Trends of Impacts of Climate Change in Agriculture Sector in South Asia

Climate Action Network South Asia

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Content Outline

1. Introduction

Climate change has emerged as a threat to the entire globe and the Intergovernmental Panel on Climate Change (IPCC) has iterated that it needed immediate action to prevent it otherwise it would lead to mass destruction (IPCC, 2007). A majority of nations, particularly developing nations, of the world have been affected and their economic growth has also been devastated by the impacts of climate change. According to the IPCC, climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2001). Therefore climate change is partly due to the natural variability and partly due to the human activity. There have been drastic changes in the patterns of climate in the last half century like immediately increases in temperature after 70's (IPCC, 2001) which can be attributed to human activities like emitting green house gasses (GHGs) into the atmosphere that are responsible for most of the warming of at least last 50 years (IPCC, 2001). Evidences suggest that climate change is affecting a large number of people across South Asia in different ways. This includes increased variability in both monsoon and winter rainfall pattern; increase in average temperature, with warmer winters; increased salinity in coastal areas, as a result of rising sea level and reduced discharge from major rivers; weakening ecosystems; the recession of glaciers in the Himalayas; and increased frequency and/or severity of extreme weather events (floods, cyclones and droughts). The region is particularly vulnerable to climate change owing to high population density, concentrated poverty, and existing climate variability. Climate change has the potential to compound the prevailing development problems and increase pressure on key resources needed to sustain growth (Sterrett, 2011; Abbas, 2009).

South Asia is still home to a predominantly rural population with more than 70 per cent of its people living in villages despite rising migration to urban centers and climate change is predicted to have severe consequences on agriculture and the rural poor in South Asia (Oxfam GB, 2009). The IPCC Fourth Assessment Report (FAR) predicts that global temperature is expected to increase in the range 2.4 to 6.4°C by the year 2100 (IPCC, 2007). Meanwhile, the global temperature had already increased 0.7°C in the twentieth century, but in the last 30 years it had raised 0.2°C per decade (Stern, 2006). Similarly the earlier predictions of IPCC said that the sea level would be rising in the range 9 to 88 cm by 2100 (IPCC, 2001). However the recent estimations by IPCC conclude that it was sea level increase was up to 0.26 to 0.59 cm (IPCC, 2007). Meanwhile, the global average sea level had also risen by 1.88 mm per year over the period 1961-2003 (IPCC, 2007).

This phenomenon will affect the developing countries disproportionately high due to three reasons: (i) geographical region (ii) high dependence on natural resources such as agriculture, and (iii) availability of less resource for adaptation (Stern, 2006). The impacts of climate change are closely with the concepts of vulnerability and adaptation. Vulnerability has been treated as a

starting point analysis and thereby adaptation is considered as the ability of the society to cope with the current extreme events (O'Brien *et al.*, 2004). During the 1980's, at the nuance period of the climate change research, the term like adaptation has emerged into the climate change research as an important issue. Adaptation is the adjustment in ecological, social, and economic systems in response to actual or expected climate stimuli and their effects or impacts (McCarthy *et al.*, 2001: 881). This term refers to the change in the process, practices, or structures to moderate the potential impacts of the climate change and also enjoying the opportunity associated with the change in the climatic system. It is expected that adaptation will reduce the vulnerability of the groups, communities, and regions to the impacts of the climate change.

1.1 Objectives of the Study

There is a limited understanding of the nature of impacts of climate change on various sectors that affect the livelihoods of the people of South Asia and how communities should adapt. Further, policy issues of the climate risk management are not limited to the issue of adaptation alone, but have to be scrutinized in the context of development (Pielke, 2007). The people of South Asia have been living with a changing environment for centuries, but now the changes are likely to be rapid, more frequent and pro-longed. The lack of data and the uncertainties associated with climate change and its dynamic nature has hampered our understanding. Agriculture being the main stay of South Asian economy and livelihood of the people, there is an imminent threat to the food security of the region. Given this background, this desk study attempts to:

(a) Analyze most recent impacts of climatic variations on ecosystems and implications on agriculture and its relation to food security
(b) Assess the impact on regional food security due to potential mitigation co-benefits
(c) Identify the various linkages of agriculture sector with adaptation planning in the region and recommend how the gaps can be addressed

1.2 Approach & Analysis

For examining the objectives described in the previous section, the paper employs a descriptive approach. Firstly, a rigorous review of literature is undertaken to gather an understanding of the recent impacts of climatic variation on agriculture and food security in the region. Secondly, the study attempts to examine select cases of adaptation interventions that have been tried out as risk mitigation options in the South Asian context at the national, regional and community level and thirdly tables some of the key challenges and constraints in this context.

2. Impacts of Climate Change in South Asia

The impacts of climate change affect the basic livelihood, livelihood patterns in the society and eco-systems i.e. billions of people face shortages of food and water, forced migration, increased risk of flooding, health problem, reduced commercial fish production, salt water intrusion, loss of infrastructure and loss of agricultural productivity as well as land. These affected sectors are fostering serious economic crisis and political wrangling within and across the countries. The issue of climate change considered as a serious environmental problem in comparison to other emerging global challenges because its impacts are trans-boundary representing a risk to the present as well as the future generations to survive now and forever.

Decreases in precipitation by the end of the 21st century for the northern and southern sub-tropics (IPCC, 2007) are predicted by more than 90 per cent of climate model simulations. Increases in precipitation extremes are also very likely in the major agricultural production areas of Southern and Eastern Asia (Christensen *et al.*, 2007). Table 1 summarizes the impacts of hydro meteorological climate change over the South Asian region.

Table 1: Summary of Hydro-meteorological Climate Change Impact in South Asia

Countries / Parameters	Temperature	Precipitation	River flow
India	• Warming at the rate of 0.48 °C over the last 100 years • Not a single year since 1993 when annual mean temperature was less than the normal • Projections show a temperature rise of 2.5°C to 4.9°C over the end of the 21st century	• Over all, the hydrological cycle is predicted to be more intense, with higher annual average rainfall as well increased drought • Summer monsoon rainfall over: a) Western Ganga Plain (GP): increasing trend (170 mm/100 yrs) from 1900. It is predicted that the rainy days will decrease b) Central GP it shows decreasing trend (5 mm/100 yrs) c) Eastern GP: decreasing trend (50 mm/100 yrs) during 1900-84 and increasing trend (480 mm/100 yrs) during 1984-99 d) Models show a maximum expected increase in precipitation	• Flows likely to be extremely high during the summer monsoon periods in the Ganga Basin • Snow melt water provides more than 85% of the winter flows in the Ganga • The present contribution is projected to reduce to about 30% over the next 50 years

		over central India (10 to 30%)	
Nepal	• Average temperature increasing at the rate of 0.06°C per year • The temperature in the Himalayas, however, is increasing at a faster rate	• Increased variability in both monsoon and winter rainfall patterns. Daily rainfall will become more erratic and intense • The eastern mid-hills will show a general increase in rainfall. Where as in the western mid-hills a general decrease is projected • The central Tarai will see a marked increase in the rainfall with prediction of around 10 to 20% • The rainfall pattern in the mid mountains will depend upon the microclimate and is difficult to be generalized	• Analysis of mean monthly river discharge show global warming would melt snow cover on the mountain tops earlier, thus shifting the peak discharge month from August to July changing the regional hydrology of the Ganga and its major tributaries • These changes are likely to impact on glacial lakes and their breach with major local impacts • Faster melting of glaciers could lead to increased flooding as well as more pronounced variations in water availability throughout the year
Pakistan	• A 3°C to 5°C overall increase in temperature over the next century • Temperature increases in both summer and winter are higher in Northern Pakistan than in Southern Pakistan • Whereas Temperature increase in Northern and Southern Pakistan are higher in winter than summer	• Increased variability of monsoon • The southern regions of the country are likely to get increased rainfall (up to 20%) where as the northern regions will experience decreased rainfall (5%)	• Glaciers contribute more than 60% of the Upper Indus Basin's flow • Studies indicate conflicting findings regarding the impact of global climate change on glaciers in Pakistan • Upper Indus Basin will see a 15% reduction in annual flow and a considerable change in intra-annual flow will be observed
Bangladesh	• Geographically part of the larger South Asian land mass the projection of	• The hydrological cycle will be more erratic with uneven, intense rainfall. It is likely that rainfall will be deficit and	• The impact of changing river flows is likely to be significant as more than 90% of flow originates outside the country

	warming rate for Bangladesh would similar to that of India	contribute to increased instances of drought	territory. The result is frequent floods and low flow condition which is likely to adversely impact the saline and fresh water balance along the coast • Cyclone and storms are likely to become more intense
Source: ISET (2008)			

Long-term changes in temperature and precipitation have direct impacts on yield. Moreover, resilience is typically low in rural areas as the existing asset base is limited, and services are often insufficient. Agriculture in South Asia is heavily reliant on the monsoons, which account for more than 70 per cent of the region's annual precipitation. Given that approximately three-fifths of the cultivated area in South Asia is rain-fed, the onset, duration, spatial extent, and total precipitation of the monsoon are critical factors in determining the livelihoods of large majority of people in rural areas. Global warming is likely to affect all these factors. For example, in India, monsoonal rainfall has decreased by approximately 5 to 8 per cent since the 1950s, and this pattern may have contributed to more intense, longer, and more widespread droughts across the region, as illustrated by the recent droughts of Rajasthan and Madhya Pradesh in India and the Sindh and Baluchistan provinces in Pakistan (Oxfam GB, 2009).

Floods, droughts, and cyclones, which already have a massive impact on South Asia, are likely to become more severe and/or more frequent across the region as a result of climate change (Parry *et al.*, 2007). In India, the area affected by floods more than doubled in the 50 years between 1953 and 2003. In Bangladesh, 60 per cent of the country is already flood prone. The 2010 floods in Pakistan affected 20 million people and were the worst in the region since 1929. With its heavy reliance on the monsoons and snow-fed rivers, water availability in South Asia is highly sensitive to climate change. In the short term, the retreating glaciers in the Himalayas will increase the risk of flood, due to extensive runoffs in the main South Asian rivers. However, in the long term, there can be no replacement for the water provided by the glaciers and their retreat could result in water shortage at an unprecedented scale, with a steep decrease in annual river flows. The Himalayan glaciers are the source of nine of the largest rivers in Asia. The Ganges, Brahmaputra, and Indus river basins practically feed over half a billion people. These people are heavily dependent on agriculture and fisheries, both of which will be negatively impacted by a reduction in freshwater availability. This could also seriously jeopardise food security for millions across South Asia (Oxfam GB, 2009).

2.1 Impact on Agriculture and Food Security

Agriculture is the mainstay of several countries in South Asia and is also one of the largest sources of employment. The sector continues to be the single largest contributor to the GDP in the region. As three-fifth of the cropped area is rain-fed, the economy of South Asia hinges critically on the annual success of the monsoons, indicative of the well-being of millions. In the event of a failure, the worst affected are the landless and the poor whose sole source of income is from agriculture and its allied activities. However, there has been striking differences in growth performance across countries. With 19 per cent contribution to the country's GDP, agriculture in India employs two-thirds of the national workforce in the country. Serving as a major livelihood resource in the country, the sector plays a critical role in defining poverty levels across different states in the country (TERI, 2007). Contribution of the agricultural sector to the GDP in other South Asian countries are also similar to that in India except in Nepal where the dependence is far higher. The sector is also the largest consumer of water in the region further sensitive to the consequences of a changing climate. In India alone, more than 85 per cent of the available water is used for irrigation purposes.

High growth rates in the agriculture sector represent Pakistan as one of the high growth rate countries in the region. Correspondingly, Pakistan has observed a decline in rural poverty from 49 to 32 per cent over the time period 1969 to 1998 (Haq, 2003). Bhutan and Nepal have fragile mountainous ecosystems. Bangladesh and Sri Lanka have low-lying coastal areas. India and Pakistan depend heavily on cultivation in drought prone arid and semiarid lands. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001) pointed out that climate change and its variability will exacerbate existing vulnerabilities to droughts and floods in Asia. The livelihoods and economic activities in South Asia are closely tied to the natural resource base, and are hence, highly sensitive to changes in the climate. In view of the findings of IPCC (2001), agriculture and aquaculture will be threatened by a combination of thermal and water stresses, sea level rise, increased flooding, and strong winds associated with intense tropical cyclones. Freshwater availability and biodiversity, which are already under pressure due to population growth and land use change, will be further impacted by climate change.

Temperature rise will adversely impact rice and wheat yields in tropical parts of South Asia where these crops are already being grown close to their temperature tolerance threshold. While direct impacts are associated with rise in temperatures, indirect impacts due to water availability and changing soil moisture status and pest and disease incidence are likely to be felt. The most significant impacts are likely to be borne by small-holder rain-fed farmers who constitute the majority of farmers in this region and possess low financial and technical capacity to adapt to climate variability and change. 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 Niño* and reduction in the number of rainy days

(Aggarwala and Frankhauser. 2008). Results of recent studies suggest that substantial decreases in cereal production potential in Asia could be likely by the end of this century as a consequence of climate change. However, regional differences in the response of wheat, maize and rice yields to projected climate change could likely be significant (Parry *et al.*, 2004; Rosenzweig and Perry, 1994). Results of crop yield projection using HadCM2 indicate that crop yields could likely increase up to 20 per cent in East and South-East Asia while it could decrease up to 30 per cent in Central and South Asia even if the direct positive physiological effects of CO_2 are taken into account. For the warming projections under A1FI emission scenarios, decreases in crop yields by 2.5 to 10 per cent in 2020s and 5 to 30 per cent in 2050s have been projected in parts of Asia (Parry *et al.*, 2004). Wheat yields in central India may drop by 2 per cent in a pessimistic climate change scenario (GoI, 2004). Kumar and Parikh (2001) show that even after accounting for farm level adaptation, a 2°C rise in mean temperature and a 7 per cent increase in mean precipitation will reduce net revenues by 8.4 per cent in India. The major food grain producing regions of Haryana, Punjab and western Uttar Pradesh experience the most negative effects, along with the coastal districts of Tamil Nadu. Punjab and Haryana are significant from the perspective of food security in India, but they also face severe depletion of groundwater resources due to intensive cultivation techniques.

An increase in average temperature in Pakistan would translate into much higher ambient temperatures in the wheat planting and growing stages. Higher temperatures are likely to result in decline in yields, mainly due to the shortening of the crop life cycle especially the grain filling period. Wheat yields are predicted to decline by 6-9 per cent in sub-humid, semiarid, and arid areas with 1°C increase in temperature (Sultana and Ali, 2006), while even a 0.3°C decadal rise could have a severe impact on important cash crops like cotton, mango, and sugarcane (MoE, 2003). Half a degree temperature rise is predicted to reduce rice output by 6 per cent, and increased dryness will adversely affect yields of key products like tea, rubber, and coconut (MENR, 2000). In the warm, semi-arid regions, deficiency of moisture would be a major constraint. Most cropping activities for e.g., coarse grain, legumes, vegetables, and potato are likely to be affected adversely due to the impacts of climate change. The highest negative impact is estimated for coarse grains and coconut production. An increase in the frequency of droughts and extreme rainfall events could result in a decline in tea yield, which would be the greatest in regions below 600 meters (Kelkar and Bhadwal, 2007). With the tea industry in Sri Lanka being a major source of foreign exchange and a significant source of income for labourers the impacts are likely to be grave. Changes in monsoon rainfall pattern and increase in maximum air temperature are two key factors on the variability of coconut production in the principal coconut growing regions. The projected coconut production after 2040 in all climate scenarios, when other external factors are non-limiting, will not be sufficient to cater the local consumption for the increased population. Among the different stakeholders in coconut industry, the coconut oil (CNO) industry would be most affected (Kelkar and Bhadwal, 2007).

Karim and Ahmed (1996) predict a net negative effect on the yields of rice, the staple food of the population, in Bangladesh. On an average during the period 1962-1988, Bangladesh lost about 0.5 million tonnes of rice annually as a result of floods that accounts for nearly 30 per cent of the country's average annual food grain imports (Paul and Rashid 1993). In Bhutan, upland crop production, practised close to the margins of viable production, can be highly sensitive to variations in climate. Climate change will cause the cultivating zone to shift upwards to unsuitable steep slopes. It is also expected to increase the severity and frequency of monsoonal storms and flooding in the Himalayas, which could aggravate the occurrence of landslides (Kelkar and Bhadwal, 2007). In addition to the danger to life and property, some of the generated sediments may be deposited in the agricultural lands or in irrigation canals and streams, which will contribute to deterioration in crop production and in the quality of agricultural lands (NEC, 2000). The overall impacts of climate change on food production for the South Asian region is summarized in Table 2.

Table 2: Impact of Climate Change on Food Production in the South Asian region

Country	Impacts
India	For 2.5°C, yield loss for rice & wheat between 32 and 40% and for 4.9 °C yield losses between 41 and 52%
Nepal	Majority of the households do not produce sufficient food. They migrate in search of livelihood. Climate change will bring significant effect on production. So far, the deficit has been met by food purchased. Climatic change may disrupt the distribution too
Pakistan	Agricultural yield losses of 6–9% for wheat with a 1°C increase in temperature
Bangladesh	A 4°C temperature increase could reduce rice production by 30% and wheat production by 50%
Source: ISET (2008)	

2.2 Impact on Water Sector

IPCC observes that the greatest vulnerability to climate change is in unsustainably managed ecosystems that are currently water stressed. By 2050, the annual runoff in the Brahmaputra is projected to decline by 14 per cent, and that in the Indus by 27 per cent (IPCC, 2001), which will have tremendous downstream consequences. Increased warming might result in increased flows initially with reduced flows later as the glacier disappears. Available records suggest that Gangotri glacier is retreating by about 30 m/yr. A warming is likely to increase melting far more rapidly than accumulation. Glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in glacier fed river systems for a few decades, followed by a reduction in flow as the glaciers disappear. India, Bhutan and Nepal are concerned about the reduction in flow of snow-fed rivers, while Maldives is threatened by saltwater intrusion into freshwater. In Pakistan, a 6 per cent decrease in rainfall will increase the net irrigation requirement for wheat by 29 per cent (Kelkar and Bhadwal, 2007).

Water availability in Bhutan is heavily dependent on heavy rainfall, glaciers or snow, land use practices, and user demand. A reduction in the average flow of snow-fed rivers, combined with an increase in peak flows and sediment yield, would have major impacts on hydropower generation, urban water supply, and agriculture. An increase in rainfall intensity may increase run-off, enhance soil erosion, and accelerate sedimentation in the existing water supplies or reservoirs. Floods in Bangladesh are mainly caused by intense monsoon precipitation over the basin areas of the Ganges, Brahmaputra and Meghna (GBM) rivers. Kelkar and Bhadwal (2007) point out that future changes in precipitation regime have four distinct implications: (i) the timing of occurrence of floods may change, with a possible change in the seasonality of the hydrological cycle, (ii) increased precipitation in the GBM basins may increase the magnitude, depth, and spatial extent of floods, (iii) timing of peaking in the major rivers may also change that may change the likelihood of synchronization of flood peaks of major rivers and (iv) increased magnitude, depth, extent and duration of floods will bring a dramatic change in land-use patterns in Bangladesh.

Out of the 2,323 glacial lakes in Nepal, 20 have been found to be potentially dangerous with respect to glacial lake outburst floods The most significant such event occurred in 1985, when a glacial lake outburst flood caused a 10-15 metre high surge of water and debris to flood down the Bhote Koshi and Dudh Koshi rivers for 90 km, destroying the Namche Small Hydro Project (Raut, 2006). For Pakistan, Omar (2007) concluded that the total annual run-off from the upper basin is likely to increase by 11 per cent to 16 per cent. It is estimated that although increased run-off could be advantageous for water supply and hydropower production it could aggravate problems of flooding, water logging, and salinity in the upper basin. Also, even with an overall water surplus, shortages might occur in local areas of the highly productive Punjab rice–wheat zone and in the unglaciated valleys of the upper basin. These areas currently lack adequate storage, conveyance, and irrigation management. Studies also indicate a negative impact on cotton, detrimental to the economy as it is the main cash crop of Pakistan and also indicate that much of the water from heavy rainfall events in Sri Lanka would be lost as run-off to the sea (Kelkar and Bhadwal, 2007).

In view of these observations it is increasingly evident that the impacts of climate change will be a concern for the economies in the South Asian region in the coming decades, especially with regards to the agriculture and water sector. As the countries struggle to achieve the developmental goals, climate change mitigation also assumes significance from the point of view of ensuring food security for the increasing population in these regions and ensuring sustainable development.

3. Climate Change Impacts and Mitigation Co-Benefits

As described in the preceding section, agriculture provides the main source of livelihood for the people in the South Asian region and hence maintaining and improving agricultural productivity is critical to achieving food security. Further, agriculture also contributes a significant share (14 per cent) of greenhouse gas (GHG) emissions, more if related land-use change (particularly deforestation) is included (WRI, 2010) and hence contributing for global warming and climate change. At the same time, impacts of climate change like long-term changes in average temperatures, precipitation, and climate variability threaten agricultural production and food security leading to the vulnerability of the livelihoods of the people. The IPCC fourth assessment report (IPCC, 2007) also observes that while mitigation of GHG emissions can lessen the impact of climate change, adaptation to climate change will be essential to ensure food security and protect the livelihoods. Many of the measures aimed at reducing GHG emissions have other impacts on the productivity and environmental integrity of agricultural ecosystems, which are mostly positive; however, these measures are often adopted mainly for reasons other than GHG mitigation. The technical mitigation potential of agriculture is high and 70 per cent of this potential could be realized in developing countries (FAO, 2009).

It is also observed that most agriculture mitigation options have a positive impact on water resources and management and improved cropland and grazing management can increase water storage and infiltration, reducing loss through runoff and leading to greater water availability in the soil and enhancing ecosystem water balance respectively (FAO, 2009). Additionally, conservation agriculture reduces evaporation from the soil, especially in drier environments. Since the combined water loss through runoff and evaporation often leaves less than half of the rainfall (or irrigated water) available for crops, the adoption of these technologies can increase crop yields and food production (FAO, 2009). Other technologies that are explicitly related to water management include: water conservation and harvesting and efficient irrigation can increase the soil carbon pool (FAO, 2008). Terraces and contour farming also have big impacts on water, providing for storage of rainfall and discharging excess runoff through a drainage system (WOCAT, 2007). Other practices which lead to an increase or stabilization of water quality are with regards to technologies that sequester carbon in grassland soils tend to maximize vegetative cover and reduce water induced erosion and sediment load (FAO, 2009). Enhanced soil moisture should also reduce vulnerability to low rainfall and drought conditions, thus increasing the capacity of farming systems to adapt to climate change.

With regards to the agricultural sector there exist many synergies and tradeoffs between agricultural adaptation, climate change mitigation, and impacts on productivity and food security. The co-benefits and trade-offs of a practice may vary from place to place because of differences in climate, soil, or the way the practice is adopted (IPCC, 2007). Practices that maintain or increase crop productivity can improve regional food security and this co-benefit may become more

important as global food demands increase in coming decades (IPCC, 2007; Follett *et al.*, 2005; Sanchez and Swaminathan, 2005). Specific examples of co-benefits and tradeoffs among agricultural management practices and food security practiced in the South Asian region are presented in Table 3.

Table 3: Agricultural Management Practices practiced in South Asian region and impact on regional food security and potential mitigation co-benefits

Agricultural Management Options	Resilience and Adaptation Practices	Impacts on Food Security and Productivity and Mitigation Co-Benefits
Cropland Management	Improved crop varieties	• Increased crop yield and reduced yield variability • Increased resilience against climate change, particularly increases in climate variability (prolonged periods of drought, seasonal shifts in rainfall, and the like)
	Changing planting dates	• Reduced likelihood of crop failure and maintained production under changing rainfall patterns, such as changes in the timing of rains or erratic rainfall patterns
	Improved crop / fallow rotation / rotation with legumes	• Increased soil fertility and yields over the medium to long term due to nitrogen fixing in soils; short-term losses due to reduced cropping intensity • Improved soil fertility and water holding capacity increases resilience to climate change
	Appropriate use of fertilizer and manure	• Higher yields due to appropriate use of fertilizer / manure • Improved productivity increases resilience to climate change; potential greater yield variability with frequent droughts
	Incorporation of crop residues	• Higher yields due to improved soil fertility and water retention in soils; tradeoff with use as animal feed • Improved soil fertility and water-holding capacity increases resilience to climate change
	Reduced or zero tillage	• Increased yields over the long term due to greater water-holding capacity of soils; limited impacts in the short term; tradeoff in terms of weed management and potential water logging. • Improved soil fertility and water-holding capacity increases resilience to climate change
	Agro-forestry	• Greater yields on adjacent cropland due to

		improved rainwater management and reduced erosion • Increased resilience to climate change due to improved soil conditions and water management; benefits in terms of livelihood diversification
Water Management	Irrigation and water harvesting	• Higher yields, greater intensity of land use. • Reduced production variability and greater climate resilience when systems are well designed and maintained
	Bunds	• Higher yields due to increased soil moisture; potentially lower yields during periods of high rainfall • Reduced yield variability in dry areas; potential increase in production loss due to heavy rains if bunds are constructed to retain moisture
	Terraces	• Higher yields due to increased soil moisture and reduced erosion; potential to displace some cropland • Reduced yield variability under climate change due to better soil quality and rainwater management
Source: IFPRI (2011); FAO (2009)		

Many of these options overlap with those proposed for adaptation to climate change and these increase system resilience, decrease output variability due to climate variability and extreme climate events and reduce impacts of climate events on food production enhancing food security. Adaptation not only increases the resilience of the vulnerable to the impacts of climate change, but it also offers co-benefits in terms of agricultural mitigation and productivity. Many of the same practices that increase resilience to climate change also increase agricultural productivity and profitability and reduce GHG emissions from agriculture. However, tradeoffs exist between increasing farm productivity and profitability, adaptation to climate change, and mitigation of GHGs.

4. Adaptation to Climate Change in South Asia

Adaptive capacity is the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change (McCarthy *et al*, 2001: 881). Adaptation refers both to the process of adapting and to the condition of being adapted. Adaptation is also considered as an importance response strategy along with mitigation in the climate policy, which are not mutually exclusive to each other, but they may be complementary to each other (Pielke, 1998; Pielke *et al.*, 2007). The Kyoto protocol (article 10) also commits parties to promote and facilitate adaptation and deploy adaptation technologies to address climate change. It has different meaning in accordance with the discipline: as in ecology, it means change in the change in the systems of the organisms and species so that they can fit with the current environment; and in social science, it means adjustment in the behaviour of the socio-economic systems. In the broader perspective, it means adjustment in the natural and the socio-economic systems in response to experienced or future climatic conditions.

Adaptation can be pro-active and reactive; it may be at international, national, local and individual level. Most often the adaptation decisions are focused on policy decisions regarding implementation of subsidies or the introduction of new techniques and building some pro-active measures as the building of dykes, irrigation, water storage capacity and flood protection etc. In addition, the adaptation options involve change in the behaviour of the affected households such as switching of crops, livelihood diversification and migration. There are two broad levels of adaptation: building adaptive capacity– creating the information and conditions (regulatory, institutional, and managerial) that are needed to support adaptation, and delivering adaptation actions – taking steps that will help to reduce vulnerability to climate risks or to exploit opportunities, planting different crops and altering the timing of crop planting (Stern, 2006). In particular, in the context of climate change, it is viewed in two ways: assessment of impacts and vulnerability (what adaptations are likely), and development and evaluation of policy response (what adaptations are recommended) (Smit *et al.*, 2009; McCarthy *et al.*, 2001). Understanding expected adaptation is essential to impact and vulnerability assessment and hence it is fundamental to estimating the costs and risks of the climate change.

At the national level, countries in South Asia have developed their own National Adaptation Programmes of Action (NAPA) like Bangladesh in 2005 and Nepal in 2010. Several countries have also developed national climate change strategies and action plans, including the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), the National Climate Change Adaptation for Sri Lanka 2011-2016, the National Action Plan on Climate Change in India, and the draft National Climate Change Policy in Pakistan. However it needs to be documented how these plans and policies have contributed in enhancing adaptation at a macro level.

Bangladesh completed its Initial National Communication on Climate Change in 2002 and since then has developed a NAPA (in 2005), and has also developed a National Climate Change Strategy and Action Plan (2008), which outlines a comprehensive strategy and plan of action for tackling climate change. One of the pillars of this plan is aimed towards food security, social protection, and health. The aim here is to ensure that the poorest and most vulnerable in society, including women and children, are protected from climate change and that all programmes focus on the needs of this group for food security, safe housing, employment, and access to basic services, including health. At a national level, India completed its Initial National Communication in 2004, and has since been actively involved in the UNFCCC negotiations. In 2008, the government released its first National Action Plan on Climate Change, which outlines existing and future policies and programmes aimed at addressing mitigation and adaptation issues. Identifying eight core 'national missions', including missions related to adaptation, it emphasises India's overall goal of maintaining high economic growth while also addressing climate change (GoI, 2006).

Nepal in 2010 finalised its NAPA, which set out the country's strategy and action plan to respond to the challenges and opportunities posed by climate change. This is developed in a consultative manner, with a focus on knowledge management, and planning and stakeholder consultation. Alongside the NAPA, the local adaptation plan of action (LAPA) has been developed with an aim to providing action at a more localised level (Ministry of Environment Nepal, 2010). Similarly, Pakistan has been involved in the UNFCCC processes since 1992. In April 2011, after two years of deliberations, the government approved the first draft national climate change policy.

Kelkar and Bhadwal (2007) observe that conditions worsen with reduced capacity of human systems to cope with changes. Many countries in South Asia vulnerable to the changes in the climate are also under pressure due to high rates of population growth, poor living conditions and deeply embedded poverty. Similarly, they mention that the communities most vulnerable to impacts are the poorest in the society and that climate change hinders the prospects of their development in the absence of proactive adaptation. With regards to India, O'Brien *et al.*, (2004) observe higher degrees of adaptive capacity in districts falling in the Indo-Gangetic plains (except for Bihar) and lower degrees of adaptive capacity in the interior regions of the country, including districts in Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka. Further, community-level case studies carried out in highly vulnerable districts of India brought out the wide disparities in adaptive capacity across villages, across communities in villages, and specifically across individuals depending on land holding size, education, caste, etc. While larger farmers are able to benefit from government subsidies (e.g. for drip irrigation), formal bank credit, crop insurance, and access to larger markets, smaller farmers are disadvantaged due to lack of information and dependence on local merchants for credit (TERI, 2007).

In view of this it must also be recognized that there are wide disparities in the capacity to adapt across regions and countries in South Asia and that access to adaptation options is severely

constrained by economic resources, technological factors, access to information and skills, infrastructure, and institutions. With this background, Table 4 lists the various interventions undertaken in the South Asian countries to generate climate change adaptation.

Table 4: Examples of Climate Change Adaptation Interventions in South Asia

Changes	Sectors	Intervention Examples
Increase in temperature	Agriculture	a) Introduction of short cropping varieties b) Diversification of crops c) Introduction of heat / moisture tolerant seed varieties d) Increase soil organic content / low tillage agriculture e) Water conservation crop management practices f) Tree planting to provide shade and fodder for livestock
	Water resources	a) Introduction of water storage methods b) Water conservation c) Monitoring and early warning systems for glacial lake outburst floods (GLOFs) d) Conservations of coastal mangroves and other vegetation
Changes in rainfall patterns and / or seasonality	Agriculture	a) Appropriate, accessible, and reliable seasonal and weather forecasts b) Crop diversifications and crop mixing c) Livelihood diversification d) Crop insurance e) Floating gardens during times of inundation
	Water	a) Rainwater harvesting at household level b) Checks on dams and plantations c) Improved drainage d) Protected/raised food, water, and sanitation e) Community water management committees
Sea level rise	Coastal livelihoods / resources	a) Introduction of salt tolerant crops / species b) Livelihood diversification c) Monitoring and early warning systems for cyclones and storm surges d) Sea defences e) Protected / raised food, water, and sanitation f) Mangrove rehabilitation
Source: Sterrett, 2011		

4.1 Adaptation Interventions in Bangladesh

- The Tidal River Management (TRM) programme is in vogue in the waterlogged, deltaic, and low-lying areas of southwest Bangladesh for generations and while it was not originally conceived as a way to adapt to climate change the technique employed may offer hope for

communities as risk of sea level rise in similar areas. This is a community-driven process and hence those involved must work together and agree to set aside each area of land for the TRM process to take place and not use the earmarked area for any other purpose. During this time the landowners will not be able to use this area and may have to be compensated. Consultations within communities and landowners have helped in the implementation of this adaptation approach.

- The Reducing Vulnerability to Climate Change (RVCC) project implemented between 2002 and 2005 in six districts in southwest Bangladesh, an area that is already affected by climate change has some useful pointers. The project was designed to reduce community vulnerability to climate change by promoting sustainable development and building local-level capacity. This project was the first of its kind, and is credited with coining the term 'community-based adaptation'. It was also the forerunner to participatory vulnerability approaches to climate change. The south-west region of Bangladesh faces problems of water logging caused by the combined effect of siltation of estuary branches, higher river bed levels, reduced sedimentation in flood protected areas, and impeded drainage, exacerbated by heavy rainfall and sea level rise. This adversely affects available agricultural land, impacting food production, soil productivity, and agricultural livelihoods. In Subarnabad village in south-west Bangladesh, the initiatives promoted in the project focus on new livelihood strategies for income and food generation. These include goat, duck, and hen rearing, chicken and crab farming, tree planting, introduction of salt-water tolerant vegetable gardens and handicraft production. Raising awareness about climate change, personal hygiene, sanitation, and the construction of latrines and deep tube wells is also one of the key aspects of the project. Villagers are also able to access loans to establish small crab farming enterprises. While these initiatives are still in the early stages, villagers have been able to slowly pay off their loans and have begun to make some profits, and have also encouraged others to venture into these livelihood activities. A key conclusion from the project was that when the awareness activities targeted in areas where a certain project is being undertaken results in better integration and reinforcement of ideas and involving members of the target audience in the development of communication tools could improve the relevance of the materials and messages (Kelkar and Bhadwal, 2007; Sterrett, 2011) .

- The Assistance to Local Communities on climate change adaptation (CCA) and Disaster Risk programme was implemented during 2008–2010 in 12 villages that were experiencing a range of problems, including droughts, floods, cyclones, sea level rise, and saline intrusion. This programme focused on a range of issues, such as the importance of local knowledge, access to and control over resources, and the role of local institutions. The key goal of the programme was to generate critical knowledge on the effectiveness of structural and non-structural community-based intervention, and the feasibility of expanding these to a national level. Through the programme a wide variety of adaptation

options were put on test including: (i) Water and sanitation, using tube wells, ring wells, pond excavation, and climate-friendly latrines, (ii) DRR, involving plinth-raising of homesteads and early warning systems, (iii) Livelihood support: distribution of livestock, such as sheep, goats and ducks, vegetable seeds and fruit tree seedlings, and handloom mills, (iv) Training of para-vets on vegetable growing and climate change for local politicians, government officials, and journalists, and (v) Climate-resilient cluster villages and handloom factory.

- In Bangladesh, adaptation interventions in general intend to address food insecurity and food production shortfalls by crop diversification and generation of other employment opportunities aiming at community development, agricultural development, credit facilities, and infrastructure improvement. One very successful intervention in the country has been the fish and shrimp production for domestic consumption and exports that are promoted with special emphasis on rural poverty alleviation and employment generation. This is done by improving the capacity of local users to manage aquatic resources in a sustainable and equitable way thereby conserving aquatic biodiversity. All these developmental programmes play an important role in enhancing the resilience of the poor. Rain water harvesting and integrated development of watersheds in rain fed areas help in increasing agricultural resilience to erratic weather events under a climate change scenario. Additionally, at a more macro level, policies and plans can seek to improve production and distribution systems to cope with fluctuations in crop yield. New technologies and practices are more readily acceptable to farming communities if well ingrained in the indigenous system. Therefore modified traditional methods for conservation of natural resources could be adopted to cope with these changes.

- The floating agriculture practice is a good and popular practice of the low-lying areas where lands remains submerged most of the year. People in Bangladesh have been practicing floating agriculture since a long time (three to four hundred years). It is a useful method considering the economical, environmental and as well as social aspects. The production rate is high from this kind of agricultural practice. First, during monsoons, when most of the land is flooded, floating agriculture is the only alternative method of cultivation. In the monsoon (mainly during June-August), farmers cultivate ladies finger (okra), cucumber, snake gourds etc. on the floating system. After the monsoon, farmers use this for cultivating spinach, aurum, spices and several other vegetables. During the monsoon, farmers use small boats to manage the floating agricultural land. Second during the winter season, farmers carry the floating bed to higher grounds where they break it and mix it with the soil to enrich the soil.

- Sharing losses is potentially a good adaptation strategy, already occurring informally within extended families or in the sense of international disaster relief and rehabilitation in

Bangladesh (Ahmed, 2006) but these are not satisfactory long term sustainable options for the poor, while micro-insurance is unavailable to most (Khan, 2007).

4.2 Adaptation Interventions in India

- Vulnerability assessment and enhancing adaptive capacity to climate change programme in India focuses on the semi-arid regions of India that are vulnerable to droughts and increasingly erratic rainfall, with the overall goal of securing rural livelihoods among poor and vulnerable communities by promoting measures that enhance their adaptive capacity and disaster preparedness. A number of pilot interventions have been undertaken in key livelihood sectors, with a view to informing and catalysing policy dialogue at different levels using the emerging field experiences as an evidence base to link practice with policy and vice versa. One of the programme's features is collaboration among various actors with complementary strengths. One of the successful Community Based Adaptation (CBA) project implemented by M.S. Swaminathan Research Foundation (MSSRF) in the semi-arid regions of India demonstrated the need for integrating science with local knowledge and the importance of a multi-pronged approach focusing on key adaptation interventions like (i) System of Rice Intensification (SRI), (ii) water resource management, (iii) Pasture land development, (iv) weather-based farming models for communities, and (v) strengthening of community-based institutions.

- Improved rice cultivation by using the System of Rice Intensification (SRI) that can increase rice harvests by 50-100%; direct-seeded rice to allow more reliable establishment of *rabi* crops on residual moisture immediately after the rice harvest, such as Chickpea or mustard, drought-tolerant and high-value crops; cultivation of early-maturing rice varieties; drought tolerant rice varieties have been seen as important adaptation strategies in rice growing areas of India.

- Water conservation is another important adaptation to an increasingly drought-prone environment. In Rajasthan, India concrete rainwater cisterns about 3- 4metres wide and 4 metres deep collect surface water from channels which run into the cistern in the rainy season have been built. Additionally rainwater '*bunds*' which are earth walls 1-2 metres in heights, built round fields following the contour lines, help to prevent soil erosion from wind and rain, as well as help to hold water in the soil by preventing rainwater from flowing away (Chadburn, 2007)

- The Sundarbans Programme in West Bengal was initiated in 2005 and works in three major, albeit non-exclusive thematic areas: biodiversity conservation, climate change and energy, and sustainable livelihoods. The programme has three main objectives: develop better understanding of current and future challenges; implement pilot projects to

demonstrate what works and how and raise awareness of issues in order to influence policy and incorporate pressing concerns into development planning. The programme has had a number of concrete achievements in the communities like: (i) Establishment of a knowledge centre, (ii) Introduction of climate-resilient agricultural and piscicultural practices, (iii) Disaster relief shelter and (iv) Early warning and disaster response teams. In the Sundarbans, India a combination of intra-dependent rice, duck, fish and *azolla* cultivation that provide food/nutrients for each other has proved successful as well as a general diversification of crops to improve community resilience (Das, 2009)

- There are several other initiatives undertaken by Government of India under the National Climate Resilient Agriculture Programme (NICRA) as part of the National Agriculture Mission of the National Action Plan on Climate Change. Under this programme substantial investments have been made to facilitate R&D work that would enhance the adaptive conditions of specific crop varieties and also strengthen the delivery of climate related information and extension services across the country through a network of more than 100 key institutes.

4.3 Adaptation Interventions in Nepal

- The Local Adaptation Programme of Action is one of seven pilot projects implemented under the LAPA programme. LAPA is not only a programme but an operational plan that identifies the adaptation priorities of climate vulnerable households and communities, as well as the preferred delivery agents (service and technology providers), and complements national scale planning initiatives, such as the NAPA. The project enabled communities to work together to achieve sustainable development outcomes. The unit of operation was at the watershed level, which was important, as the problems facing communities – whether they are upstream or downstream – are linked at this level.

- Adapting to changing seasons and flash flooding project took place over a period of three years from 2004 to 2007 in one watershed in the south-western area of the lesser Himalayan foothills, and focused on 200 households. The majority of the population living in the area are dependent on natural resources and the monsoons for their livelihoods, which is mainly subsistence, although many families work outside the area (either in waged labour elsewhere in Nepal or overseas) to meet their needs. Among the activities that were undertaken, three areas were prioritised: (i) Social networks, (ii) Awareness-raising, and (iii) Participatory technology development.

- Improving livestock rearing productivity undertaken in a number of places as a climate change adaptation measure, in Nepal where improved breeds of goats are being promoted. Livestock provide food, income and drought security. It is observed that local breeds are

hardy, but low in productivity, so cross breeding with non-native breed has maintained resilience, yet at the same time increased meat and milk production.

4.4 Adaptation Interventions in Pakistan

- The CBA and Advocacy programme aimed to enhance the capacity of coastal and rural communities to adapt to climate change through: (i) Support for improved availability of fresh water for consumption and agriculture, (ii) Support to small-scale farmers with appropriate practices for agriculture, (iii) Investigation in options for reducing the impact of salinity on agricultural production, and (iv) Support to communities to reduce the impacts of floods and cyclones. The project was initiated after Oxfam undertook community-based research in 2008 aimed at better understanding the implications of climate change for communities living in the Badin coastal region. The project area covers two disaster-prone villages, Mohammad Ali Chandio and Village Khamoon Mullah, in the Union Council of Bhugra Memon in Tehsil and District Badin.

- A three-year project on desert and flood plain adaptation was undertaken with 300 poor and vulnerable households in two ecological zones in the Punjab region, the former rangelands of the Thal desert region and the floodplains of the Chenab River. As the project focused on rural communities, the technologies predominantly consisted of alternative agricultural practices. These included the following: (i) Identifying alternative crops in partnership with local experts, government, academic and civil society stakeholders. Each variety was selected for its ability to tolerate drought and flood conditions and its positive impact on soil stability, (ii) Establishing tree plantations from local species. In total, 60,000 tree saplings were planted by participating households, (iii) Focusing on female farmers by helping them to diversify their incomes from the traditional cash crops of wheat, rice, and sugarcane through the introduction of good quality vegetable seeds that were planted in each of the project sites and over the duration of the project. However, this strategy was not without its problems in the Thal project site, with damage to crops from lizards and termites, a lack of experience in growing vegetables, and poorer weather and soil conditions affecting the success of some of the interventions, (iv) Training women on alternative livelihood options, such as veterinary services and (v) Setting up a demonstration site to raise community awareness of livestock management techniques, organic vegetable farming, and the importance of NRM. However, this site was not maintained during the whole project owing to a lack of interest from the community.

4.5 Adaptation Interventions in Sri Lanka

- Adapting agriculture to increasing salinity project took place over a period of three years, working with 500 households to help them to identify traditional rice varieties suitable for cultivation in degraded paddies through a participatory research process. The project also

worked to extend community and institutional knowledge of climate change. The community were able to reach a consensus over the main challenges posed by climate change to community livelihoods, through a process of participatory research. The project sought to reduce the risks of crop failure and unprofitable yields through developing a strategy aimed at building capacity on resource use and management by seeking to establish and replicate best practices in crop cultivation. This was done mainly by training paddy farmer groups, which were mobilised to adopt and develop sustainable practices.

Some other successful adaptation interventions relate to the Mandarin production in Bhutan is severely affected by long dry spells in the flowering season, to counter which bamboos are used for drip irrigation (as a modified version of polythene pipe drip irrigation). Similarly in northeast India, bamboo pipes are used to divert stream and spring water to irrigate plantations. Other examples are cage aquaculture in household ponds and waterlogged areas in Bangladesh, ploughing fields in the Indian hills in the early morning before dew or fog has evaporated, use of a type of grass ("*pang*") to line water tanks and irrigation channels to control seepage, and storage of seeds in cow dung in the Andamans (Kelkar and Bhadwal, 2007; IPCC 2007).

The most crucial gaps identified are: the problem of institutionalizing the approach to climate change adaptation; the translation and implementation of national policies to local level; and the task of integrated climate action planning. The region has plenty of successful adaptation examples across varied ecosystems. There is no single adaptation option that could solve the problem of a particular location or sector. Adaptation is about a portfolio of options. Finding the right entry points for a specific location is critical. From the experiences of different countries in the region there is so much to learn and share. The future of adaptation in the region depends on the ability to synergize the past, sometimes more traditional approaches with modern technology and science. Much depends on the ability to provide right kind of forecasts, weather information, early warnings and appropriate and timely extension services to manage climate risks. Institutions matter most and it is not the agenda of the communities to manage and it is pertinent that the capacities of the institutions have to be built to rise up to the occasion.

5. Conclusion

Climate change is going to impose significant stress on existing resources throughout the South Asian region. It is likely to increase the severity of extreme events with the river basins experiencing constant water scarcity thereby increasing the vulnerability of regions and the people. The population in these regions will also be susceptible to greater risk due to the dependence on climate sensitive sector like agriculture for their living. The impacts of climate change on food security, access to water and agriculture will have severe implications for the achievement of sustainable development. Further, as the economy continues to grow and development benefits reach to the different sections of the society the vulnerability concerns will intensify due to higher levels of exposure. It poses a challenge for the policy makers to design policy which can simultaneously reduce the exposure and increase the adaptive capacity of the people to buffer the impacts of climate change.

Accurate scientific information, database management and dissemination are essential to plan adaptation measures and formulate and implement adaptation policies. There is also a need to link adaptation initiatives in disaster risk reduction and management and mainstreaming climate policy into the regular developmental and governmental activities both at a national and local level. Local governments and institutions along with the private sector can also play an important role in implementing programmes concerning adaptation to climate change in all South Asian countries. Adequate devolution of power to the local governments while maintaining a synergy between the state and the society can be helpful in capacity building at a local level and prioritizing climate change adaptation in the development interventions undertaken by them. The private sector is also involved in a big way in the agriculture sector and hence options to attract investment in designing of adaptive processes and providing innovative solutions need to be explored and streamlined.

The National Action Plans of the countries in South Asia addresses the adaptation concerns at a national level and forms the guiding document. With regards to India, initiatives like the National Action Plan on Climate Change (NAPCC) and the State Actions Plans aim at integrating mitigation and adaptation challenges with the country's development objectives. However, adaptation efforts in these countries have so far been fragmented, lacking a strong link between national climate change strategies, plans, and existing disaster risk reduction, agricultural, and other relevant policies (Sterrett, 2011). For example the various action plans for India are implemented through key organizations and stakeholders and hence the success of the objectives under these requires mainstreaming climate change adaptation in these. Moreover, on a sub national level it is observed that present coping capacity may be very limited particularly for small farmers, rural communities eking out precarious livelihoods dependent on natural resources, urban poor living in marginalized conditions, women and children. There are several good practices and policies that need to be scaled up. While government programmes in these sectors address issues relevant for

strengthening adaptive capacity to climate change, they do not as yet explicitly incorporate the increased risks due to climate change. In view of this some of the gaps that are observed in the current scenario pertain to: (i) lack of information on climate impacts and vulnerability assessment in some of the region's most vulnerable areas that are hotspots of climate change, (ii) lack of information on hydro-geological changes and water management in hot spots, (iii) identifying factors that enable and constrain autonomous adaptation and the cost effectiveness of adaptation interventions, (iv) role of financial mechanisms in spreading risk (risk sharing strategies and social networks), and (v) capacity-building and knowledge management.

Forums like the South Asian Association for Regional Cooperation (SAARC) can provide a platform to promote regional cooperation among South Asian countries to address issues related to climate change adaptation. Currently there is very minimum effort from SAARC on this front. Further, since we are still learning about adaptation and its practices in different countries documentation and shared learning become important. This includes not only documentation of successful adaptation interventions but also documentation cases of mal-adaptation. It is also important to identify the differences in capacity-building within and among different stakeholders, devise common framework to monitor and evaluate climate change adaptation and undertake cross country comparisons.

In the last few years, though some moderate strides have been made towards agriculture's inclusion on the official climate change policy agenda still there are huge gaps in terms of gathering / extending appropriate climate impact related information, understanding of the issues, documentation of evidences to substantiate arguments put forth to achieve mitigation and adaptation goals in the context of agriculture from the developing countries perspective. This paper has made an attempt to highlight some of the progress made in the agricultural adaptation as well as point to the gaps in the South Asian context.

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