where climate change, sustainable agriculture, poverty, food security and human development are interlinked.

While natural and human factors influence the climate, it is "human footprints" that are contributing to climate change through increasing emissions of greenhouse gases and declining capacity to sequester them. Climate change is seen as a direct consequence of the way humans carry out their activities. The framework in terms of human activities such as *production, exchange* and *consumption* would be helpful to analyse the impact of climate change on agriculture, livelihoods and food security. It would be useful to identify how *nature* of such human actions intersects with rural livelihoods and food security issues in the context of poverty and climate change.

The paper is organized as follows. Section 2 provides an account of livelihoods and vulnerabilities of rural people across Asia-Pacific region. It follows IPCC's concept of vulnerability in terms of exposure, sensitivity and adaptive capacity. Vulnerability to climate change differs across areas and population thus raising important questions about equity. Attention also will be devoted in particular to population groups that are dependent on climate-sensitive occupations, the poor and vulnerable groups (women, children, indigenous people, coastal dwellers, mountainous population, island dwellers etc.). Section 3 examines the impact of climate change on agriculture and food security. The analysis covers how climate change affects agriculture and food security directly and indirectly. It also examines the impact of agriculture on climate change and identifies certain agricultural practices/technologies which are unsustainable and contribute to CO2 emissions and climate change.

Section 4 discusses about the adaption and mitigation practices and policies for reducing the impact of climate change on livelihoods and food security. Main areas of concern and opportunity for changes in the existing practices and policies will be identified. Options for adaptation and mitigation and requirements for implementation at local, national and international level of these measures will be discussed. The last Section provides the conclusions and recommendations.

2. Livelihoods and Vulnerabilities of Rural People across Asia-Pacific Region

This section examines the existing people's livelihoods (agriculture and non-agriculture) and vulnerabilities to the population in the countries of Asia-Pacific region.

As a background to the analysis on vulnerabilities, this section first looks at livelihoods in different countries in Asia-Pacific region. Then it looks at vulnerabilities based on the criteria of exposure, sensitivity and adaptive capacity.

2.1. Livelihoods in Rural Areas

Rural households get livelihoods through agriculture; others through rural labour market and self employment in rural non-farm economy; and others through migrating to towns, cities and other countries. Agriculture is the major source of livelihood in many Asia-Pacific countries but several other countries have substantial share of rural non-farm sector also. Migration is an important source of income. In recent years, international remittances for some countries in Asia have been increasing. Countries like India, Maldives, Bangladesh, Pakistan, Sri Lanka, Nepal, Philippines get large amount of remittances from abroad. Income from remittances sent by migrants often increases the land, livestock, and human capital base of rural household members who stayed behind. Remittances can also offset income shocks, protecting households' productive asset base.

The share of rural population shows that many countries have large size of population in rural areas. Four countries have more than 80% share while 10 countries have shares between 70% and 80% (Table 1). Only 12 countries have less than 50% share of rural population. The share of rural population seems to be the highest in South Asia with all the countries having more than 60% rural population.

As discussed above, large numbers of population are dependent on agriculture for livelihoods. In this region, 'more than 60% of the economically active population and their dependents – which amounts to 2.2 billion people – rely on agriculture for their livelihoods. Although share of agriculture in GDP is low, the share of agriculture in employment is high in several countries of the region.

South Asia comprising eight countries is the largest sub-region in terms of population in this region. Although declining, the contribution of agriculture to GDP is still substantial in this sub-region. South Asian countries have high shares of agriculture in total employment. Countries like Nepal, Bhutan, and Afghanistan have more than 60% with India having 56% of workers in agriculture.

Table 1. Share of rural population, shares of agriculture, industry and services in total employment in Asia Pacific Region: 2009

Country	Share of Rural Population	Share of Agricu. in Total Employ(%).	Share of Industry in Total Employ(%).	Share of Services in Total Employ(%).
East Asia and North East				
Cambodia	80.5	59.1 (2008)	8.7 (2008)	8.6 (2004)
China	53.4	38.1	17.7 (2002)	16.1 (2002)
Korea Republic of	18.5 (2008)	7.0	25.9 (2007)	66.6 (2007)
Lao, PDR	70.3 (2007)	78.5 (2005)	9.3 (2003)	8.6 (2003)
Mongolia	37.4 (2008)	34.7	16.8 (2005)	44.2 (2008)
Vietnam	70.4	51.9	21.5	24.7 (2004)
South East				
Indonesia	56.9 (2005)	41.2	13.2	39.9 (2007)
Malaysia	36.3	13.5	17.2	56.7 (2007)
Philippines	35.0 (2008)	32.3	8.7	48.8 (2007)
Thailand	66.2 (2008)	39.0	14.4	37.4 (2007)
Timor-Leste	72.2 (2008)	--	--	--
Pacific				
Cook Islands	29.8 (2003)	4.9 (2006)	30.7 (2008)	68.0 (2008)
Fiji Islands	48.7 (2008)	1.3 (2008)	--	--
Kiribati	56.4 (2005)	--	--	--
Marshal Islands	29.3 (2007)	--	--	--
Micronesia	77.5 (2008)	--	--	--
Nauru	--	--	--	--
Palau	22.6 (2005)	7.8 (2005)	2.6 (2005)	--
Papua New Guinea	86.3 (2008)	72.3 (2000)	3.6 (2000)	22.7 (2000)
Samoa	77.1 (2008)	--	--	--
Solomon Islands	82.1 (2008)	--	--	--
Tonga	75.3 (2008)	27.9 (2006)	--	37.3 (2003)
Tuvalu	--	--	--	--
Vanuatu	75.3 (2008)	--	--	--
South and West				
Afghanistan	78.4	69.6 (2004)	6.2 (2004)	--
Bangladesh	65.6 (2008)	48.1 (2006)	14.5 (2005)	37.4 (2005)
Bhutan	69.1 (2005)	65.4	17.2 (2005)	39.2 (2005)
India	70.6 (2008)	56.1 (2005)	18.8 (2005)	25.1 (2005)
Maldives (the)	65.0 (2006)	3.8 (2006)	24.3 (2006)	59.8 (2006)
Nepal	82.8 (2008)	65.7 (2001)	13.4 (2001)	20.1 (2001)
Pakistan	64.2	45.1	12.9	35.4 (2007)
Sri Lanka	84.9 (2006)	34.0	25.0	41.1

Source: ADB (2010); Note 1: List of countries supported by UNDP Regional Bureau for Asia Pacific (RBAP); Note 2 : For some countries, in the case of employment shares the total of three sectors do not add up to 100; Note 3. Data for few countries are not readily available. – refers to not available

The share of industry in employment is lower for the countries in the region as compared to the share in services (Table 1). In South Asia, the share of non-agricultural income varies from 34% in Nepal to 43% in Bangladesh (Table 2). The structure of rural employment shows that off-farm employment in South Asia is around 27% for males (Table 3). The share of non-agricultural employment for women in South Asia is only about 6% while the percentage of non active or non-reported for women is quite high.

Income from remittances through migration is also high in South Asian countries. In Bangladesh, the share of remittances in rural incomes was 29%. This share is also high in Nepal and, Pakistan (Table 2). Recent data shows that remittances as per cent of gross national income from Nepal and Bangladesh respectively were 13.2% and 8.9%.

South Asia possesses diverse farming systems ranging from intensive rice-wheat systems to sparse arid regions and mountains. Rice producers in Eastern India and the Terai of Nepal suffer from frequent droughts; Bangladesh, Bihar and Assam (States in India) suffer yield losses from frequent floods and submergence; and the wheat farmers in North-West Frontier Province (NWFP) of Pakistan face similar problems to many parts of Afghanistan. Average rainfall for the region is about 1300 mm per year. Irrigation coverage is high varying from 80% in Pakistan to 30 to 40% in India, Afghanistan and Sri Lanka. Irrigation supports the major crops like rice, wheat, sugarcane in India and Pakistan and rice in Nepal (see Lal et al, 2011).

South Asia has over 420 million people living on less than one dollar a day. It also has the highest concentration of under-nourished (299 million) and poor people, and accounts for about 40 percent of the world's hungry (Mittal and Sethi, 2009). In South Asia, over 40 per cent of children under-5 years of age are under-nourished and in many areas, under-nutrition rates are as high as those in the poorest African countries (e.g., Somalia and Chad).

Table 2 Rural households' diverse sources of income (Income Shares %)

Countries	Agricultural Income		Non-Agricultural Income		Transfers and others
	Self employed	Wage	Wage	Self Employed	--
South Asia					
Bangladesh 2000	0.15	0.13	0.21	0.22	0.29
Nepal 1995	0.35	0.18	0.19	0.15	0.14
Pakistan 2001	0.43	0.06	0.24	0.12	0.17
South East Asia					
Indonesia 2000	0.17	0.09	0.34	0.23	0.16
Vietnam 1998	0.35	0.04	0.08	0.49	0.04

Source: World Development Report (2008)

Southeast Asia comprises the 10 independent members of the Association of Southeast Asian Nations (ASEAN) and it is home to 563 million population. Agriculture contributed to a significant portion of GDP in 2006—12.9% in Indonesia, 14.2% in the Philippines, 10.7% in Thailand, and 20.4% in Viet Nam. In 2004 the sector accounted for 43.3% of the region's total employment—it accounted for 57.9% of employment in Viet Nam, 43.3% in Indonesia, 42.3% in Thailand, and about 37.1% in the Philippines. The sub-region receives over 2000 mm of rainfall per year. As a result, agricultural areas remain largely rainfed whereas irrigation coverage is only around 17%. These agro-climatic conditions favour crops such as rice, sugarcane and oil palm fruit, which are the dominant crops. Poultry and chicken are of great importance in Indonesia while the Philippines produce a significant amount of pig meat.

Most Southeast Asian poor live in rural areas and rely on the agriculture sector for their livelihoods. As such, agriculture provides a safety net for the poor (ADB, 2009 a). And increasing demand for food and industrial crops has intensified agricultural production and competition for land and water resources. Much of the region's growth is also dependent on natural resources, particularly forestry, putting considerable pressure on the environment and ecosystems.

The share of non-agricultural income in rural areas is high in South East Asian countries with Indonesia and Vietnam having 57%. The share of self employed in non-agriculture is the highest in Vietnam. and Indonesia (Table 2).

East Asia is the second-largest sub-region in terms of population, with 1.4 billion inhabitants who mostly reside in China. While agriculture accounts for 12% of GDP in China, nearly 64% of the economically active population is employed in agriculture (ADB and IFPRI, 2009). Although food security has been improving in this sub region, nearly 30% of the population in Mongolia is undernourished. Given significant land scarcity in East Asia, countries like China and the Republic of Korea have started to lease or purchase land in other parts of the world.

Rainfall is lowest in Mongolia and moderate in China. Of course China has large variations across the country. Republic of Korea receives the most rainfall, with an average of over 1300 mm per year. Rice is the major crop, with China producing 187 million tonnes in 2007. Other principal crops/commodities include maize, pig meat, and milk in China and rice, fresh vegetables, and milk in Republic of Korea.

Table 3. Rural Employment by Sector, Men and Women

	South Asia	East and the Pacific (excl.China)
Men		
Agriculture, self employed	33.1	46.8
Agriculture, wage earner	21.8	9.4
Non-agriculture, self-employed	11.8	11.5
Non-agriculture wage earner	15.4	17.4
Nonactive or not reported	14.6	14.4
Women		
Agriculture, self employed	12.7	38.4
Agriculture, wage earner	11.4	5.7
Non-agriculture, self-employed	2.9	11.3
Non-agriculture wage earner	2.7	8.4
Nonactive or not reported	64.3	35.5

Source: World Development Report (2008)
Note: Data are for 2000 or the nearest year.

The Pacific is the smallest sub-region in terms of population with 9.4 million inhabitants. Eleven of the 14 countries have less than 500,000 population. The most populous country is Papua New Guinea, with 5.9 million people. More than 80% of the population of the Pacific islands are rural and about 67% are dependent on agriculture for their livelihoods (ADB and IFPRI, 2009).

The data on the importance of agriculture to GDP, malnutrition, and irrigation coverage for these countries are not readily available. The available data for Papua New Guinea, shows that agriculture's share of GDP has risen from 32% in 1995 to 42% in 2005. The share of employment in agriculture was around 40% in this country. Calorie availability has improved only slightly during 1995 (2,560 Kcals) to 2005 (2660 kcals).

2.2. Vulnerability in Asia-Pacific Region to Climate Change

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007). The IPCC defines vulnerability as a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001). In other words, vulnerability includes three components: ***exposure, sensitivity and adaptive capacity***. The estimation of key vulnerabilities in any system, and damage implied, will depend on exposure (the rate and magnitude of climate change), sensitivity, which is determined in part and where relevant by development status, and adaptive capacity.

Tubiello and Rosenzweig (2008) provides framework of exposure, sensitivity and adaptation for assessing vulnerability in agricultural sector. Table 4 gives the indicators of vulnerability in the agricultural sector. As the table shows, the exposure refers to biophysical indicators. The measures of exposure can be soil and climate (temperature/precipitation), crop calendar, water availability and yields.

On *exposure*, the past and present climate trends and variability in Asia show that they are generally characterized by increasing surface air temperature which is more pronounced during winter than in summer (p.472, IPCC, 2007). Increasing trends in temperature have been observed across the sub-regions of Asia. The observed increase in some parts of Asia during recent decades ranged between less than 1^0C to 3^0C per century. It is found that increase in surface temperatures are more pronounced in North Asia.

Regarding rainfall trends, interannual, interseasonal and spatial variability have been observed in the past few decades all across Asia. It may be noted that declining trends in annual mean rainfall are observed in North-East and North China, coastal belts and arid plains of Pakistan, parts of North-East India, Indonesia, Philippines and some areas in Japan. On the other hand, annual mean rainfall exhibits increasing trends in Western China, South-Eastern coast of China, Changjiang Valley, Bangladesh, Arabian Peninsula and western coasts of the Philippines (IPCC, 2007).

On changes in extreme climatic events, generally, the frequency of occurrence of more intense rainfall events in many parts of Asia has increased, causing severe floods, landslides while the number of rainy days and total annual amount of precipitation has declined.

Table 4. Framework for Vulnerability Criteria

Categories	Vulnerability Criteria	Measurement Class
Biophysical indicators	Exposure	• Soil and climate • Crop calendar • Water availability and storage • Biomass/yield
Agricultural system characteristics	Sensitivity	• Land resources • Inputs and technology • Irrigation share • Production
Socio-economic data	Adaptive capacity	• Rural welfare • Poverty and nutrition • Protection and trade • Crop insurance

Source: Adapted from Tubiello and Rosenzweig (2008)

The temperature projections for the 21st Century based on the IPCC's Fourth Assessment Report (AR4) Atmosphere-Ocean General Circulation Models (AOGCMs) suggest a significant acceleration of warming over that observed in the 20th Century. The projections show that temperature increase is less rapid similar to global mean warming, in South-East Asia, stronger over South Asia and East Asia and greatest in Central, West and North Asia. It may be noted that in general, projected rise in temperature over all sub-regions of Asia is higher during northern hemispheric winter than during summer for all time periods. The highest warming is projected at high latitudes in North Asia. The warming is significant in Himalayan high lands including the Tibetan Plateau and arid regions of Asia.

The consensus of AR4 models indicates an increase in annual precipitation in most of Asia during the century – the relative increase being largest and most consistent by the models in North and East Asia. The mean winter precipitation will *very likely* to increase in Northern Asia and the Tibetan Plateau and *likely* increase in West, Central, South-East and East-Asia. On the other hand, summer precipitation will likely increase in South, South-East, North and East Asia but decline in West and Central Asia. Most of the AR4 models project a decline of precipitation in December, January and February. Increase in precipitation, however, does not mean that the number of rainy days has increased. The amount of rain can be higher during the same number or less number of rainy days. It is also to be noted that an increase in occurrence of extreme weather events including heat wave and intense precipitation events is also projected in South Asia, East Asia, and South-East Asia. An increase of 10 to 20% in tropical cyclone intensities for a rise in sea-surface temperature of 2 to 4^{0}c to the current threshold temperature is also projected in these countries. In coastal areas of Asia, the current rate of sea-level rise is reported to be between 1 to 3 mm/yr which is marginally greater than the global average (IPCC, 2007).

The Fourth Assessment Report of IPCC defines sensitivity as "the degree to which a system is affected, either adversely or beneficially, by *climate variability* or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to *sea-level rise*)". As shown in Table 5, the sensitivity indicators can be high water stress, high land degradation, and low technology and, high dependence of livelihoods on agriculture. These indicators show the sensitivity to climate change and extreme weather.

Adaptive capacity is the ability of an affected system, region, or community to cope with the impacts and risks of climate change (Third Assessment Report TAR, IPCC 2001). Enhancement of adaptive capacity can reduce vulnerability and promote sustainable development across many dimensions. Adaptive capacity in human systems varies considerably among regions, countries, and socioeconomic groups. The ability to adapt to and cope with climate change impacts is a function of wealth, technology, information, skills, infrastructure, institutions, equity, empowerment, and ability to spread risk (IPCC 2007). Groups and regions with adaptive capacity that is limited along any of these dimensions are more vulnerable to climate change damages, just as they are more vulnerable to other stresses.

Vulnerable sectors, countries, areas and people

Vulnerability to climate change differs considerably across countries, sectors, vulnerable areas and population thus raising important questions about **equity**. Livelihoods can be affected adversely due to vulnerability in climate change for poor and vulnerable groups such as women, children, indigenous population and those residing in mountains/high lands, arid/semi-arid areas, coastal and plains, forest based and other natural based economies.

Vulnerability across sectors

The general trajectory of warming across the Asian Pacific region will depend partly on global emission scenarios but the impact will depend on local conditions and manifestations. The average results of global circulation models in terms of global averages and the associated global distributions for three SRES (Special Report on Emission Scenarios) scenarios[4] for the 2020s and 2090s were analyzed (Rozegrant et al, 2010) and these temperatures were translated into subjective judgments of sectoral vulnerabilities for the sub-regions across Asia (Table 5). The assigned confidence levels could provide guidance in weighing which of the sectors ought to be the priority concerns based on the most likely future outcomes (IPCC, 2007). For example, food and fibre, biodiversity, water resources, land degradation are highly vulnerable with high confidence for East and South Asia. This is also true for South East Asia except for water

[4] These scenarios are issued by the Intergovernmental Panel on Climate Change (IPCC) in 2000. The SRES scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. See website http://www.ifpri.org/book-775/ourwork/researcharea/climate-change/terms-definitions#carbfert

resources. In the case of South and South East Asia, human health is also highly vulnerable at high confidence level (Table 5).

Table 5. Vulnerability for Key Sectors for sub regions in Asia

Sub-region	Food and Fibre	Biodiversity	Water resources	Coastal ecosystem	Human health	settlements	Land degradation
North Asia	+1/H	-2/M	+1/M	-1/M	-1/M	-1/M	-1/M
Tibetan Plateau	+1/L	-2/M	-1/M	N/A	No info	No info	-1/L
East Asia	-2/VH	-2/H	-2/H	-2/H	-1/H	-1/H	-2/H
South Asia	-2/H	-2/H	-2/H	-2/H	-2/M	-1/M	-2/H
Southeast Asia	-2/H	-2/H	-1/H	-2/H	-2/H	-1/M	-2/H

Vulnerability: -2= highly vulnerable; -1=Moderately vulnerable; 0=slightly or not vulnerable; +1=moderately resilient; +2= most resilient
Level of confidence: VH=very high; H=high; M=Medium; L=Low; VL=Very Low
Source: p. 497, Chapter 10, IPCC 2007

Vulnerable countries and areas

One way of identifying vulnerable countries is to use few indicators based on the framework of exposure, sensitivity and adoptive capacity. ADB and IFPRI (2009) have identified vulnerable countries in the Asia-Pacific region based on few indicators. Countries for which data are available were classified as highly exposed if the temperature is expected to increase by at least 2^0C or if annual precipitation levels are projected to change by at least 20%. If we use this indicator, 26 countries of the Asia-Pacific region are highly exposed to climate change (Table 6)[5]. Share of labour employed in agriculture is used for measuring level of sensitivity to climate change. Countries with agricultural employment above 40% were considered highly sensitive. We have used the latest data from Table 1 above for this criterion. It shows that 12 countries in the region fall under high sensitivity category. The level of poverty is used as an indicator for adaptive capacity. A poverty ratio of 30% was considered to indicate low adaptive capacity. We have used the latest data on poverty given in ADB (2010). This gives population below the poverty line of $1.25 (ppp) per day. This indicator shows that among the countries for which data are available five countries have low adaptive capacity.

Table 6 Countries Identified as Vulnerable to Climate Change in Asia and the Pacific

High Exposure[a]	**High Sensitivity[b]**	**Low Adaptive Capacity[c]**
Afghanistan	Afghanistan	Bangladesh
Bangladesh	Bangladesh	India
Bhutan	Bhutan	Lao PDR
Cambodia	Cambodia	Nepal
China, People's Republic of	India	Timor-Leste

[5] It excludes Central Asia

India	Indonesia	
Indonesia	Lao PDR	
Korea, Republic of	Myanmar	
Lao PDR	Nepal	
Mongolia	Pakistan	
Myanmar	Papua New Guinea	
Nepal	Viet Nam	
Pakistan		
Papua New Guinea		
Philippines		
Sri Lanka		
Thailand		
Vietnam		

Lao PDR = Lao People's Democratic Republic.
Note: Poor outcomes in all three areas (shaded in dark grey) indicate high vulnerability, and poor outcomes in two areas (shaded in light gray) indicate significant vulnerability. Only countries with data for all three indicator n components were included. Data was not available for many of the Pacific Island countries.
[a] Exposure was reflected as the delta change in both temperature and annual precipitation in 2050 compared with current climate [1950–2000]. Countries were classified as being highly exposed if the temperature increases by at least 2^{o}C or if annual precipitation levels increase or decrease by at least 20%.
[b] countries with agricultural employment above 40% are considered to be highly sensitive.)
[c]Adaptive capacity was represented by poverty level. A poverty level of more than 30% is considered to be low adaptive capacity.
Source: For column 1, ADB and IFPRI (2009); Table 1 and 2 of the present study respectively for columns 2 and 3. The climate scenarios are derived from Hijmans et al. (2005) for the HadCM3 A2a scenario.

It may be noted, however, that there are limitations for the analysis done in Table 6. The indicators taken are only partial and there are several vulnerabilities other than these indicators. Moreover, some countries are not included as data are not available. For example, many Pacific Island countries are not included in the analysis because of data problem. Thus, the above analysis does not mean Pacific Island countries are not vulnerable.

Within countries, many areas are vulnerable. For example, coastal areas are vulnerable in many sub-regions (see Box 1). The fragile ecosystem vulnerable to climate change impacts in South Asia are: mountain/Himalayan ecosystem (e.g. Nepal, India, Bhutan), mangroves, salt marshes and coral reefs (e.g. India, Bangladesh and Sri Lanka), semi-arid and arid resource poor dry lands (e.g. India and Pakistan). The low lying coastal regions would be affected due to Sea Level Rise (SLR) and/or increase in extreme climate events (e.g. Maldives and Bangladesh) (Ad Spijkers, 2011) Semi-arid tropics are vulnerable due to reduced rainfall and increased evapotranspiration and drought (North West Bangladesh,; Sindh and Balochistan of Pakistan; Central and Peninsular India). Small Islands are extremely vulnerable due to high exposure of population and agricultural infrastructure to sea level rise (e.g. Maldives) and increased storms. The North Eastern hoar region and the Magna Basin of Bangladesh are vulnerable to flash floods (Ad Spijkers, 2011). Similarly, there are many other vulnerable areas in other sub-regions of Asia.

Box 1: Predictions of Rising Sea Levels for Countries of Asia and the Pacific

Countries in South Asia, Southeast Asia, and the Pacific Islands are highly vulnerable to rising sea levels, which increase the risk of floods. The global sea level gradually rose during the 20th century and continues to rise at increasing rates (Cruz et al. 2007). In Asia and the Pacific, the sea level is expected to rise approximately 3–16 centimeters (cm) by 2030 and 7–50 cm by 2070 in conjunction with regional sea level variability (Preston et al. 2006).

Under a conservative scenario of a 40 cm rise in sea level between today and the end of 21st century, the number of people facing floods in coastal areas will increase from 13 million to 94 million annually, with 60% of this increase occurring in South Asia (the coasts of Bangladesh, India, Pakistan, Myanmar, and Sri Lanka) and 20% in Southeast Asia (the coasts of Indonesia, the Philippines, Thailand, and Viet Nam) (Cruz et al. 2007). Studies on the vulnerability of coastal zones to rising sea levels and storm surges are severely hampered by lack of data on coastal protection, including both natural and artificial protection systems. It is likely, however, that the low-lying river deltas of Bangladesh, the PRC, India, Viet Nam, and the small island states in the Pacific face the largest risk of coastal inundation, soil erosion, displacement of communities, loss of agricultural land, intrusion of saline waters into surface and groundwater, and other consequences of a rise in sea level (Arnell et al. 2002; Parry, Rosenzweig, and Livermore 2005; Preston et al. 2006). In the Zhujiang Estuary in the PRC, for instance, rising sea levels of 0.4 to 1.0 meters can induce further saltwater intrusion of 1–3 km (Bates et al. 2008). Although this particular distance is quite small, such distances can be significant if they interrupt domestic or irrigation water supplies. Source: ADB and IFPRI (2009)

Pacific Islands

The Fourth Assessment Report of IPCC also confirms and strengthens previous observations reported in the IPCC Third Assessment Report (TAR) which show that characteristics such as limited size, proneness to natural hazards, and external shocks enhance the vulnerability of islands to climate change. In most cases they have low adaptive capacity, and adaptation costs are high relative to gross domestic product (GDP). Most small islands have a limited water supply, and water resources in these islands are especially vulnerable to future changes and distribution of rainfall. In the Pacific, a 10% reduction in average rainfall (by 2050) would lead to a 20% reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati. Reduced rainfall coupled with sea-level rise would compound this threat.

Kiribati and Tuvalu are considered to be at a relatively higher risk than other Pacific island countries from sea-level rise. Papua New Guinea, the Pacific region's largest country, is expected to experience greater risk from both flash flooding across the highlands and coastal flooding along the south coast. Sea-level rise, inundation, seawater intrusion into freshwater lenses, soil salinisation and, decline in water supply are very likely to adversely impact coastal agriculture. Away from the coast, changes in extremes (e.g., flooding and drought) are likely to have a negative effect on agricultural production. Climate change is likely to heavily impact coral reefs, fisheries and other marine-based resources (IPCC, 2007). Ronneberg (2004) uses the Marshall Islands as a case study to explain that the linkages between patterns of consumption and production, and the effects of global climate change, pose serious future challenges to improving the life of the populations of small island developing states.

Vulnerable Population

Vulnerable Poor: It would be interesting to see the share of poor in vulnerable areas. Ranawana (2008) provides the information on environmentally poor for 2005 and 2020. It shows the share of poor in upland areas, dry land areas, flood-affected wet land areas, coastal areas and, slum areas. The projections show that the share of vulnerable poor in Asia-Pacific region would increase from 52.7% in 2005 to 70.3% in 2020. In the sub-regions, the share would rise from 55.0% to 68.3% in West and Central Asia (including Pakistan); 56.4% to 71.5% in South Asia (excluding Pakistan); 53% to 61.7% in South East Asia; 44.7% 69.9% in East Asia (Mongolia and PRC) and; 55.9% to 68.5% in Pacific.

In the above vulnerable areas, only slum poor belong to urban areas. Otherwise, rural poor dominate in the vulnerable areas. It looks like the share of poor invulnerable areas is going to increase in all the sub-regions of the Asia-Pacific region.

Vulnerable Groups
The most vulnerable people will suffer more from climate change. Therefore, climate change should be addressed in a way that is fair and just, cognizant of the needs and risks faced by the vulnerable groups and adherent to the human rights principles of nondiscrimination and equality. Any sustainable solution to climate change must take into account its human impact and the needs of all communities in a holistic manner (IPCC, 2007).

Populations at greater risk from food insecurity, including smallholder and subsistence farmers, pastoralists, traditional societies, indigenous people, coastal populations and artisanal fisher folk, will suffer complex, localized impacts of climate change. These groups, whose adaptive capacity is constrained, will experience the negative effects on yields of low-latitude crops, combined with a high vulnerability to extreme events (FAO, 2010). Smallholder and subsistence farming households in the dry land tropics are particularly vulnerable to increasing frequency and severity of droughts.

Vulnerability of women
Men and women are affected differently in all phases of climate-related extreme weather events, from exposure to risk and risk perception; to preparedness behaviour, warning communication and response; physical, psychological, social and economic impacts; emergency response; and ultimately to recovery and reconstruction (Fothergill, 1998; quoted in FAO, 2010). Many of the world's poorest people are women living in rural areas in developing countries who are currently dependent on subsistence agriculture to feed their families and who are disproportionately affected by the lack of modern fuels and power sources for farming, household maintenance and productive enterprises (FAO, 2010). Climate change could add to water and food insecurity and increase these women's work levels; particularly in Africa and Asia (Parikh and Denton, 2002; quoted in FAO, 2010).Women in poor households are especially vulnerable on all these counts, with few resources for adaptation.

Climate change can also increase the vulnerability of households due to migration. Here women's livelihoods could be markedly threatened, since they are much more dependent on agriculture than men, who have shifted in larger proportions to nonfarm jobs. It would affect the children's food security and human development. Remittances may not be able to compensate the vulnerability of households. The migrants at destination places also face many vulnerabilities of non-local status.

3. Climate Change, Agriculture and Food Security

In this section, we examine the following issues.

(a) What do the different models tell us about the projections on the impact of climate change on agriculture and food security in Asia-Pacific region?

(b) How climate change affects change in livelihoods in agriculture and rural non-agriculture?

(c) What is the impact of climate change on food security?

(d) How agriculture affects climate change?

We try to analyze these issues in production, exchange and consumption framework.

3.1. Results of Models on the Likely Impact of Climate Change on Agriculture and Food Security in Future.

Here we look at the results of models on the projections relating to the impact of climate change on production and consumption.

Nelson et al (2009) study provides detailed estimates of the likely impact of climate change on agricultural production, consumption, prices, and trade for different regions of the world in future. It uses International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) linked to a biophysical crop model Decision Support System for Agro technology Transfer (DSST).

The results contain with and without **CO2 fertilization effect which refers to increased plant growth due to an increase in carbon dioxide in the atmosphere**. Plants absorb carbon and convert it to oxygen as part of photosynthesis. The extent to which this sequestration effect reduces the concentration of carbon in the atmosphere is unknown[6].

The results of the study are summarized below.

Impact on Crop Production

Table 7 shows the effects of climate change on crop production in 2050 compared to production without climate change based on the National Centre for Atmospheric

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[6] See climate change glossary. See website http://www.ifpri.org/book-775/ourwork/researcharea/climate-change/terms-definitions#carbfert

Research, US (NCAR) and model of the Commonwealth Scientific and Industrial Organization Australia (CSIRO) model scenarios. These are without CO2 fertilization. The negative effects of climate change are more pronounced for South as compared to East Asia and the Pacific.

In South Asia, climate change leads to a 14 per cent decline in rice production relative to no climate change scenario, a 44 to 49 percent decline in wheat production, a 9 to 19 decline in maize production and 12.2 to 19.6 percent decline in sorghum production. The results are mixed for the East Asia and Pacific sub-region. Rice production declines by about 10 percent while wheat production increases slightly.

Table 7. Climate Change Effects on Crop Production, No C02 fertilization

Agricultural Product	South Asia	East Asia and the Pacific	Developing Countries	World
Rice				
2000 (mmt)	119.8	221.7	370.3	390.7
2050 No CC (mmt)	168.9	217.0	2434.9	455.2
2050 No CC % change	41.0	-2.1	17.4	16.5
CSIRO (% change)	-14.3	-8.1	-11.9	-11.9
NCAR (% Change)	-14.5	-11.3	-13.6	-13.5
Wheat				
2000 (mmt)	96.7	102.1	377.9	583.1
2050 No CC (mmt)	191.3	104.3	663.6	917.4
2050 No CC % change	97.9	2.1	75.6	57.3
CSIRO (% change)	-43.7	1.8	-29.2	-23.2
NCAR (% Change)	-48.8	1.8	-33.5	-27.4
Maize				
2000 (mmt)	16.2	141.8	321.3	619.2
2050 No CC (mmt)	18.7	264.7	556.2	1061.3
2050 No CC % change	15.7	86.6	73.1	71.4
CSIRO (% change)	-18.5	-12.7	-10.0	0.2
NCAR (% Change)	-8.9	8.9	-2.3	-0.4
Millet				
2000 (mmt)	10.5	2.3	27.3	27.8
2050 No CC (mmt)	12.3	3.5	66.2	67.0
2050 No CC % change	16.5	50.1	142.5	141.0
CSIRO (% change)	-19.0	4.2	-8.5	-8.4
NCAR (% Change)	-9.5	8.3	-7.0	-7.0
Sorghum				
2000 (mmt)	8.4	3.1	43.0	59.9
2050 No CC (mmt)	9.6	3.4	102.6	123.5
2050 No CC % change	13.9	11.6	138.7	106.2
CSIRO (% change)	-19.6	1.4	-2.5	-2.6
NCAR (% Change)	-12.2	6.7	-1.5	-2.5

Source: Nelson et al, 2009

Impact on Prices

Between 2000 and 2050, even with no climate change, the price of rice would rise by 62 percent, maize by 63 percent, soybean by 72 percent, and wheat by 39 per cent. The climate change results in additional price increases – a total of 32 to 37 percent for rice, 52 to 55 percent for maize, 94 to 111 percent for wheat, and 11 to 14 percent for soybeans. The results also show that if C02 fertilization is effective in farmers' fields, these 2050 prices are 10 percent smaller. Similarly, the meat prices are 33 percent higher by 2050 without climate change and 60 percent higher with climate change and no CO2 fertilization of crops.

Impact on Food Consumption, Calorie Consumption and Child Malnutrition

The increase in per capita consumption of meat and cereals between 2000 and 2050 would be lower with climate change as compared to no climate change scenario in both South Asia and East Asia and Pacific sub-regions because of the projected relatively high commodity prices. Similarly, the per capita calorie availability would be lower under climate change compared to no climate change scenario in 2050. For example, the per capita calorie availability in South Asia would increase from 2424 kcal/day in 2000 to 2660 kcal/day in 2050 without climate change. With climate change, the kcal/day would be 2226 under NCAR and 2255 under CSIRO in 2050. These per capita calories are much lower than even with base line scenarios of 2000.

The total number of malnourished children would be higher with climate change as compared to the scenario of no climate change in 2050 in both South Asia and East Asia and the Pacific regions. For example, the number of malnourished children in South Asia would decline from 76 million in 2000 to 52 million without climate change in 2050. With climate change the number of malnourished children would be 59 million in 2050. With C02 fertilization, there would be some decline in the number but it would be still higher with climate change in comparison with no climate change scenario.

Thus, the results of the models in Nelson et al (2009) show that impact of climate change on production, consumption and malnutrition is likely to be negative in large parts of Asia by 2050[7].

Costs of Adaptation

The study of Nelson et al (2009) show that agricultural productivity investments (agricultural research, irrigation expansion, irrigation efficiency, rural roads) of US $7.1-7.3 billion per year are needed at global level to raise calorie consumption enough to offset the negative impacts of climate change on the health and well being of children. Investments for South Asia needed are about $1.5 billion per year. East Asia and Pacific needs are just under $1 billion per year. ADB and IFPRI (2009) mentions investments in female education and drinking water are also important for reduction in malnutrition.

3.2. Impact of climate Change on Agriculture

After presenting the results of models, we discuss the evidence on the impact of climate change on production, exchange and consumption particularly based on IPCC (2007) reports.

As mentioned above, apart from natural factors, human actions on production, exchange and consumption relating to agriculture would have impact on climate change. Similarly, the impact of climate change on agricultural production and consumption depends on a combination of natural and human actions. The climate change can have both positive and negative effects depending on the location. For example, climate change reduces yields of crops in some areas (e.g.South Asia) while it increases yields in some other

[7] See ADB and IFPRI (2009) for results on India, China and South East Asia.

areas (e.g. parts of China). Human actions will have both positive and negative effects on agricultural production and consumption. These actions can have positive impact on adaptation and mitigation of climate change and reduce the impact of climate change on agriculture, livelihoods and food security. It can have negative impact if humans follow unsustainable production and consumption practices.

It is, however, difficult to distinguish between natural factors and human actions on the evidence of climate change impact on production and consumption. The purpose here is to provide the findings on past trends and likely future trends based on various studies.

IPCC (Chapter 10, 2007) report provides the following findings on the impact of climate change on agriculture production in the past and likely future trends in Asia.

(a) The impact of observed changes in climate trends, variability and extreme events show that the crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events. Several studies have shown that production of rice, maize and wheat in the past few decades has declined in many parts of Asia due to increasing water stress arising partly from increasing temperature, increasing frequency of El Nino and reduction in the number of rainy days (Wijeratne, 1996: Aggarwal et al, 2000; Jin et al, 2001; Fischer et al, 2002; Tao et al, 2003 a; Tao et al, 2004). Peng et al (2004) study at the International Rice Research Institute indicates that the yield of rice decreased by 10% for every 1^0C in growing season minimum temperature. The frequency of occurrence of climate induced disease and heat stress in Central, East, South and South-East Asia has increased with rising temperatures and rainfall variability. There have been increased flooding in coastal and low lying areas (see Box 2 on flooding in Bangladesh).

Box 2: The 'flood of the century' in Bangladesh

Flooding is a normal part of the ecology of Bangladesh. With climate change, 'abnormal' flooding is likely to become a standing feature of the future ecology. Experience following the flood event of 1998—dubbed the 'flood of the century'— highlights the danger that increased flooding will give rise to long term human development setbacks.

The 1998 flood was an extreme event. In a normal year, around a quarter of the country experiences inundation. At its peak, the 1998 flood covered two-thirds of the country. Over 1,000 people died and 30 million were made homeless. Around 10 percent of the country's total rice crop was lost. With the duration of the flood preventing replanting, tens of millions of households faced a food security crisis.

Large-scale food imports and government food aid transfers averted a humanitarian catastrophe. However, they failed to avert some major human development setbacks. The proportion of children suffering malnutrition doubled after the flood. Fifteen months after the flood, 40 percent of the children with poor nutritional status at the time of the flood had still not regained even the poor level of nutrition they had prior to the flood.

Households adjusted to the negative impact of flooding in several ways such as reduced spending, asset sales and increased borrowing. Poor households were more likely to sell assets as well as take on debts. Fifteen months after the floods had receded, household debt for the poorest 40 percent averaged 150 percent of monthly expenditure—twice the pre-flood level.

Management of the 1998 floods is sometimes seen as a success story in disaster management. To the extent that an even larger loss of life was averted, that perception is partially justified. However, the flood had long term negative impacts, notably on the nutritional status of already malnourished children. The affected children may never be in a position to recover from the consequences. Poor households suffered in the short term through reduced consumption and increased illness, and through having to take on high levels of household debt—a strategy that may have added to vulnerability.

Source: UNDP (2007) adapted from del Ninno and Smith 2003; Mallick et al. 2005.

(b) Regarding projections in future, studies such as Parry et al, (1999) and, Rosenzweig et al, (2001) have suggested that substantial decline in cereal production potential in Asia could be likely by the end of this century due to climate change. However, sub-regional differences in the response of wheat, maize and rice yields to projected climate change could likely to be significant. Results of crop yield projection using HadCM2 shows that crop yields could **increase** up to 20% in East and South-East Asia while they could **decrease** up to 30% in South Asia by the mid-21st century. Murdiyarso (2000) indicates that the combined influence of fertilization effect and the accompanying thermal stress and water scarcity in some regions under the projected climate change scenarios, rice production in Asia could decline by 3.8% by the end of the 21st Century. In Bangladesh, production of rice and wheat might drop by 8% and 32% respectively, by the year 2050 (Faisal and Parveen, 2004). Crop simulation modeling studies based on future climate change scenarios by Fischer et al (2002) show indicate that substantial losses are likely in rainfed wheat in South and South-East Asia. For example, a 0.5^{0}C rise in winter temperature would reduce wheat yield by 0.45 tonnes per hectare in India (Kalra et al, 2003)). Lal (2007) shows that in South Asia, the drop in yields of non-irrigated wheat and rice will be significant for a temperature increase of beyond 2.5^{0}C incurring a loss in farm level net revenue of between 9% and 25%. Studies also have shown that a 2^{0}C increase in mean air temperature could decrease rain-fed rice yield by 5 to 12% in China (Lin et al, 2004). The impact on agriculture would have implications for human development as shown by the case study of Mekong Delta in Vietnam (Box 3).

Box3: Climate change and human development in the Mekong Delta

Over the past 15 years, Viet Nam has made spectacular progress in human development. Poverty levels have fallen and social indicators have improved, putting the country ahead of schedule on almost all of the MDGs. Climate change poses a real and imminent danger to these achievements—and nowhere more so than in the Mekong Delta.

Viet Nam has a long history of dealing with extreme weather. Located in a typhoon zone, with a long coastline and extensive river deltas, the country is close to the top of the natural disasters league table. On average, there are six to eight typhoons each year. Many leave an extensive trail of destruction, killing and injuring people, damaging homes and fishing boats, and destroying crops. The country’s 8,000 kilometres of sea and river dykes, some of which have been developed through communal labour over centuries, testify to the scale of national investment in risk management.

The Mekong Delta is an area of special concern. One of the most densely populated parts of Viet Nam, it is home to 17.2 million people. It is also the ‘rice basket’ of the country, playing a critical role in national food security. The Mekong Delta produces half of Viet Nam’s rice and an even larger share of fisheries and fruit products.

The development of agriculture has played a pivotal role in poverty reduction in the Mekong Delta. Investment in irrigation and support for marketing and extension services has enabled farmers to intensify production, growing two or even three crops a year. Farmers have also constructed dykes and embankments to protect their fields from the flooding that can accompany typhoons and heavy rains.

Climate change poses threats at several levels. Rainfall is predicted to increase and the country will face more intensive tropical storms. Sea levels are expected to rise by 33 cm by 2050 and 1 metre by 2100.

For the low-lying Mekong Delta this is a particularly grim forecast. The sea-level rise projected for 2030 would expose around 45 percent of the Delta's land area to extreme salinization and crop damage through flooding. Crop productivity for rice is forecast to fall by 9 percent. If sea levels rise by 1 metre, much of the Delta would be completely inundated for some periods of the year.

How might these changes impact on human development in the Mekong Delta? While poverty levels have been falling, inequality has been increasing, driven partly by high levels of landlessness. There are still 4 million people living in poverty in the Delta. Many of these people lack basic health protection and school drop-out rates for their children are high. For this group, even a small decline in income or loss of employment opportunities linked to flooding would have adverse consequences for nutrition, health and education. The poor face a double risk. They are far more likely to live in areas vulnerable to flooding—and they are less likely to live in more robust permanent homes.

Source: UNDP (2007) adapted from Chaudhry and Ruysschaert 2007; Nguyen 2007; UNDP and AusAID 2004.

(c) Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle associated with global warming. Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in South Asia (IPCC, 2007)

Hot spots of key future climatic impacts

The IPCC (2007) report provides the hot spots of key future climate impacts and vulnerabilities as given below (p.481, WGII, Ch.10, IPCC, 2007)

- Forest production in North Asia is likely to benefit from carbon fertilization. But the combined effects of climate change, extreme weather events and human activities are likely to increase the forest fire frequency.
- The Lena delta has been retreating at an annual rate of 3.6-4.5 m due to thermo-erosion processes which are likely to be influenced by projected rise in temperature.
- Net primary productivity of grassland in colder regions of Asia is projected to decline and shift northward due to climate change. The limited herbaceous production, heat stress from higher temperature and poor water intake due to declining rainfall could lead to reduced milk yields and increased incidence of diseases in animals.
- Cereal yields could decrease up to 30% by 2050 even in South Asia. In West Asia, climate change is likely to cause severe water stress in 21st century.
- In East Asia, for 1^{o}C rise in surface air temperature expected by 2020s, water demand for agricultural irrigation would increase 6 – 10% or more.
- The gross per capita water availability in India will decline from ~1820 m^3/yr in 2001 to as low as ~1140 m^3/yr in 2050.

- Rice yield is projected to decrease up to 40% in irrigated lowland areas of central and southern Japan under doubled atmospheric CO_2.
- Increase in coastal water temperatures would exacerbate the abundance and/or toxity of cholera in South Asia.
- The projected relative sea level rise, including that due to thermal expansion, tectonic movement, ground subsidence and the trends of rising river water level are 70-90, 50-70 and 40-60 cm in the Huanghe, Changjiang and in the Zhujiang Deltas respectively by the year 2050.
- Tibetan Plateau glaciers of 4 km in length are projected to disappear with 3^oC temperature rise and no change in precipitation. If current warming rates are maintained, glaciers located over Tibetan Plateau are likely to shrink at very rapid rates from 500,000 km2 by the 2030s.
- With a 1 m rise in sea level, 2,500 km^2 of mangroves in Asia are likely to be lost; Bangladesh would be worst affected by the sea level rise in terms of loss of land Approximately 1,000 km^2 of cultivated land and sea product culturing area is likely to become salt marsh, and 5,000 km^2 of Red River delta, and 15,000 – 20,000 km^2 of Mekong River delta are projected to be flooded.
- Around 30% of Asia's coral reefs are likely to be lost in the next 30 years due to multiple stresses and climate change.

Impact on Trade (Exchange)

Agricultural trade flows depend on the interaction between comparative advantage in agriculture (as determined by climate and resource endowments) and a wide ranging set of local, regional, national, and international trade policies. It is known that free trade allows comparative advantage to be fully exploited. But, restrictions on trade may worsen the effects of climate change by reducing the ability of producers and consumers to adjust (Nelson et al, 2009). Some modeling work on climate and agriculture say the following : "the combined model and scenario experiments demonstrate that the world, for the most part, appears to be able to continue to feed itself under the SRES scenarios[8] during the rest of this century. The explanation for this is that production in the developed countries generally benefits from climate change, compensating for declines projected for developing nations (Parry et al, 2004, p.66). ADB and IFPRI (2009) study shows that overall net cereal imports are expected to increase in East Asia and South Asia under all climatic scenarios. For example, China's net imports of cereals would be 88 million tons in 2050 without climate change. In the case of climate change, it would be 106 million tons for China in 2050. If climate change reduces productivity of certain crops in some regions and does not increase adequately in other regions, trade cannot compensate for the global decline in productivity[9]. However, the trade flow changes partially offset local climate change productivity effects, allowing regions of the world with less negative effects to supply those with more negative effects (Nelson et al, 2009a). Basically, other

[8] See footnote 3 for explanation of SRES scenarios
[9] This means countries can't import the required commodities because of limited trade in these commodities.

countries' producers and consumers help through trade to reduce the human suffering of developing countries due to climate change.

Impact of Climate Change on Food Consumption and Food Security

Climate change will affect all four dimensions of food security, namely food availability (i.e. production and trade), stability of food supplies, access to food and food utilization (FAO, 2003).

This because low production may affect incomes and high food prices may reduce access to food. Nutrition levels would also be affected adversely.

According to Bouis (2008), there are four basic factors for the adverse impact of high food prices on nutrition levels.

"(I) Expenditures on non-staple foods by poor consumers comprise 40-60% of total expenditures on food.
(II) Demand for food staples (rice, wheat, maize etc. depending on the geographical region and culture) is highly inelastic. Income and price elasticities for food staples in the aggregate are low.
(III) In diets, minerals and vitamins are concentrated in non-staple foods; energy is concentrated in staple foods
(IV) Current intakes of vitamins and minerals are already too low, resulting in high prevalence rates of micronutrient deficiencies. Modest decrease in current intakes of minerals and vitamins will drive these prevalence rates significantly higher, with severe consequences for the nutritional status of the poor and public health" (p.1, Bouis, 2008).

To conclude, all the aspects of food security would be adversely affected by climate change in the region. The models have projected that the risk of hunger due to climate change is likely to be higher in Asia and Pacific region. For example, projections have shown that risk of hunger remain high with an additional 49 million, 132 million and 266 million people of Asia projected under A2 scenario without carbon fertilization that could be at risk of hunger by 2020, 2050 and 2080 respectively (Parry et al, 2004; quoted in IPCC, 2007). In terms of per cent increase in risk hunger, it is projected under A2 scenario without CO_2 fertilization that an increase of 7 to 14% by 2020s , 14 to 40% by 2050s and 14 to 137% by 2080 are likely (Parry et al, 2004; quoted in IPCC, 2007).

Impact on Migration

Climate change may lead to migration of people in different countries of the region. There has been significant attention to climate-induced migration which has grown considerably in recent years, reinforced by storms and flooding that have stimulated temporary or longer term dislocation of millions of people in countries such as Pakistan, the People's Republic of China, the Philippines, and Sri Lanka. Over time, "climate migrants" have come to incarnate the human face of climate change, though very little is yet known about the way populations will react to changes in the environment and weather (ADB, 2011). Migration depends on many factors including climate change. It is difficult to isolate climate change induced migration.

On climate change and migration in the Asian region, The IPCC In its Fourth Assessment Report, says the following: “Climate-related disruptions of human populations and consequent migrations can be expected over the coming decades. Such climate-induced movements can have effects in source areas, along migration routes and in the receiving areas, often well beyond national borders. Periods when precipitation shortfalls coincide with adverse economic conditions for farmers (such as low crop prices) would be those most likely to lead to sudden spikes in rural-to-urban migration levels in PRC and India. Climatic changes in Pakistan and Bangladesh would likely exacerbate present environmental conditions that give rise to land degradation, shortfalls in food production, rural poverty and urban unrest. Circular migration patterns, such as those punctuated by shocks of migrants following extreme weather events, could be expected. Such changes would likely affect not only internal migration patterns, but also migration movements to other western countries” (p.488, Cruz et al. 2007).

3.3. Impact of Agriculture on Climate Change

So far we discussed the impact of climate change on agriculture and food security. This sub-section examines the reverse of it i.e. the impact of agriculture on climate change. Climate change is largely attributed to the outcome of GHG emissions. The human actions in production and consumption are mainly responsible for increase in GHG emissions. We discuss here how the unsustainable production and consumption patterns in agriculture are responsible for the rise of these emissions.

Agriculture alone contributed 13 per cent of total global GHG emissions in 2000 0r 5729 MtCO2-equivalents. If we add emissions due to deforestation, agriculture's share would be 30 per cent to global emissions. Emissions from this sector are primarily CH4 and N20 making the agriculture sector the largest producer of non-CO2 emissions, accounting for 60 percent of the world total in 2000 (WRI 2008).

The sources of emissions from agriculture are: 37% from Fertilizers (N2O), 11% from rice (CH4), 32% from livestock (CH4), 13% from residue burning and/or forest clearing and, 7% from manure management (CH4 and N2O) (USEPA 2006a).

The production and consumption patterns in agriculture are not sustainable. Green revolution in agriculture benefited the farmers. However, it has neglected the problems relating to unsustainable exploitation of land and water, adoption of mono-culture and excessive use of mineral fertilizers and chemical pesticides. M.S. Swaminathan who is one of the architects of green revolution recognized already in the early days of India’s green revolution that the new breakthroughs could create major new ecological problems if not properly managed.

The kinds of problems that exploitative agriculture can create were described by M.S.Swaminathan at the Indian national congress in as early as 1968 in the following words.

" Exploitative agriculture offers great dangers if carried out with only an immediate profit or production motive. The emerging exploitative farming community in India should become aware of this. Intensive cultivation of land without conservation of soil fertility and soil structure would lead, ultimately, to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. unscientific tapping of underground water will lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high-yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened prior to the Irish potato famine of 1854 and the Bengal rice famine in 1942. Therefore the initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture, and without first building up a proper scientific and training base to sustain it, may only lead us, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity" (quoted in Swaminathan 2010, pp.27 and 28)

He thus appealed to the farmers as early as 1968 not to harm the long term production potential for short term gain. **He also advised the farmers for avoiding the temptation to convert the *green* revolution into a *greed* revolution.**

Some of the production practices in agriculture and forestry adding to GHG emissions are given below.

Overuse of fertilizers is one of the causes for rise in GHG emissions. Nitrous oxide (N2O) emissions from soils are responsible for GHG emissions. N2O is produced by microbial transformations of nitrogen in the soil, under both aerobic and anaerobic conditions. The emissions, therefore, are often directly related to nutrients added to the soil in the form of mineral fertilizers and animal manure (Flynn, 2009). Some have argued that urea-based fertilizers lead to higher N2O emissions than ammonia or nitrates do. But, recent research shows that both environmental factors, such as soil conditions and climate, and management factors such as tillage also play important roles in determining the proportion of applied nitrogen lost as N2O (Flynn,2009).

Soil organic carbon has been depleted through (a) the long-term use of extractive farming practices and (2) the conversion of natural ecosystems (such as forest lands, prairie lands, and steppes) into croplands and grazing lands. Most agricultural soils have lost 30 to 40 mt of carbon per hectare, and their current reserves of soil organic carbon are much lower than their potential capacity (Lal, 2009)

Studies have shown that rice cultivation is an important anthropogenic source of not only atmospheric methane but also of N2O. 90 per cent of world’s rice is produced and consumed in Asia, and 90 per cent of rice land is –at least temporarily-flooded and it is one of the reasons for its emissions of the major greenhouse gas (GHG), methane. The methane emissions from rice fields are determined mainly by water regime and organic inputs, but they are also influenced by soil type, weather, tillage management, residues, fertilizers, and rice cultivar (Wassmann et al 2009).

Deforestation is another important source for increase in GHG emissions. The global forest cover is 3952 million ha, which is about 30 percent of world's land area. Most relevant for the carbon cycle is that between 2000 and 2005, gross deforestation continued at a rate of 12.9 million ha/yr. This is mainly as a result of converting forests to agricultural land, but also due to expansion of settlements, infrastructure, and unsustainable logging practices (IPCC quoting FAO, 2006; MEA 2005). Due to afforestation, landscape restoration and natural expansion of forests, the most recent estimate of net loss of forest is 7.3 million ha/yr. The loss is still largest in South America, Africa and South East Asia. According to the Millennium Ecosystem Assessment (2005) scenarios, forest area in the developing regions will decrease by about 200 to 490 million ha. between 2000 and 2050. In addition to the creasing forest area globally, forests are severally affected by disturbances such as forest fires, pests and climatic events including drought, wind, snow, floods. All these factors have also carbon balance implications.

Livestock contribute 18 per cent of global anthropogenic GHG emissions. The main sources and types of GHGs from livestock systems are methane production from animals (25 per cent), carbon dioxide (CO_2) from land use and its changes (32 per cent), and nitrous oxide (N_2O) from manure and slurry management (31 per cent) (Herrero and Thornton, 2009). The systems for producing different kinds of livestock are highly diverse. The rapidly expanding industrial livestock operations in Asia and those linked to deforestation in Latin America add more to GHG emissions than the small holder crop-livestock, agropastoral, and pastoral livestock systems (Herrero and Thornton, 2009).

Consumption Patterns : The consumption patterns particularly of the developed countries and the rich are mostly responsible for rise in GHG emissions. The Human Development Report 1998 says that ever expanding consumption puts strains on the environment – emissions and wastes that pollute the earth and destroy ecosystems, and growing depletion and degradation of renewable resources that undermine livelihoods. The inequalities in consumption are stark. For example, the richest fifth consume 45% of all meat and fish and the poorest fifth only 5%. Similarly, richest fifth consume 58% of total energy, the poorest fifth only 4%. (HDR, 1998). The world's dominant consumers are overwhelming. It concentrated among the well-off – but the environmental damage from the world's consumption falls most severely on the poor. UNDP (2007) discusses about the inequalities in carbon foot printing. While China may be about to overtake the US as the world's largest emitter of CO_2, per capita emissions are just one-fifth of the size. Emissions from India are rising. Even so, its per capita carbon footprint is less than one-tenth of that in high income countries. The per capita increase in emissions since 1990 for the United States (1.6 tonnes) is higher than the total per capita emissions for India in 2004 (1.2 tonnes). The distribution of current emissions points to an inverse relationship between climate change risk and responsibility. The poor countries need to accelerate their consumption growth but they need not follow the path taken by the rich and high growth economies. For example, developing countries can look at the supply chain of agricultural production and try to change their consumption patterns to reduce GHG emissions.

There are significant variations in the contribution of various sub-regions in the Asia-Pacific region to GHG emissions. Asian region accounts for 37% of the world's total emissions from agricultural production. China alone accounts for more than 18% of the total GHGs. South and East Asia emit the largest shares of emissions in the Asia-Pacific region – the contribution of South Asia and East Asia (including China) being 20% and 23% respectively. Both sub-regions together contribute 43% of global N_2O emissions from soils (Table 8). East Asia alone emits 68% of global CH_4 emissions from rice production. Emission trends in N_2O and CH_4 will continue and by 2020 N_2O from soils is expected to double approximately 2000 Mt CO_2-eq/yr, CH_4 emissions are expected to rise to 1250 Mt CO_2-eq/yr, and CH_4 emissions from livestock will rise by a third to approximately 800 Mt CO_2-eq/yr. Overall, the developing countries of South and East Asia are expected to increase 2,800 Mt CO_2 – eq/yr across all agricultural sources by 2020. Therefore, mitigation policies are needed for reductions in GHG emissions in the Asia-Pacific region (more on this in sub-section 4.2)

Table 8: GHG emissions by Main Sources in the Agriculture Sector in different Sub-regions, 2005

Subregion and emissions	**N2O from soils**	**CH4 from enteric**	**CH4 from rice**	**CH4 ,N2O from manure**	**CH4, N2O from burning**	**Total**
South Asia						
Mt CO2-eq/yr	536	275	129	40	24	1,005
% of region's total	53	27	13	4	4	100
% of source's world total	20	15	20	9	3	17
East Asia						
Mt CO2-eq/yr	600	294	432	127	53	1,505
% of region's total	40	20	29	8	4	100
% of source's world total	23	16	68	29	14	25
Sub Total (Developing regions)						
Mt CO2-eq/yr	1,946	1,300	617	211	363	4,438
% of region's total	44	29	14	5	8	100
% of source's world total	74	70	97	48	92	74
Subtotal for developed regions						
Mt CO2-eq/yr	700	554	20	225	32	1,531
% of region's total	46	36	1	15	2	100
% of source's world total	26	30	3	52	8	26
Total						
Mt CO2-eq/yr	2,646	1854	637	436	395	5,969
% of region's total	44	31	11	7	7	100
% of source's world total	100	100	100	100	100	100

Note: CH_4 indicates methane; N_2O, nitrous oxide; and Mt CO_2-eq/yr, megatons of carbon dioxide equivalent per year.
Source: USEPA (2000 a); Quoted in Rosegrant et al (2010)

4. Challenges due to Climate Change and Opportunities for Adaptation and Mitigation

This section examines challenges due to climate change and opportunities for adaptation and mitigation. We also discuss implications for livelihoods, agriculture and food security due to adaptation practices. It affects both **production and consumption** of the households. It is possible that some of the adaptation and mitigation policies can have negative implications for livelihoods and food security.

4.1. Adaptation Practices, Strategies and Opportunities

Adaptation to climate change takes place through adjustments to reduce vulnerability or enhance resilience in response to observed or expected changes in climate and associated extreme weather events (IPCC, 2007, p.720). Adaptation measures can be divided into two categories: (a) individual or autonomous; (b) policy driven or planned. Autonomous adaptations are initiatives by private actors rather by governments due to actual or anticipated climate change. Planned adaptation is the result of policy decision by public agency or governments based on an awareness that conditions are about to change or have changed and that action is required to minimize losses or benefit from opportunities (Rosegrant et al, 2010). Table 9 provides examples of autonomous and planned adaptation strategies for agriculture.

Table 9. Adaptation responses and issues

Type of response	Autonomous	Policy driven
Short run	-Crop choice, crop area, planting date -risk pooling insurance	-improved forecasting -research for improved understanding of climate risk
Long run	-Private investment (on-farm irrigation) -private crop research	-large scale public investment (water, storage, roads) -crop research
Issues	-costly to poor -social safety nets -trade-offs with integration	-uncertain return on investment -costs

Source: Rosegrant et al (2009)

Many studies (e.g. Parry, 2002; Droogers 2004; Batima et al 2005) on the impacts of climate change on agriculture and possible adaptation options have been published since the Third Assessment Report. IPCC (2007) summarizes more common adaptation measures that have been identified in several studies (Table 10). These measures are intended to increase adaptive capacity by modifying farming practices, improving crops and livestock through breeding and investing in new technologies and infrastructure. Some of the specific examples of adaptation include grassland management to the actual environmental conditions as well as the practice of reasonable rotational grazing to ensure the sustainability of grassland resources (Li et al, 2002, Wang et al 2004; quoted in IPCC 2007). Some other examples of adaptation are improvement of irrigation systems and breeding of new rice varieties to minimise the risk of serious productivity losses caused by climate change, and information, education and communication programmes to enhance the level of awareness and understanding of the vulnerable groups (IPCC, 2007).

Changes in management of agriculture and allied activities could also enhance adaptive capacity. One example is the integration of fisheries and aquaculture management into coastal zone management to increase the coping ability of small communities in East Asia, South Asia and South-East Asia to sea-level rise.

Table 10 Adaptation Measures in Agriculture

1^{0}C temperature increase in June to August

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

Farm Management

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

Livestock production

- Breeding livestock for greater tolerance and productivity
- Increase stocks of forages for unfavourable time periods
- Improve pasture and grazing management including improved grasslands and pastures
- Improve management of stocking rates and rotation of pastures
- Increase the quantity of forages used to graze animals
- Plant native grassland species
- Increase plant coverage per hectare
- Provide local specific support in supplementary feed and veterinary service

Fishery

- Breeding fish tolerant to high water temperature
- Fisheries management capabilities to cope with impacts of climate change must be developed

Development of agricultural bio-technologies

- Development and distribution of more drought, disease, pest and salt-tolerant crop varieties
- Develop improved processing and conservation technologies in livestock production
- Improve crossbreeds of high productivity animals

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, fishers and farmers to timely weather forecasts

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Source: IPCC (2007), Ch.10, p.490

Autonomous Adaptation: Local Coping Strategies as Adaptation Tools

Countries in the Asia –Pacific region have long a history of coping with extreme changes in weather. These coping strategies would be useful to have long term adaptation strategies. Rural poor also cope with increased climate variability. However, inspite of some commonalities, the coping strategies and indigenous knowledge vary by sub-region, country and provinces.

ADB and IFPRI study (2009) presents local coping strategies collected from various studies in different sub-regions of the Asia region. These strategies are given in Tables 11 and 12.

South Asia

The coping strategies are given for South Asian countries (taken from ADB and IFPRI (2009) study) in Table 11 are summarized as follows.

(a) Farmers in Bangladesh have devised a number of coping strategies at the farm level as coping strategies during the *bonna* (high intensity) floods. Farmers in *Jamalpur* district and other coastal areas such as the Brahmaputra/Indo-Gangetic River Basin have established community rice/fish farms, a practice known as integrated agriculture-aquaculture (IAA), in floodplains or during the flood season (ADB and IFPRI, 2009). This practice ensures increase in incomes, food and nutrition availability, improve use of resources and promotes community cooperation.

(b) One of the adoption strategy common to most South Asian countries is appropriate crop selection as a response to flooding. Farmers in Bangladesh adjust their transplanting of *aman* (a wet season rice variety) by transplanting late varieties to avoid crop losses due to variations in the recurrence of floods (ADB and IFPRI, 2009). It enables growing of additional crops which increases the incomes of farmers.

(c) Another method of cultivating crops during the flood season is hydroponics which is done particularly in water logged areas. Crops like vegetables are grown in flooding gardens. This practice not only gives subsistence food but also provides additional income. Raising ducks is another method of adaptation during monsoon period (ADB and IFPRI, 2009).

(d) Raising sea levels leads to flooding and water logging. In the state of Goa, India, farmers in water logged areas practice *Khazan* which is a traditionally community managed Integrated Agriculture-Aquaculture (IAA) system (ADB and IFPRI, 2009). Apart from community level cooperation, this practice promotes a mutually beneficial relationship between rich and poor by generating employment and labour sharing.

(e) Drought or aridity is another natural disaster of significance in South Asia. In general, the most common adaptation strategy for reducing the impact of drought is sustainable water management through tanks and dams. The examples are (i) *anicuts* (small to medium-sized dams) are used to harvest rainwater and serve as reservoirs in India; (ii) *laths* which are temporary structures 1-3 meters deep, used for traditional flood irrigation in Sindh, Pakistan; (iii) underground tanks or *Kunds* in the Thar Desert of India; (iv) ground barriers (such as contour bunds, *nallah* bunds, or gabions) and shallow excavations (such as contour trenches, farm ponds, and reservoirs in bedrock) in

Maharashtra, India; (v) bamboo stems for drip irrigation in Bhutan and; (vi) cascading tanks in Sri Lanka (ADB and IFPRI, 2009)

(f) There are also methods for controlling soil erosion and land degradation. These methods in the Himalayas include terracing, field leveling, plowing, sheet erosion control and biofencing (ADB and IFPRI, 2009). Application of manure or ash from organic manure, crop residues can also enhance soil fertility.

Table 11. Local Coping Strategies as Adaptation Tools to mitigate the impacts of Climate Change in Agriculture: South Asia

Sub-region/country	Local Area	Natural Disaster	Impacts	Adaptation Action	Local coping strategies
Bangladesh	Jamalpur district	Floods	Loss of livelihoods	Livelihood diversification through integrated agriculture-aquaculture system	Establishing a community rice-fish farm
--	--	Floods	Loss of crops-loss of livelihoods	Appropriate crop selection. Alternative cultivation methods	Adjusting timing of transplanting Aman cultivation to more frequent floods
	South western	Floods	Waterlogging	Alternative cultivation methods like hydroponics	Growing of crops or vegetables in floating gardens
	Southwestern coastal area	Floods	Low survival and/or productivity of poultry	Poultry breeding	Raising ducks during monsoon. Diet diversification
		Raising sea levels	Loss of crops	Appropriate crop selection	Cultivating maize and fodder grass during dry season
	Northwestern Barind tract	Drought and/aridity	Water shortage	Improved cropping system through alternative cultivation method	Adjusting timing of transplanting aman seeding practices for more frequent droughts.
		Drought and/aridity	Land degradation, soil erosion	Soil conservation livelihood diversification	Home gardening as a means to climate proofing farming
Bhutan	Wangling, jangbi,phumzur, villages in trongsa district	Erratic rainfall	Loss of crops	Diet diversification	Harvesting wild vegetables, fruits and tubers from the forest by the Monpas, a Bhutaneses ethnic group
		Drought and/or aridity	Loss of crops, water shortage	Sustainable water management	Using bamboo stems for drip irrigation during the dry season
		Drought and/or	Loss of crops	Alternative	Managing

		aridity		cultivation methods	common pool resources
Himachal Pradesh	Erratic rainfall	Water shortage	Sustainable water management	Utilizing and distributing glacier run-off	
Several North Eastern States	Erratic rainfall	Loss of crops	Appropriate crop selection	Domesticating indigenous varieties of cereals and fruit trees	
Himalayas	Erratic rainfall	Loss of crops	Alternative cultivation methods	Growing apricots, walnuts, grapes, and vegetables in the cold deserts.	
	Erratic rainfall	Loss of crops	Appropriate crop selection in cold deserts	Rotational cropping seed selection	
Western Himalayas	Erratic rainfall	Loss of crops	Disaster risk management-appropriate cropping practices	Using meteorological indicators and animal behavior to predict rain	
Himalayas	Erratic rainfall	Water shortage	Rainwater harvesting	Using roofs, ponds, and tanks to harvest rain, dew and fog water	
Himalayas	Erratic rainfall	Loss of crops	Appropriate crop selection	Rotational cropping seed selection	
Goa	Sea level rise	Water logging	Integrated agriculture-aquaculture system	Balancing agriculture and fisheries through sluice gates. Application of Khazan-traditionally community managed integrated agri-aquaculture ecosystems	
	Drought and /or aridity	Water shortage	Rainwater harvesting	Building anicuts (small and medium-sized dams) to serve water reservoirs	
Himalayas	Erratic rain/drought	Land degradation	Nutrient management	Manure and ash application to increase soil fertility, organic manure	
Central Himalayas Garwal region	Drought/aridity	Loss of crops	Diet diversification	Use of wild foods and medicinal plants by Bhotiya tribes (Tolccha, Marchha, Jadhs)	
Thar desert	Drought/aridity	Water shortage	Rainwater harvesting	Building underground tanks	
North East	Drought/aridity	Loss of crops. Water shortage	Sustainable water management	Using bamboo to transport stream and spring water to irrigate plantations	

Andaman and Nicobar islands	Drought/aridity	Loss of crops	Alternative cultivation method	Intercropping with banana and using plant residues. Selecting and storing rice, pulse and vegetable seeds	
Gujarat	Drought/aridity	Water shortage	Rainwater harvesting	De-silting,cleaning,and deepening of ponds to collect rain water	
Maharashtra	Drought and /aridity	Water shortage/soil erosion	Rainwater harvesting	Building ground barriers and shallow excavations through various barriers	
Orissa	Drought/aridity	Loss of crops	Appropriate crop selection	Storing and exchanging rice varieties and medicinal plants	
Rajasthan	Drought/aridity	Water shortage	Rain water harvesting	Harvesting water and recharging ground water with earthen check dams	
	Drought/aridity	Loss of crops	Appropriate crop selection	Cultivating bajra millet in arid regions	
	Drought/aridity	Loss of crops	Appropriate crop selection. Income diversification	Growing 'Sona Mukhi' (*Cassia angustifolia)* as medicinal cash crop	
	Drought/aridity	Land degradation	Nutrient management	Using worms to process organic waste	
Tamil Nadu	Drought/aridity	Water shortage	Sustainable water management	Improving wells and irrigation	
	Drought/aridity	Loss of crops	Post-harvest management	Threshing, winnowing, cleaning and drying for dry land crops	
Uttar Pradesh	Floods	Loss of crops	Appropriate crop selection	Breeding rice varieties in flood-prone areas	
	Drought/aridity	Land degradation	Nutrient management	Increasing soil fertility through gypsum, manure, and compost applications	
Nepal	--	Extreme cold	Loss of crops	Post-harvest management	Processing green and leafy vegetables
Pakistan	Sindh	Droughts and aridity	water shortage	Sustainable water management	Building laths at different levels to irrigate fields
Sri Lanka	--	Droughts and	Water shortage	Rainwater	Using stored

		aridity		harvesting (cascading tanks)	water efficiently
	--	Droughts and aridity	Water shortage	Rainwater harvesting	Managing water by women
	--	Droughts and aridity	Loss of crops	Alternative cultivation methods	Zero-tillage paddy cultivation
		Droughts and aridity	Loss of crops	Land redistribution	Temporary redistribution of private fields (bethama practice) covering parts of land among shareholders
		Droughts and aridity	Loss of crops	Pest control	Controlling weed growth through dry straw in paddy fields

Source: Adapted from ADB and IFPRI (2009)

East and South East Asia

There are also several local coping strategies in East and South East Asia. ADB and IFPRI (2009) study provides these strategies that are given in Table 12 and are summarized below.

(a) In Western Sichuan in Southwestern China, livestock breeders select *jiulong* (vally-type) and *maiwa* (platea-type) yak during extremely cold weather. This practice ensures continuous production of yak and provides a source of food and income for farmers.

(b) Farmers in West Java, Indonesia, grow fish in *huma* or dry swidden fields drought conditions and in *sawah* or wet fields during flooding. This is similar to the IAA system in South Asia. This provides income and food security for the farmers.

(c) Lao PDR and communities in Attapeu Province in the Mekong Delta, diversify their diets during the flood season from rice based diets to edible aquatic resources such as fish, crabs and other food from the Delta (ADB and IFPRI, 2009).

Table 12. Local Coping Strategies as Adaptation Tools to mitigate the impacts of Climate Change in Agriculture: East Asia and South East Asia

Sub-region/country	Local Area	Natural Disaster	Impacts	Adaptation Action	Local coping strategies
East Asia					
People's Republic of China (PRC)	Western and Northern PRC of Yellow River (loess highlands	Floods	Soil Erosion	Check dams- control soil erosion	Controlling Soil erosion through construction of a series of dams or dam-fields
	Western Sichuan, Tibetan Plateau	Extreme cold	Low survival and/or productivity of livestock	Appropriate livestock breeding	Livestock selection, for example, breeding jiulong (valley-type_ and maiwa (plateau-type)

South East Asia	West Java	Drought and/ aridity/floods	Loss of crops	Alternative cultivation methods	Growing fish on huma (dry swidden fields) and sawah (wet fields)
Timor	--	Erratic rainfall	Loss of crops	Appropriate crop selection	Strategies for seed selecting and planting to cope with disasters
Greater Mekong Sub-region Lao-PDR	Attapeu province	Floods	Loss of crops	Alternative cultivation methods. Diet diversification	Diversifying rice based diets during flood season
Greater Mekong Sub-region Mekong Delta	--	Floods, sea-level rise, storms	Loss of crops, loss of land. Damage to human settlements	Disaster risk management	Building forecasting capacity and adaptation strategy

Source: Adapted from ADB and IFPRI (2009)

Planned or policy Driven adaptations

The coping mechanisms of adaptation are not enough for the wellbeing of the households. The choices of adaptation policies are, however, shaped by public policy. Planned adaptation or public policy driven adaptation is thus required. Possible supporting policies to stimulate adaptation measures are shown in Table 13. The policies relating to adaptation are generally an extension of development policy that tries to eradicate structural causes of poverty and food insecurity. The policies that should be supported include ‘promoting growth and diversification, strengthening institutions, protecting natural resources, creating markets in water and environmental services, improving the international trade system, enhancing resilience to disasters and improving disaster management, promoting risk sharing (including social safety nets and weather insurance), and investing in research and development, education and health” (Rosegrant et al, 2010, p.33)

These adaptation and other policies should be adopted by the government and implemented by the institutions in direct contact with the households. For example, the adaptation responses like changing planting dates and tillage practice may need technical services provided by local extension agencies and coordinated by regional research institutions and universities. Public policy thus plays an important role in adaptation to climate change. The planned adaptation strategies need to address high priority areas and not just confine to reactive measures. Specific policy driven measures for the agriculture sector include drought contingency plans, efficient water allocation, seed research and development, elimination of subsidies and taxes, efficient irrigation, conservation management practices, and trade liberalization (Smith and Lenhurt, 1996; quoted in Rosegrant et al, 2010)

Table 13. Adaptation options and supporting policies given climate change

Adaptation Options	Supporting Policies
Short term	
Crop insurance for risk coverage	Improve access, risk management, revise pricing incentives, etc.
Crop/livestock diversification to increase productivity and protect against diseases	Availability of extension services, financial support, etc.
Adjust timing of farm operations to reduce risks of crop damage	Extension services, pricing policies, etc.
Change cropping intensity	Improve extension services, pricing policy adjustments
Livestock management to adjust to new climate conditions	Provide extension services
Changes in tillage practices	Extension services to support activities, pricing incentives
Temporary mitigation for risk diversification to withstand climate shocks	Employment/training opportunities
Food reserves and storage as temporary relief	------
Changing crop mix	Improve access and affordability, revise pricing, etc.
Modernize farm operations	Promote adoption of technologies
Permanent migration to diversify income opportunities	Education and training
Define land-use and tenure rights for investments *(Both short and long term)*	Legal reform and enforcement
Develop crop and livestock technology adapted to climate change stress: drought and heat tolerance, etc.	Agricultural research (crop and livestock trait development), agricultural extension services
Develop market efficiency	Invest in rural infrastructure, remove market barriers, property rights, etc.
Expand irrigation and water storage	Investment from public and private sectors
Efficient water use	Water pricing reforms, clearly defined property rights, etc
Promote international trade	Pricing and exchange rate policies
Improve forecasting mechanisms	Distribute information across all sectors, etc.
Strengthen institutional and decision-making structures	Reform existing institutions on agriculture, etc.

Source: Rosegrant et al (2010) adapt from Kurukulasuriya and Rosenthal (2003)

In the agricultural advisory services and information systems, extension is one of the important services for farmers. It is recognized that a mature extension system is characterized by multiple extension funding and service provision. Insurance is one of the mechanisms to manage the risk due to climate change. However, innovative approaches are needed. In Mongolia, livestock insurance is arranged through public-private partnerships (see Box 4).

Box 4 ***Public-private partnerships for sharing climate risks: Mongolia livestock insurance***

An important concept of climate-risk management is risk-sharing by communities, governments, and businesses. In Mongolia livestock herders, the national government, and insurance companies developed a scheme to manage the financial risks arising from severe winter-spring cold episodes (*dzuds*) that periodically result in widespread livestock mortality. Such episodes killed 17 percent of livestock in 2002 (in some areas up to 100 percent), amounting to losses of $200 million (16 percent of GDP).

In this scheme herders retain the responsibility for smaller losses that do not affect the viability of their business or household, and they often use arrangements with community members to buffer against smaller losses. Larger losses (of 10–30 percent) are covered through commercial livestock insurance provided by Mongolian insurers. A social insurance program through the government bears the losses associated with catastrophic livestock mortality that would overwhelm herders and insurers alike. This tiered approach defines a clear framework for self-insurance by herders, commercial insurance, and social insurance.

An important innovation is the use of index insurance rather than individual livestock insurance, which had been ineffective because the verification of individual losses tends to be fraught with moral hazard and often prohibitively high costs. With this new type of insurance, herders is compensated based on the average livestock mortality rate in their district, and an individual loss assessment is not required. This gives Mongolian insurers incentives to offer commercial insurance to herders, which they had been reluctant to do.

The scheme provides advantages for all. Herders can buy insurance against unavoidable losses. Insurers can expand their business in rural areas, strengthening the rural financial service infrastructure. The government, by providing a well-structured social insurance, can better manage its fiscal risk. Even though a catastrophic event exposes the government to significant potential risk, the government had been compelled politically to absorb even greater risk in the past. Because the government covers catastrophic outcomes, the commercial insurance, limited to moderate levels of mortality, can be offered at affordable rates.

Sources: Mahul and Skees 2007; Mearns 2004. Quoted in WDR (2010)

Social protection programmes are also important for reducing risks faced by households due to climate change. Bangladesh shows how it can be done by having several social protection programmes even in poor countries (see Box 5). Public works programme is an important component of social protection policies. In India, the provision of employment has been extensively used as a tool of entitlement protection for many centuries. But, the most important programme now is the National Rural Employment Guarantee Scheme (NREGS). It is now called Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). The objective of the scheme is to enhance livelihood security in rural areas by providing at least 100 days of guaranteed wage employment in a financial year to every household. The primary objective is employment creation. The auxiliary objective is regenerating natural resource base and creating productive assets. Third one which is process objective is to strengthen grass root democracy by infusing transparency and accountability in governance. MGNREGA can be used as climate change adaptation in order to reduce risks and improve the livelihoods of the poor (see Box 6).

Box 5. ***Safety nets: From supporting incomes to reducing vulnerability to climate change***

Bangladesh has had a long history of cyclones and floods, and these could become more frequent or intense. The government has safety nets that can be tailored fairly easily to respond to the effects of climate change. The best examples are the vulnerable-group feeding program, the food-for-work program, and the new employment guarantee program.

The vulnerable-group feeding program runs at all times and usually covers more than 2 million households. But it is designed to be ramped up in response to a crisis: following the cyclone in 2008, the program was expanded to close to 10 million households. Targeting, done by the lowest level of local government and monitored by the lowest administrative level, is considered fairly good.

The food-for-work program, which normally operates during the low agriculture season, is ramped up during emergencies. It too is run in collaboration with local governments, but program management has been subcontracted to nongovernmental organizations in many parts of the country. Workers who show up at the work site are generally given work, but there is usually not enough to go around, so the work is rationed through rotation.

The new employment guarantee program provides those with no other means of income (including access to other safety nets) with employment for up to 100 days at wages linked to the low-season agricultural wage. The guarantee element ensures that those who need help get it. If work cannot be provided, the individual is entitled to 40 days of wages at the full rate and then 60 days at half the rate.

Bangladesh’s programs, and others in India and elsewhere, suggest some lessons. Rapid response requires rapid access to funding, targeting rules to identify people in need—chronic poor or those temporarily in need—and procedures agreed on well before a shock hits. A portfolio of “shovel-ready” projects can be preidentified as particularly relevant to increasing resilience (water storage, irrigation systems, reforestation, and embankments, which can double as roads in low-lying areas). Experience from India and Bangladesh also suggests the need for professional guidance (engineers) in the selection, design, and implementation of the public works and for equipment and supplies.

Source: Contributed by Qaiser Khan. WDR(2010)

Box 6. ***Workfare in India under the Indian National Rural Employment Guarantee Act***

India over time has developed an employment guarantee program built on an earlier successful scheme in the state of Maharashtra. The program establishes, through self-selection, the right of up to 100 days of employment at the statutory minimum wage for every household that volunteers. Households do not have to demonstrate need, and some wages are paid even if work cannot be provided.

The program makes provision for at least a third of the work to be available to women, on-site child care, and medical insurance for work injuries; work must be provided promptly and within five kilometers of the household where possible. The operation is transparent with lists of works and contractors publicly available and on the program’s Web site, allowing public oversight against corruption and inefficiency. Since the program’s inception in 2005, 45 million households have contributed 2 billion days of labor and undertaken 3 million tasks.[a]

With appropriate guidance, the program can support climate-smart development. It operates at scale and can direct significant labor toward appropriate adaptive works, including water conservation, catchment protection, and plantations. It provides funds for tools and other items necessary to complete activities and technical support for designing and implementing the projects. It can thus become a core part of village development through productive, climate-resilient asset creation and maintenance.[b]

Sources: a. National Rural Employment Guarantee Act—2005, http://nrega.nic.in/ (accessed May 2009).
b. CSE India, http://www.cseindia.org/programme/nrml/update_january08.htm (accessed May 15, 2009); CSE 2007. Quoted in WDR (2010)

Crop insurance is another way of helping the farmers from the risks of reduction in yields due to climate change. Weather index based insurance has been introduced in recent years in many countries. It allows individual smallholder farmers to hedge against agricultural production risks, such as droughts or floods. The product pays out in events that are triggered by a publicly observable index, such as rainfall recorded on a local rain gauge. As a result, advocates argue that payouts can be calculated and disbursed quickly and automatically without the need for households to formally file a claim (Gine', 2009). Area based rainfall index insurance has some attractive features such as less adverse selection, less administrative costs, potential for a secondary market, can be sold non-farmers, can be linked to microfinance and can clear the way for innovation in mutual insurance (Hazell and Skees, 2006). Some developments have emerged in India in recent years to offer rainfall insurance contracts. ICICI Lombard General Insurance Company began a pilot insurance program that will pay farmers when there are rain shortfalls in one area, and pay others in case of excess rain. BASIX used ICICI Lombard and technical assistance from the Commodity Risk Management Group of the World Bank to develop and launch the new rainfall insurance products. BASIX began operations in March 2001, in the districts of Mahbubnagar in Andhra Pradesh and Raichur and Gulbarga in Karnataka in India. In 2003, the new rainfall insurance was targeted at individual farmers for three categories of groundnut and castor farmers: small, medium, and large. Government may have to help in setting up basic infrastructure. In 2007-08 budget, the finance minister announced that he would ask Agricultural Insurance Corporation (AIC) to start a weather based crop insurance scheme on a pilot basis in two or three states as an alternative to the present crop insurance by the government.

IPCC (2007) on Asia provides sector-specific practices, options and constraints on adaptation. The sectors considered are: Agriculture and food security, hydrology and water resources, coastal and low lying areas, natural ecosystems and biodiversity and human health. We already mentioned above in section 3 on IPCC's suggestions on agriculture and food security. Regarding hydrology and water resources, there are many adaptation measures that could be applied in various parts of Asia to minimize the impacts of climate change on water resources and use: several of which address the existing inefficiency in the use of water. On coastal and low lying areas, the response to sea-level rise could mean protection, accommodation and retreat. The Integrated Coastal Zone Management (ICZM) concept[10] is being embraced as a central organizing concept in the management of fisheries, coral reefs, pollution, megacities and individual coastal systems in China, India, Indonesia, Japan, Korea, the Philippines, Sri Lanka, Vietnam and Kuwait (IPCC, 2007). The probability of significant adverse impacts of climate

[10] European Commission says "CZM is a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning (in its broadest sense), decision making, management and monitoring of implementation. ICZM uses the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics. 'Integrated' in ICZM refers to the integration of objectives and also to the integration of the many instruments needed to meet these objectives. It means integration of all relevant policy areas, sectors, and levels of administration. It means integration of the terrestrial and marine components of the target territory, in both time and space". See http://en.wikipedia.org/wiki/Integrated_coastal_zone_management

change on Asian forests is high in the next few decades. Among other things, comprehensive intersectoral programmes that combine measures to control deforestation and forest degradation with measures to increase agricultural productivity and sustainability will likely contribute more to reducing vulnerability of forests to climate change, land use change and other stress factors than independent sectoral initiatives. For effective adaptation measures on health, the potential impacts of climate variability and change on human health need to be identified, along with barriers to successful adaptation and the means of overcoming such barriers (IPCC, 2007).

Migration as an adaptation practice

As mentioned above, it is difficult to isolate climate change related migration from those of other factors. International migration and migration within countries are going to increase with climate change.

In many countries of Asia and Pacific region, migration is also used as one of the adaptation measure at household level. The migrants send significant amount of remittances from foreign countries as well as rural and urban areas within countries.

But, planned adaptation is also needed for climate change related migration. ADB (2011) report indicates that international cooperation mechanisms have not been set up to manage these migration flows, and protection and assistance schemes remain inadequate, poorly coordinated, and scattered, and national governments and the international community must urgently address this issue in a proactive manner.

The report also says that if properly managed, climate-induced migration could actually facilitate human adaptation, creating new opportunities for dislocated populations in less vulnerable environments.

Significant funding will be required to utilize migration as an adjustment or coping mechanism in the face of climate change. Migration-related adaptation within poorer countries will require transfer of resources—human, technological, and financial—from better-off countries and the international community (ADB, 2011).

Key constraints and measures to strengthen adaptation: The IPCC report (2007) says that effective adaptation and adaptive capacity in Asia, particularly in developing countries, will continue to be limited by several ecological, social and economic, technical and political constraints including spatial and temporal uncertainties associated with forecasts of regional climate. Low level of awareness among decision makers of the local and regional impacts of El Nino, limited national capacities in climate monitoring and forecasting, and lack of coordination in the formulation of responses also act as constraints.

It may be noted that poverty is identified as the largest barrier to developing the capacity to cope and adapt. Insufficient information and knowledge on the impacts of climate change and responses of natural systems to climate change will continue to hamper effective adaptation particularly in Asia. It is also likely that in countries of Asia facing pervasive poverty, hunger, terrorism, serious domestic conflicts, epidemics and other pressing and urgent concerns, there is going to be less attention on the issues relating to climate change and the need to implement adaptation. The slow change in political and institutional landscape in response to climate change and the existing legal and institutional framework in most Asian countries remains inadequate to facilitate implementation of adaptation (IPCC, 2007).

Stern (2007) suggested some measures which could be useful to address some of the constraints mentioned above and strengthen adaptation in Asia. These include: improving access to high quality information about the impacts of climate change; reducing the vulnerability of livelihoods and infrastructure to climate change; promoting good governance including responsible policy and decision making; empowering communities and other local stakeholders so that they participate actively in vulnerability assessment and implementation of adaptation; adaptation and vulnerability assessment by setting in place early warning systems and information distribution systems to enhance disaster preparedness; mainstreaming climate change into development planning at all scales, levels and sectors (Chapter 10, IPCC, 2007)

Trade off between adaptation practices and livelihoods

Both autonomous and policy driven adaptation practices can have negative effects on livelihoods in rural areas. For example, sometimes incomes of farmers may decline due to adjustments in practices relating to agricultural crops. Similarly, livestock provides livelihoods for many farmers and non-land asset households. Adaptations in grazing etc. can lead to reduction in incomes and livelihoods. Forest related adaptations also may hamper the livelihoods of forest dwellers. Sometimes planned or policy driven adaptations may provide barriers or disincentive to adaptation. Planned adaptation in terms of expanding irrigation may displace people. Adaptation relating to migration also may have negative effects on the migrant population as well as the members of the households left behind in the places of origin. Therefore, adaptation practices and policies should try to reduce trade off between adaptation and livelihoods.

4.2. Opportunities for Mitigation Strategies in Asia-Pacific Region

As discussed above, agriculture is part of the problem and solution for reducing GHG emissions. Agriculture and forestry contribute nearly a third of global anthropogenic GHG emissions. Therefore, mitigation strategies should focus on activities in these sectors. It may be noted, however, that oceans, lakes, forests and agricultural lands also sequester and store large amounts of carbon, thus contributing to climate change mitigation (FAO, 2009).

Agricultural practices can make a significant contribution at low cost to increasing soil carbon sinks and GHG emission reductions. It should be in the framework of sustainable development. In other words, sustainable production and sustainable consumption in agriculture, forestry and fisheries should be the driving forces for reducing GHG emissions.

There are very few studies which looked at mitigating strategies in the framework of sustainable production and consumption. In an interesting paper, Young et al (2010) report the research based on the University of Leeds' supply chain as part of its sustainable development programme. The research examines the reduction of GHG emissions in its supply chain. It looks at an understanding of emissions in food chain of its life cycle which consists of multiple phases : primary production, processing, packaging, distribution, preparation and consumption and waste management. This study says that the "GHG emissions released in these phases vary considerably depending on the product being produced and consumed and on the management of energy during each of the production phases" (Young et al, 2010, p.367). Table 14 provides some of the factors that impact GHG emissions in each phase of the supply chain. The study, however, acknowledges that data do not exist to measure all of the variables listed and the data that exist are not easily comparable.

Table 14 Factors affecting GHG emissions of food production

Phases	*GHG impact factors*
Primary production	Machinery used
	Age of machinery
	Use of renewable energy vs. fossil fuel
	Type of produce (e.g. meat vs. vegetables)
	Organic vs. conventional production
	Use of fertilizers and pesticides
	Use of animal feed
	Distance and mode of transport of animal feed, fertilizers and pesticides
Processing (include assembly and storage)	Number of stages in the production process
	Source of energy used in each stage
	Method and time of storage
	Efficiency of equipment
	Distance and mode of transport between processing plants
Preparation and consumption	Source of energy used in preparation
	Method and time of storage (refrigeration and freezing)
	Efficiency of equipment
	Number of people consuming the product
	Distance and mode of transport for collection
Distribution	Mode of transport (air, rail, sea, road)
	Age of transport
	Fuel type
	Distance traveled
	Speed traveled
	Percentage of empty running
	Use of back haulage
	Traffic congestion
	Driver behavior
	Route planning
	Fleet performance management
	Refrigerated transportation
Packaging and end-of-life management	Purpose of the packaging
	Type of material
	Material status (virgin material, recycled, reused)

	Percentage of recycled material
	Ability to recycle or re-use the material
	Distance material travels from source/supplier
	Distance to end-of-life management
	Energy use during end-of-life treatment

Source: Young, Costello and Kerr (2010)
Note: They collected these factors from various sources. See this study for various references.

We now examine the mitigation strategies and measures needed in agriculture and forestry in Asia and Pacific region to reduce GHG emissions. The discussion will be mostly on production compared to consumption as more information is available on the former.

There are variety of options exists for mitigation of GHG emissions in agriculture, livestock and forestry. These are discussed below.
Several mitigation options in agriculture range from crop, tillage/residue, nutrient, rice, water, manure/biosolid, grazing lands, organic soils, livestock and manure management practice, to land cover change, agro-forestry, land restoration, bioenergy, enhanced energy efficiency and increased carbon storage in agricultural products (IPCC, WGIII, 2007.)

A summary of measures for mitigating gas emission in agriculture and forestry sector given in IPCC (2007, Ch.8) are presented in Table 15.

Table 15. Proposed measures for mitigating gas emission in Agriculture

		Mitigative effects[a]			**Net mitigation[b] (confidence)**	
Measure	**Examples**	**CO2**	**CH4**	**N2O**	**Agreement**	**Evidence**
Cropland management	Agronomy	+		+/-	***	**
	Nutrient management	+		+	***	**
	Tillage/residue management	+		+/-	**	**
	Water management (irrigation, drainage)	+/-		+	*	*
	Rice management	+/-	+	+/-	**	**
	Agro-forestry	+		+/-	***	*
	Set-aside, land-use change	+	+	+	***	***
Grazing land management/ pasture improvement	Grazing intensity	+/-	+/-	+/-	*	*
	Increased productivity (e.g., fertilization)	+		+/-	**	*
	Nutrient management	+		+/-	**	**
	Fire management	+	+	+/-	*	*
	Species introduction (including legumes)	+		+/-	*	**
Management of organic soils	Avoid drainage of wetlands	+	-	+/-	**	**
Restoration of degraded lands	Erosion control, organic amendments, nutrient amendments	+		+/-	***	**
Livestock management	Improved feeding practices		+	+	***	***

	Specific agents and dietary additives		+		**	***
	Longer term structural and management changes and animal breeding		+	+	**	*
	Improved storage and handling		+	+/-	***	**
Manure/biosolid management	Anaerobic digestion		+	+/-	***	*
	More efficient use as nutrient source	+		+	***	**
Bio-energy	Energy crops, solid, liquid, biogas, residues	+	+/-	+/-	***	**

Notes: a + denotes reduced emissions or enhanced removal (positive mitigative effect);
- denotes increased emissions or suppressed removal (negative mitigative effect);
+/- denotes uncertain or variable response.
b A qualitative estimate of the confidence in describing the proposed practice as a measure for reducing net emissions of greenhouse gases, expressed as CO_2-eq:
Agreement refers to the relative degree of consensus in the literature (the more asterisks, the higher the agreement);
Evidence refers to the relative amount of data in support of the proposed effect (the more asterisks, the more evidence).
Source: adapted from Smith et al., 2007a by IPCC (2007).

Opportunities for mitigating GHG fall into three broad categories: carbon sequestration into soils, on-farm emission reductions and bioenergy production which displaces GHG emissions from fossil fuel use. These are discussed below.

Technical potential for Mitigation

The technical potential can be defined as the theoretical amounts of emissions that can be reduced and the amounts of carbon that can be sequestered given the full application of current technologies. In other words, it does not consider the costs of implementation and the current policy and economic conditions. It only provides the order of magnitude that current methods of mitigation may allow (Rosegrant et al, 2010).

There have been several attempts to assess the technical potential for mitigation of GHG emissions in agriculture. Of published estimates of technical potential, only Caldeira et al (2004) and Smith et al (2007) provide global estimates considering all GHGs together. The technical potential at global level for mitigation options in agriculture by 2030, considering all gases, was estimated to be 4500 MtCO_2-/eq/yr by Calderia et al (2004) and 5500-6000 MtCO_2-eq/yr by Smith et al (2007) (IPCC, 2007, WG III, Ch.8 p.515). The estimates of technical potential at regional show that Asia has the highest potential for mitigation options among the regions at 45 percent. It was followed by LAC and Europe, 14 percent each; Sub-Saharan Africa, 12 percent; North America and the Middle East and North Africa (MENA), 6 percent each; and Australia 2 percent (Rosegrant et al, 2010).

Carbon Sequestration

GHGs can be absorbed from the atmosphere through sinks. Sequestered carbon is stored in soils, resulting in increases in soil organic carbon. Of the global technical potential estimated by Smith et al (2007), about 89% is from soil carbon sequestration, about 8% from mitigation of methane and about 2% from mitigation of soil N_2O emissions (p.506, WG III, IPCC 2007). Carbon sequestration potential can be achieved through different management practices, such as improved crop land and grazing land management, agro forestry and the rehabilitation of degraded lands. For example, reduced or no-till agriculture in association with diversified cropping patterns and increased soil cover limits soil disturbance and increases soil carbon (FAO, 2009). Reduced deforestation, more sustainable forest management and adoption of agroforestry (integration of tree and crop cultivation) have particularly good potential to capture significant amounts of carbon and other GHGs and, at the same time, contribute to poverty reduction (FAO, 2010). Technologies include: tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change (IPCC, 2007). Soil organic carbon can be increased through grazing land management, which improves the cover of high productivity grasses and overall grazing intensity. In Asia, large potential exists in India which has one of the world's largest grazing land areas (Rosegrant et al, 2010).

On-farm mitigation
Adoption of better management practices and more efficient management of carbon and nitrogen flows can reduce emissions caused by agriculture, forestry and fisheries. Improved management practices that reduce on-farm emissions include fertilizer management, manure management, rice farming and livestock management.

Nutrient Management: Nitrogen applied in fertilizers, manures, biosolids and other N sources are not used efficiently by crops. Management strategies to improve the nitrogen use efficiency of crops which reduce fertilizer requirements and associated GHG emissions, focus on fertilizer best management practices. A note written for IFPRI by Flynn (2009) says that the best practices should look at application type, application rates, application timing and application placement. For example, balancing application rates of nitrogen with other required nutrients including phosphorus, potassium and sulphur is a major way of improving nitrogen use efficiency. Similarly, appropriate nitrogen application rates are important as excess nitrogen can lead to more emissions.

Another way of mitigation is switching to organic production which can reduce fertilizer use and N2O emissions. Better use of existing organic sources of nutrients, including animal manure, crop residues, and nitrogen-fixing crops such as legumes. Such organic nitrogen sources may also contribute to raising sequestration of carbon in soils (Flynn, 2009). However, yields may be lower with organic farming as compared to cultivation with chemical fertilizers. One has to weigh the benefits of reduction in emissions with decline in yields. This may have implications for livelihoods and incomes.

Reducing Methane Emission from Irrigated Rice: Changing water management seems to be the most promising mitigation option for reducing emissions in irrigated rice cultivation. Midseason drainage (a common irrigation practice adopted in major rice growing regions of China and Japan) and intermittent irrigation (common in northwest India) significantly reduce methane emissions by over 40 per cent(Wassmann et al, 2009). Box 7 provides a case study of Philippines in reducing methane emissions through new irrigation schemes. The technical potential of improved rice management to reduce

GHG emissions is 300 $MtCO_2$-eq/yr (IPCC, 2007).

Box 7 Mitigating methane emissions through new Irrigation Schemes (Bohol, Philippines)
Bohol Island is one of the biggest rice-growing areas in the Philippines' Visayas regions. Before the completion of the Bohol Integrated Irrigation System (BIIS) in 2007, two older reservoirs (Malinao and Capayas Dam) were beset by problems and unable to ensure sufficient water during the year's second crop (November to April), especially for farmers who live farthest downstream from the dam. This problem was aggravated by the practice of unequal water distribution and a preference by farmers for continuously flooded rice growing conditions. In the face of declining rice production, the National Irrigation Administration (NIA) created an action plan for the BIIS. This included the construction of a new dam (Bayongan Dam; funded by a loan from the Japan Bank for International Cooperation) and the implementation of a water-saving technology called Alternate-Wetting and Drying (AWD) which was developed by the International Rice Research Institute (IRRI) in cooperation with national research institutes. The visible success of AWD in pilot farms combined with specific training programmes for farmers, were able to dispell the widely held perception of possible yield losses from non-flooded rice fields. Ample adoption of AWD facilitated an optimum use of irrigation water, so that the cropping intensity could be increased from 119 % to 160 % (related to the maximum of 200 % in these double-cropping systems). Moreover, according to the revised IPCC methodology (IPCC 2006), 'multiple aeration', to which the AWD corresponds, potentially reduces methane emissions by 48 % compared to continuous flooding of rice fields. AWD therefore generates multiple benefits related to methane emission reduction (mitigation), reducing water use (adaptation where water is scarce), increasing productivity and contributing to food security (Bouman *et al*. 2007). Source: FAO, 2010a

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Reducing CH_4 Emissions from Livestock System: Livestock, predominantly ruminants such as Cattle and sheep, are important sources of CH_4, accounting for about one-third of global anthropogenic emissions of this gas. The methane is produced primarily by enteric fermentation and voided by eructation (IPCC, 2007). The methods to reduce enteric fermentation include improving digestive efficiency of livestock with improved feeding practices and dietary additives. The efficacy of these methods depends on feed quality, livestock breed and age, and whether the livestock is grazing or stall fed (Rosegrant et al, 2010). Farmers should be provided incentives to offset payments for adopting livestock systems that reduce emissions yet maintain their livelihoods. The technical potential to mitigate livestock emissions is 300 Mt CO_2-eq/yr (IPCC, 2007).

Manure management: Animal manures can release significant amounts of N_2O and CH_4 during storage, but the magnitude of these emissions varies. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling, use of solid covers, mechanically separating solids from slurry, or by capturing the CH_4 emitted. To some extent, emissions from manure might be curtailed by altering feeding practices or by composting the manure (p.510, WB, III, IPCC, 2007).

Bio-fuels

Agricultural crops and residues are seen as sources of feedstocks for energy to displace fossil fuels. A wide range of materials have been proposed for use, including grain, crop residue, cellulosic crops (e.g. switch grass, sugarcane) and various tree species. These products can be burned directly, but can also be processed further to generate liquid fuels such as ethanol or diesel fuel. Such fuels release CO_2 when burned but this displaces CO_2 which otherwise would have come from fossil carbon. The net benefit to CO_2, however, depends on energy used in growing and processing the bioenergy feedstock.

(Ch.8, WGIII, IPCC, 2007). With oil prices near an all time high and few alternative fuels for transport, several countries are actively supporting the production of liquid bio fuels. The economic, environmental, and social impacts of biofuels are widely debated. As a renewable energy source, biofuels could help mitigate climate change and reduce dependence on oil in the transportation sector (WDR, 2008).

Ethnol and biodiesel are mostly produced and consumed in Brazil, the USA and Europe. New players are emerging in bio fuel production - biodiesel from palm oil in Indonesia and Malaysia and biodiesel from jatropha, pongamia and other feed stocks in India. There is potential for biofuels in Asia-Pacific region. Indonesia, Malaysia, and the Philippines (see Box 8 on palm oil) have national blending targets for biofuels while India, Thailand are making significant investments in conversion technologies and in expanding the production of key feedstocks. However, its economic viability is being questioned.

Biofuel can accelerate climate change because of burning of forests to clear land for bioenergy crop production. Growth of biofuel sector may lead to water shortages and contamination. Use of sugarcane as a feedstock is particularly water intensive. Some estimates show that rise in bioenergy demand accounted for 30 per cent of weighted average grain prices between 2000 and 2007. A rise in food expenditure for households that are net buyers of food may lead to substitution of starch staples for micro nutrient rich food and increase in malnutrition (FAO, 2010).

Box 8 ***Palm oil, emission reductions, and avoided deforestation***

Palm oil plantations represent the convergence of many current land-use issues. Palm oil is a high-yielding crop with food and biofuel uses, and its cultivation creates opportunities for smallholders. But it infringes on tropical forests and their many benefits, including greenhouse gas mitigation. Cultivation of palm oil has tripled since 1961 to cover 13 million hectares, with most of the expansion in Indonesia and Malaysia and more than half on recently deforested lands. Recent announcements for new palm oil concessions in the Brazilian Amazon, Papua New Guinea, and Madagascar raise concerns that the trend is likely to continue.

Smallholders currently manage 35 to 40 percent of the land under palm oil cultivation in Indonesia and Malaysia, providing a profitable diversification in livelihoods. However, harvested palm nuts must be delivered to mills for processing within 24 hours of harvesting, so holdings tend to cluster around mills. Thus a high proportion of the area around mills is converted to palm oil, either as large tract commercial plantations or densely clustered smallholdings. Certain landscape design practices, such as the creation of agroforestry belts to smooth the transition between palm oil plantations and forest patches, can help make the plantation landscape less inimical to biodiversity while providing further diversification for smallholders.

The mitigation value of biodiesel derived from palm oil is also questionable. Detailed life-cycle analysis shows that the net reduction in carbon emissions depends on the land cover existing before the palm oil plantation (figure). Significant emission reductions derive from plantations developed on previous grasslands and cropland, whereas net emissions will increase greatly if peatland forests are cleared for producing palm oil.

The expansion of the carbon market to include REDD (Reduced Emissions from Deforestation and forest Degradation) is an important tool to balance the relative values of palm oil production and deforestation on one hand, and forest protection on the other. This balance will be critical to ensure biodiversity protection and emission reduction.

Recent studies show that converting land to palm oil production may be between six to ten times more profitable than maintaining the land and receiving payments for carbon credits through REDD, should this mechanism be limited to the voluntary market. If REDD credits are given the same price as carbon credits traded in compliance markets, the profitability of land conservation would increase dramatically, perhaps even exceeding profits from palm oil, making agricultural conversion less attractive. Therefore, done right, REDD could realistically reduce deforestation and thereby contribute to a global mitigation effort.

Sources: WDR (2010) taken from Butler, Koh, and Ghazoul, forthcoming; Henson 2008; Koh, Levang, and Ghazoul, forthcoming; Koh and Wilcove 2009; Venter and others 2009.

FAO (2010) indicates that appropriate policies can make bioenergy development more pro poor and environmentally sustainable. For example, poor farmers can grow energy crops on degraded or marginal land not suitable for food production. Further investment may be needed in developing technologies to convert cellulose to energy, which could provide small holders with a market for crop residues (FAO, 2010).

As discussed above, nearly 60% of the population in Asia and the Pacific region depend on agriculture and, therefore, have significant opportunities to contribute to effective emission reduction strategies. **There are also other advantages like synergizing with adaptation, livelihood strategies and sustainable development**. Moreover, with the establishment of carbon markets, mitigation strategies in agriculture and forestry sector have the potential to generate incomes in the rural areas and thereby increase in adaptive capacity. Global technical mitigation potential in agriculture is high. However, the global estimates should be interpreted with caution as the biophysical capability to sequester carbon will vary across agroecological conditions. It may also be noted that technical mitigation may not be realistic as they do not consider the effects on food security, heterogeneity in management capacity, or the costs of mitigation (Rosegrant et al, 2010). Therefore, economic mitigation potential is generally preferred over technical one.

Economic Mitigation Potential

The economic mitigation potential indicates that overall, opportunities for emission mitigation in the agricultural sector at no or low cost are modest. The economic potential calculations come from two main sources: USEPA (2006 a,b) and Smith et al (2007). Smith et al (2007) estimated global economic potential for agricultural mitigation for 2030 of 1500-1600, 2500-2700, and 4000-4300 MtCO2-eq/yr at carbon prices of up to 20, 50 and 100 US$/tCO2-eq, respectively. The USEPA (2006) provided estimates of the agricultural mitigation potential (global and regional) at various assumed carbon prices, for N2O and CH4 only but not for soil carbon sequestration. Without carbon sequestration, the estimates show that 9%, 12% and 15% of emission could be reduced from the base line at carbon prices of up to $30/tCO2-eq by 2030 respectively in India, China and South and Southeast Asia. China and India could each reduce CH4 emissions from rice fields by 26% over the baseline scenario at low cost (that is less than $15 per ton of CO^2 –eq) by 2020 (ADB and IFPRI, 2009). Expanding mitigation options should include potential from soil carbon sequestration which enhances the economic mitigation potential in Asia. Estimates show that Asia could potentially reduce emissions by 276.79 MT CO2-eq/yr at a carbon price of $20 per ton of CO2-eq, which represents approximately 18% of the total global economic potential (including soil carbon sequestration). The benefit stream from agricultural mitigation in Asia at this price could amount more than $5.5 billion a year (ADB and IFPRI, 2009).

Some of the strategies such as high-yielding crop varieties, shifting to rice and/or wheat production systems, alternating dry/wet irrigation are likely to mitigate emissions and build resilience by conserving water, reducing land requirements, and reducing fossil-fuel use (see Box 9)[11].

Green technologies and Evergreen Revolution

Green technologies are important for adaptation and mitigation. Box 10 provides some discussion on the technologies needed for sustainable agriculture. These should be adopted throughout the value chain: production, processing and marketing.

The need for adopting the methods of an evergreen revolution has become very urgent now. As Swaminathan (2010) mentions, among other things, there are two major pathways to fostering an evergreen revolution. The first is organic farming. Productive organic farming needs considerable research support, particularly in the areas of soil fertility replenishment and plant protection. The other pathway to an evergreen revolution is green agriculture. In this context, ecologically sound practices like conservation farming, integrated pest management, integrated nutrient supply and natural resources conservation are promoted. Green agriculture techniques could also include the cultivation of crop varieties bred through use of recombinant DNA technology if they are good in resisting to biotic and abiotic stresses or have other attributes like improving nutritive quality (Swaminathan, 2010).

Box 9 ***Promising approaches that are good for farmers and good for the environment***

Promising practices

Cultivation practices such as zero-tillage (which involves injecting seeds directly into the soil instead of sowing on ploughed fields) combined with residue management and proper fertilizer use can help to preserve soil moisture, maximize water infiltration, increase carbon storage, minimize nutrient runoff, and raise yields. Now being used on about 2 percent of global arable land, this practice is likely to expand. Zero tillage has mostly been adopted in high-income countries, but is expanding rapidly in countries such as India. In 2005, in the rice–wheat farming system of the Indo-Gangetic plain, farmers adopted zero-tillage on 1.6 million hectares; by 2008, 20–25 percent of the wheat in two Indian states (Haryana and Punjab) was cultivated using minimum tillage. And in Brazil, about 45 percent of cropland is farmed using these practices.

Promising technologies

Precision agriculture techniques for targeted, optimally timed application of the minimum necessary fertilizer and water could help the intensive, high-input farms of high-income countries, Asia, and Latin America to reduce emissions and nutrient runoff, and increase water-use efficiency. New technologies that limit emissions of gaseous nitrogen include controlled-release nitrogen through the deep placement of super granules of fertilizer or the addition of biological inhibitors to fertilizers. Remote sensing technologies for communicating precise information about soil moisture and irrigation needs can eliminate unnecessary application of water. Some of these technologies may remain too expensive for most developing-country farmers (and could require payment schemes for soil carbon conservation or changes in water pricing). But others such as biological inhibitors require no extra labor and improve productivity.

Learning from the past

Another approach building on a technology used by indigenous peoples in the Amazon rain forest could sequester carbon on a huge scale while improving soil productivity. Burning wet crop residues or manure (biomass) at low temperatures in the almost complete absence of oxygen produces biochar, a charcoal-type

[11] Also see Nelson (2009)

solid with a very high carbon content. Biochar is highly stable in soil, locking in the carbon that would otherwise be released by simply burning the biomass or allowing it to decompose. In industrial settings this process transforms half the carbon into biofuel and the other half into biochar. Recent analysis suggests biochar may be able to store carbon for centuries, possibly millennia, and more studies are underway to verify this property.

Sources: WDR (2010) taken from de la Torre, Fajnzylber, and Nash 2008; Derpsch and Friedrich 2009; Erenstein 2009; Erenstein and Laxmi 2008; Lehmann 2007; Wardle, Nilsson, and Zackrisson 2008.

Barriers to Mitigation

There are several barriers to mitigation in agriculture in Asia and the Pacific region. The crop land management, livestock management, reducing deforestation etc. can reduce GHG emissions. Small holders also can benefit from carbon markets. However, increasing carbon stocks or reducing GHG emissions from the land depend on the issue of property rights (Merkelova and Meizen-Dick, 2009). Property rights, land holdings, and the lack of a clear single party land ownership in certain areas may inhibit implementation of management changes (IPCC, 2007). Tenure security for small holders is important if they are to take full advantage of schemes such as carbon sequestration payments. As mitigation markets grow, there is a danger that poor people with insecure property rights will be excluded. Agriculture-based mitigation responses should be designed to include not just the *de jure* owners, but also the users and managers of natural resources with customary rights (Merkelova and Meizen-Dick, 2009).

IPCC (2007) indicates some other possible barriers to implementation of mitigation policies. These are: availability of capital, the rate of capital stock turnover, the rate of technological development, risk attitudes, need for research and outreach, and consistency with traditional practices. Some others include: pressure for competing uses of agricultural land and water, demand for agricultural products and, high costs of certain enabling technologies (e.g. soil tests before fertilization). Ease of compliance also can be one barrier. For example, straw burning is quicker than residue removal and also can control some weeds and diseases and therefore farmers favour straw burning.

Trade-offs between Mitigation strategies and Livelihoods

There can be trade-offs between mitigation measures and livelihoods. It is possible that strategies that try to reduce GHG emissions can hurt livelihoods in agriculture particularly small and marginal farmers. Reducing deforestation can have significant biodiversity, soil and water conservation benefits, but may result in loss of economic welfare for some stakeholders. Appropriately designed forestation and bioenergy plantations can lead to reclamation of degraded land, manage water runoff, retain soil carbon but could compete with land for agriculture and may be negative for biodiversity (IPCC, 2007). As mentioned above, bioenergy may reduce emissions but can threaten livelihoods and food security particularly of the poor. Similarly, many poor small and marginal farmers and landless households depend on livestock for their livelihoods. The mitigation measures on livestock and manure management may harm the livelihoods of the poor. Organic farming can reduce GHG emissions. But, it can reduce productivity, incomes and food security of the farmers and others.

4.3. Climate-Smart Agriculture

FAO (2010a) discusses strategies needed for climate-smart agriculture. *It is defined as agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals.*

It provides examples of climate-smart production systems such as soil and nutrient management, water harvesting and use, pest and disease control, resilient eco systems, genetic resources etc. It also discusses about efficient, harvesting, processing and supply chains. Efficient harvesting and early processing can reduce post-harvest losses and preserves food quantity, quality and nutritional value of the product (FAO, 2010a). This approach also ensures better use of co-products and by-producrs, either as feed for livestock, to produce renewable energy in integrated systems or to improve soil fertility.

The report says that 'there is a need for policies, infrastructures and considerable investments to build the financial and technical capacity of farmers (especially small holders) to enable them to adopt climate-smart practices that could generate economic rural growth and ensure food security" (p.4, FAO, 2010a).

The study provides the following messages for climate-smart agriculture.

- Agriculture in developing countries must undergo a significant transformation in order to meet the related challenges of food security and climate change.
- Effective climate-smart practices already exist and could be implemented in developing country agricultural systems.
- Adopting an ecosystem approach, working at landscape scale and ensuring intersectoral coordination and cooperation is crucial for effective climate change responses.
- Considerable investment is required in filling data and knowledge gaps and in research and development of technologies, methodologies, as well as the conservation and production of suitable varieties and breeds.
- Institutional and financial support will be required to enable smallholders to make the transition to climate-smart agriculture.
- Strengthened institutional capacity will be needed to improve dissemination of climate-smart information and coordinate over large areas and numbers of farmers.
- Greater consistency between agriculture, food security and climate change policy-making must be achieved at national, regional and international levels.
- Available financing, current and projected, are substantially insufficient to meet climate change and food security challenges faced by the agriculture sector.
- Synergistically combining financing from public and private sources, as well as those earmarked for climate change and food security are innovative options to meet the investment requirements of the agricultural sector.
- To be effective in channeling fast-track financing to agriculture, financing mechanisms will need to take sector-specific considerations into account.

Integrating mitigation with adaptation and sustainable development strategies

Integration of pathways of mitigation with those of adaptation and sustainable development is needed to tackle the problems due to climate change. It is known that synergies between adaptation and mitigation strategies exist, but they have to be exploited. Many changes in agricultural and water management practices, as well as crop productivity improvements contribute both to adaptation and mitigation. For example, the strategies include zero or low-till management practices, soil and water conservation techniques, and alternative wetting and drying for rice production. These practices can help environment, improve livelihoods and food security of the region.

The IPCC report (Chapter 8, WGIII, 2007) advocates synergies of mitigation strategies with adaptation and sustainable development. Agriculture mitigation measures often have synergy with sustainable development policies, and many explicitly influence social, economic, and environmental aspects of sustainability. Many options also have co-benefits (improved efficiency, reduced cost, environmental co-benefits) as well as trade-offs (e.g. increasing other forms of pollution) and balancing these effects will be necessary for successful implementation.

It may, however, be noted that the interactions between mitigation and adaptation in the agriculture sector may occur simultaneously but differ in their spatial and geographic characteristics. The main climate change benefits may occur in the long term but adaptation measures may have impact in both short term and long term. It is important to note that in many regions of the Asia-Pacific region, non-climate policies related to macro economics, agriculture and the environment, have a larger impact on agriculture mitigation than climate policies (IPCC, 2007).

Role of Women

Women play important role in both adaptation and mitigation strategies (See Box 10).

Box 10. ***Empowered women improve adaptation and mitigation outcomes***

Women and men experience climate change differently. Climate-change impacts and policies are not gender neutral because of differences in responsibility, vulnerability, and capacity for mitigation and adaptation. Gender-based patterns of vulnerability are shaped by the value of and entitlement to assets, access to financial services, education level, social networks, and participation in local organizations. In some circumstances, women are more vulnerable to climate shocks to livelihoods and physical safety—but there is evidence that in contexts where women and men have equal economic and social rights, disasters do not discriminate. Empowerment and participation of women in decision making can lead to improved environmental and livelihood outcomes that benefit all.

Women's participation in disaster management saves lives

Community welfare before, during, and after extreme climatic events can be improved by including women in disaster preparedness and rehabilitation. Unlike other communities that witnessed numerous deaths, La Masica, Honduras, reported no deaths during and after Hurricane Mitch in 1998. Gender-sensitive community education on early warning systems and hazard management provided by a disaster agency six months before the hurricane contributed to this achievement. Although both men and women participated in hazard management activities, ultimately, women took over the task of continuously monitoring the early warning system. Their enhanced risk awareness and management capacity enabled the municipality to evacuate promptly. Additional lessons from post disaster recovery indicate that putting women in charge of food distribution systems results in less corruption and more equitable food distribution.

Women's participation boosts biodiversity and improves water management

Between 2001 and 2006 the Zammour locality in Tunis saw an increase in vegetal area, biodiversity preservation, and stabilization of eroding lands in the mountainous ecosystem—the result of an antidesertification program that invited women to share their perspectives during consultations, incorporated local women's knowledge of water management, and was implemented by women. The project assessed and applied innovative and effective rainwater collection and preservation methods, such as planting in stone pockets to reduce the evaporation of irrigation water, and planting of local species of fruit trees to stabilize eroded lands.

Women's participation enhances food security and protects forests

In Guatemala, Nicaragua, El Salvador, and Honduras women have planted 400,000 maya nut trees since 2001. Beyond enhanced food security, women and their families can benefit from climate change finance, as the sponsoring Equilibrium Fund pursues carbon-trading opportunities with the United States and Europe. In Zimbabwe, women lead over half of the 800,000 farm households living in communal areas, where women's groups manage forest resources and development projects through tree planting, nursery development, and woodlot ownership and management.

Women represent at least half of the world's agricultural workers, and women and girls remain predominantly responsible for water and firewood collection. Adaptation and mitigation potential, especially in the agriculture and forestry sectors, cannot be fully realized without employing women's expertise in natural resource management, including traditional knowledge and efficiency in using resources.

Women's participation supports public health

In India indigenous peoples know medicinal herbs and shrubs and apply these for therapeutic uses. Indigenous women, as stewards of nature, are particularly knowledgeable and can identify almost 300 useful forest species.

Globally, whether in Central America, North Africa, South Asia, or Southern Africa, gender-sensitive climate change adaptation and mitigation programs show measurable results: women's full participation in decision making can and will save lives, protect fragile natural resources, reduce greenhouse gases, and build resilience for current and future generations. Mechanisms or financing for disaster prevention, adaptation, and mitigation will remain insufficient unless they integrate women's full participation—voices and hands—in design, decision making, and implementation.

Sources: WDR (2010) contributed by Nilufar Ahmad, based on Parikh 2008; Lambrou and Laub 2004; Neumayer and Plumper 2007; Smyth 2005; Aguilar 2006; UNISDR 2007; UNDP 2009; and Martin 1996.

Small Farmers, livelihoods Sustainable Development

Sustainable development basically depends on how small farmers benefit from agriculture, environment, adaptation and mitigation and sustainable development policies. Improving the productivity, profitability and sustainability of smallholder farming is the main pathway out of poverty in using agriculture for development.

Collective action among farmers in input use and marketing is becoming an important form of institutions for agriculture, adaptation due to climate change and sustainable development in several parts of Asia-Pacific region. Examples in Asia are: water user associations, small farmer producer organizations, women's self help groups.

Agriculture mitigation could provide benefits for small farmers. There is a significant potential for small farmers to sequester soil carbon if appropriate policy reforms are implemented. The emerging market for trading carbon emissions offers new possibilities for agriculture to benefit from land uses that sequester carbon. The main obstacle to realizing broader benefits from the main mechanisms for these payments – the clean development mechanism for these payments –the Clean Development Mechanism (CDM) of Kyoto Protocol – is its limited coverage of afforestation and reforestation (Rosegrant et al, 2010). Negotiations for the period after 2012 should correct this major flaw and explore credits for sequestration of carbon in soils, 'green' bio fuels etc. For mitigation, a future climate treaty will need a better incentive structure particularly for small farmers to encourage full participation and compliance. Successful implementation of soil carbon trading would generate significant co-benefits for soil fertility and for long term agricultural productivity (IPCC, 2007). The outcome of international negotiations will have major impact on the role of agriculture in mitigation.

Role of all Stakeholders for Sustainable Development

As discussed in IPCC (2007), making decisions about sustainable development and climate change is no longer the sole purview of governments. There is an increasing recognition that we should have more inclusive concept of governance which includes the concept of governance, which includes the contributions of various levels of government, private sector, non-governmental actors, and civil society. For example, private sector can play an important role in adopting green technologies for agriculture. Similarly, civil society groups have been major demanders of sustainable development and are critical actors in implementing sustainable development policy.

National and Global Level Actions

Climate change policies at the national level are expressed through national action plan for adaptation and national appropriate mitigation actions. Better integration of food security, safety nets, adaptation policies offers the potential to reap significant benefits. At the international level, cooperation is needed regarding technologies and financing.

5. Conclusions and Recommendations

This paper examines the following.

- Provides an account of livelihoods and vulnerabilities of rural people across the Asia-Pacific region.
- Examines the impact of climate change on agriculture and food security.
- Analyses the impact of agriculture on climate change
- Discusses about the adaptation and mitigation practices and policies for reducing the impact of climate change on livelihoods and food security.

The major conclusions of the paper are summarized as follows.

(1) *Livelihoods:* Rural households get livelihoods through agriculture, rural non-farm sector and migration. The sources of livelihoods differ from one country to another Thus, agriculture is the major source of livelihood in many Asia-Pacific countries but several countries have substantial share of rural non-farm sector also. Migration is an important source of income in rural areas for several countries.

(2) *Vulnerability* : It is high for many areas and population in the Asia-Pacific region. The IPCC defines vulnerability as a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. Within countries, there are many areas which are vulnerable to climate change. Livelihoods are more vulnerable in mountainous areas like Himalayas, arid and semi-arid areas like Pakistan and India, vast coastal areas in South, South East Asia and pacific islands and forest areas in the region. Small Islands are extremely vulnerable due to high exposure of population and agricultural infrastructure to sea level rise (e.g. Maldives) and increased storms. Poor and vulnerable groups are women, children, indigenous people, coastal dwellers, mountainous population and island dwellers. Indigenous population forms the most vulnerable group due to climate change.

(3) Impact of Climate Change on Agriculture and food security
The impact of observed changes in climate trends, variability and extreme events show that the crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events. Recent studies on projections have suggested that substantial decline in cereal production potential in Asia could be likely by the end of this century due to climate change. However, crop yields could increase in some regions due to climate change. Results of crop yield projections show that crop yields could increase up to 20% in East and South-East Asia while they could decrease up to 30% in Central and South Asia by the mid-21st century. Estimates of malnourished children based on various scenarios for the countries in the Asia-Pacific region show that for the region as a whole, there is a significant increase in malnourished children of about 14 to 16% in 2050 due to climate change without CO2 fertilization.

(4) *Impact of agriculture on climate change*: Agriculture is both problem and solution for climate change. Agriculture activities release significant amounts of green house gas (GHG) emissions into the atmosphere. In 2000, agriculture's share of total GHGs was 13%. If we add land use changes, agriculture contributes to around 30% of global GHGs. Asian region accounts for 37% of the world's total emissions from agricultural production. China alone accounts for more than 18% of the total GHGs.

(5) *Adaptation Practices and Opportunities*: The paper discusses the adaptation practices and the opportunities in the region. The Fourth Assessment Report (IPCC, 2007) summarizes more common adaptation measures that have been identified in several studies. Countries in the Asia –Pacific region have long history of coping with extreme changes in weather. These coping strategies would be useful to have long term adaptation strategies. However, inspite of some commonalities, the coping strategies and indigenous knowledge vary by sub-region, country and provinces which are given in the paper. The paper argues for innovative adaptation measures and integrating important ongoing development initiatives for strengthening adaptation measures.

(6) Mitigation measures and Opportunities: Agricultural mitigation can make farming more resilient to the vagaries of climate change and can also indirectly helps in reducing adverse impact on hunger and poverty. IPCC report (2007) indicates that there are variety of options for mitigation of GHG emissions in agriculture and forestry. Nearly 60% of the population in Asia and the Pacific region depend on agriculture and, therefore, have significant opportunities to contribute to effective emission reduction strategies. There are also other advantages like synergizing with adaptation, livelihood strategies and sustainable development. Moreover, with the establishment of carbon markets, mitigation strategies in agriculture and forestry sector have the potential to generate incomes in the rural areas and thereby increase in adaptive capacity.

Policy Recommendations

(i) Focus on Small Farmers, vulnerable areas and population: Asia-Pacific region is a land of small farmers. In order to have climate change sensitive and pro-poor policies, there is a need to focus on small farmers. The policies include : (a) Improve price incentives and increase the quantity and quality of public investment; (b) Make product markets work better; (c) Improve access to financial services and reduce exposure to uninsured risks; (d) Enhance the performance of producer organizations; (f) Promote innovation through science and technology; (g) Make agriculture more sustainable and a provider of environment services.

Agriculture mitigation could provide benefits for small farmers. There is a significant potential for small farmers to sequester soil carbon if appropriate policy reforms are implemented. The emerging market for trading carbon emissions offers new possibilities for agriculture to benefit from land uses that sequester carbon.

The importance of collective action in climate change adaptation and mitigation is recognized. Research and practice have shown that collective action institutions are very important for technology transfer in agriculture and natural resource management among small holders and resource dependent communities. For example, Asia-Pacific region has many producer organizations of small farmers. They should be expanded and strengthened all over the region to improve agricultural productivity, water management, better market access etc. Small holder groups can also facilitate effective implementation of PES schemes focused on carbon sequestration.

Although all countries in Asia-Pacific region are affected by climate change, there is a need for additional focus on vulnerable countries, areas and population. The targeted assistance on adaptation and mitigation investments should be given to the most vulnerable to climate change. Asia-Pacific region has large share of environmentally poor. These poor are concentrated in upland areas, dry land areas, flood-affected wet land areas, coastal areas and slum areas. There is a need to have specific policies on these vulnerable areas and poor.

Apart from location specific policies, social protection measures can help vulnerable and the poor. Responding to the shocks and vulnerabilities of the poor and marginalized through social policy has been one of the major functions of the governments all over the world. Policies related to social protection assume importance in this context, as they would directly deliver support to the needy. By now it is recognized that presence of social protection can maintain social cohesion and can improve or prevent irreversible losses of human capital. Social protection programmes thus also contribute to promotion of human development. Recent research has shown risk and vulnerability justification should be added since the poor do not have formal instruments for risk mitigation and coping. All over Asia-Pacific region, there are many social protection programmes. They can be used as adaptation policies. For example, India's public works programme National Rural Employment Guarantee Scheme is an important one which can be an important adaptation and mitigation policy as it also improved assets in agriculture and rural areas

(ii) Need to focus on climate-smart agriculture, green agriculture and rural non-farm activities: Agriculture is a major source of livelihoods in the Asia-Pacific region as 60% of the population depends on it. The analysis in this paper showed that Climate change would have negative effects on agriculture yields including food crops. The effects on agriculture and food systems would directly affect the primary income source and livelihoods and food security of billions of people in the region. The climate change would also increase food prices. It would have adverse effect on food security particularly on human development represented by nutrition levels in the paper. Due to all the negative effects, all the stakeholders particularly the governments have to focus on reducing the negative effects of climate change by focusing on agriculture and forestry sector. *Climate-smart and green agriculture practices have to be followed without hurting the food security and livelihoods of the population particularly the poor. Among others, promotion of organic farming and practicing green agriculture are two major pathways for evergreen revolution.*

In order to have climate-smart and green and sustainable agriculture, there is a need to improve national research and extension programmes.

Inspite of large differences in climates across countries, the differences in prices are relatively small. International trade in agriculture could be one of the reasons for this result. However, when prices rise, many countries adopt to protection policies like export bans which can hurt the poor countries. Therefore, there is a need to promote trade to compensate the effects of climate change like increase in food prices.

Agriculture alone cannot sustain livelihoods in future. There is a need to shift workers to rural non-agricultural activities. Apart from rural manufacturing and services, non-distress migration can be one option. Infrastructure, credit, technology, services in rural areas should be strengthened to promote rural non-farm activities.

One of the policy implication of the studies on climate change and malnutrition is to invest in improving agricultural productivity and non-agricultural activities like roads, female education and clean drinking water. The analysis also shows that investing in improving agricultural productivity is not enough and investments have to be made in education and clean drinking water in order to have impact on nutrition.

(iii) Opportunities for Adaptation: There are many local coping strategies in several parts of Asia-Pacific region. However, these are not enough. It may be noted that public policy has important role in facilitating adaptation to climate change. Planning for adaptation and implementing well-targeted adaptation policies will require resources beyond the capacity of most governments in developing countries. Investments and incentives to create and provide improved technology and management techniques are necessary. In order to reduce vulnerability to climate change, important ongoing development initiatives need to be strengthened. But, neither autonomous adaptation policies by private sector or individuals nor development policies by the public sector would be sufficient to enable the developing countries in Asia and Pacific region to adapt climate change. Adaptation will require innovative policies.

Important ongoing development activities that should be strengthened in Asia and the Pacific include providing secure property rights for farmers, continuing agricultural market development, reforming distorting trade and agricultural input and output price support policies, strengthening environment policies, enhancing social protection and providing micro finance and disaster protection.

The IPCC report says that effective adaptation and adaptive capacity in Asia, particularly in developing countries, will continue to be limited by several ecological, social and economic, technical and political constraints including spatial and temporal uncertainties associated with forecasts of regional climate, low level of awareness among decision makers of the local and regional impacts of El Nino, limited national capacities in climate monitoring and forecasting, and lack of coordination in the formulation of responses.

It may be noted that poverty is identified as the largest barrier to developing the capacity to cope and adapt. Insufficient information and knowledge on the impacts of climate change and responses of natural systems to climate change will continue to hamper effective adaptation particularly in Asia. It is also likely that in countries of Asia facing pervasive poverty, hunger, terrorism, serious domestic conflicts, epidemics and other pressing and urgent concerns, there is going to be less attention on the issues relating to climate change and the need to implement adaptation. The slow change in political and institutional landscape in response to climate change and the existing legal and institutional framework in most Asian countries remains inadequate to facilitate implementation of adaptation.

As suggested by Stren (2007) some measures could be useful to address some of the constraints mentioned above and strengthen adaptation in Asia. These include: improving access to high quality information about the impacts of climate change; reducing the vulnerability of livelihoods and infrastructure to climate change; promoting good governance including responsible policy and decision making; empowering communities and other local stakeholders so that they participate actively in vulnerability assessment and implementation of adaptation; adaptation and vulnerability assessment by setting in place early warning systems and information distribution systems to enhance disaster preparedness; mainstreaming climate change into development planning at all scales, levels and sectors.

Migration can be one of the adaptation practices. International migration and migration within countries are going to increase with climate change. Asia and the Pacific ranks amongst the global regions that are projected to be most impacted by climate change. If properly managed, climate-induced migration could actually facilitate human adaptation, creating new opportunities for dislocated populations in less vulnerable environments. Significant funding will be required to utilize migration as an adjustment or coping mechanism in the face of climate change. Migration-related adaptation within poorer countries will require transfer of resources—human, technological, and financial—from better-off countries and the international community.

(iv) Opportunities for Mitigation:

The most prominent options for mitigation 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.

Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency. Lower but still significant mitigation is possible with improved water and rice management; set-asides, land use change (e.g. conversion of crop land to grassland).

Many mitigation opportunities use current technologies and can be implemented immediately, but technological development will be a key driver ensuring the efficacy of additional mitigation measures in the future. Technologies to improve yields would useful.

Mitigation options for forestry sector include: Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use. Technologies include: tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change.

There are also other advantages like synergizing with adaptation, livelihood strategies and sustainable development. Moreover, with the establishment of carbon markets, mitigation strategies in agriculture and forestry sector have the potential to generate incomes in the rural areas and thereby increase in adaptive capacity.

There are opportunities in the three categories of mitigation strategies viz., carbon sequestration into soils, on-farm emission reductions and emission displacements from the transport sector through biofuel production.

It is known that synergies between adaptation and mitigation strategies exist, but they have to be exploited. Many changes in agricultural and water management practices, as well as crop productivity improvements contribute both to adaptation and mitigation. For example, the strategies include zero or low-till management practices, soil and water conservation techniques, and alternative wetting and drying for rice production. These practices can help environment, improve livelihoods and food security of the region. Women play important role in both adaptation and mitigation strategies

It is also important to note that in many regions of Asia-Pacific region, non-climate policies related to macro economics, agriculture and the environment, have a larger impact on agriculture mitigation than climate policies.

(v) Regional and International Cooperation: Another important policy is to improve regional cooperation among governments in Asia and the Pacific region. This cooperation has to address the climate change issues by ensuring effective implementation of national adaptation and mitigation strategies, and of current and future funding mechanisms to address climate change. Apart from regional cooperation initiatives like CACILM (Central Asian Countries Initiatives for Land Management) and GMS (Greater Mekong Sub-region), regional organizations like ASEAN (Association of South East Asian Nations) and SAARC (South Asian Association for Regional Cooperation) should play important roles in technology and knowledge transfer (ADB, 2009). For example, the regional initiatives can focus on agriculture and food security, livelihoods and ecosystem services as all of these contribute to mitigation and adaptation of climate change.

For solving climate change related problems, global cooperation is important. At the international level, new mechanisms have to be devised to provide a range of public goods including climate information, forecasting, research and development of crops adapted to new weather patterns, and techniques to reduce land degradation (WDR, 2010). The Clean Development Mechanism (CDM) of the Kyoto Protocol has its limited coverage of afforestation and deforestation. Deforestation has to be included as it contributes nearly a fifth of global GHG emissions. Carbon financing has to be extended beyond sector mitigation to land-use programmes such as grasslands restoration and forest conservation that offer benefits to the poor. We have to incorporate agricultural adaptation and mitigation in the international climate change negotiations. It provides opportunities for financing and provide technologies for adaptation and mitigation particularly for vulnerable population and areas in developing countries.

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