Adapting South Asian Agriculture to Changing Climate and Declining Land Resources

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Introduction

South Asia, home to almost one-fourth of human population, is one of the fastest growing regions of the world. The per-capita GDP has increased from US$ 790 in 2001 to US$ 1282 in 2010. Population of the region increased at more than 2.0 percent annually during 2005-10. Almost one third of the people now live in urban areas. The region has experienced a large growth in agriculture during last few decades; food grain production has increased from 172 million tons (m t) in 1970 to more than 400 m t in 2010. In the same period milk production has increased from 32 m t to 172 m t, and meat from 3.7 m t to 17.6 m t. The exceptional increase in production has been achieved through high-yielding varieties and improved management practices. Government policies, institutional arrangements and infrastructural development significantly contributed in transforming the agri-food system of South Asian countries. However, the contribution of agriculture to Gross Domestic Product in South Asia has decreased to 14-25% depending upon the country; due to the phenomenal growth in other sectors of the economy such as services and industry.

Despite such impressive progress in food production, South Asia remains home for 42% of world's poor, 25% of the world's hungry and 40% of the world's malnourished children and women, about a third higher than figures for Sub-Sahara Africa. Achieving the Millennium Development Goals has remained a daunting task for most of the countries in this region. The majority of poor and under-nourished lives in rural areas and depends on agriculture for food and livelihoods. The South Asia region continues to be ranked very low on most indicators. The

Human Development Index values are, for example, 138 for Nepal, 129 for Bangladesh, 125 for Pakistan and 119 for India. The region is characterized as alarming to serious with respect to indicators of under-nourishment and child malnutrition. The Global Hunger Index score for South Asia has marginally declined from 23.5 in 2001 to 22.6 in 2011 while in Sub-Sahara Africa the decline was from 23.8 to 20.5 over the same period. These indicators suggest a paradox... The impressive economic growth and remarkable increase in food production have not contributed to alleviating poverty and reducing hunger. This reveals that economic and agricultural development excluded the deprived population. Therefore, future growth strategies should include sustainable agricultural development.

The South Asian population is predicted to increase by almost 700 million people in the next 40 years. This, accompanied with rising per capita income, and urbanization will lead to an increase in demand for food grains and a gradual shift of expenditure from cereals to meat, milk, fish and other animal products. It is estimated that by 2030, the food grain requirements in South Asia will be almost 35% more than the current demand (Kumar et al., 2009). On the other hand, the large population and agricultural pressure on land in South Asia has been very demanding on natural resources, especially water and land, and has resulted in their degradation over time. The additional food will have to be produced from the same or even shrinking land resources due to increasing competition for land from the non-agricultural sectors. The tasks of alleviating poverty and attaining food security at the household and sub-national/regional level are thus major challenges. Climate change is likely to compound the problem further.

All countries of South Asia frequently experiences natural climatic extremes and disasters. Bangladesh, parts of India and Sri Lanka are low-lying coastal areas prone to cyclones, sea-level rise, and floods. Bhutan, Nepal, India and Pakistan have several mountain ecosystems that are vulnerable to glacier melt. Semi-arid and arid parts of India, Afghanistan, Pakistan and Bangladesh frequently experience heat and drought stress leading to considerable production variability. A detailed analysis by Attri and Tyagi (2010) for the period 1901-2009 showed an increasing trend of mean annual temperature of 0.56°C per 100 years. The authors also indicated that there was a much higher increase in post monsoon and winter seasons (0.7°C to 0.77 °C/100 years) as compared to monsoon (0.33 °C/100 years) and pre-monsoon season (0.64 °C/100 years). Annual rainfall over India does not show any clear trends; however, the winter season rainfall shows a decreasing trend, and the post-monsoon season shows an increasing trend. The frequency of extreme rainfall also shows an increasing trend during the southwest monsoon season (Attri and Tyagi, 2010). This is accompanied by a decreasing trend in smaller rainfall events.

IPCC has projected that the global mean annual surface air temperature increase by the end of this century is likely to be in the range of 1.8 to 4.0°C (IPCC, 2007a). For South Asia, the projections are 0.5 to 1.2^{o}C rise in mean annual temperature by 2020, 0.88 to 3.16^{o}C by 2050 and 1.56 to 5.44^{o}C by 2080 depending upon the scenario of future development (IPCC, 2007b). Overall, the temperature increases are likely to be much higher in winter season than in monsoon season. It is very likely that hot extremes, heat waves, and heavy precipitation events will become more frequent. The projected sea-level rise by the end of this century is likely to be 0.18 to 0.59 meters.

Several studies have shown that, unless it adapts, South Asia could lose 10-40% of crop production by the end of the century due to global warming, despite the beneficial aspects of increased CO_2 (Aggarwal, 2009; Nelson et al., 2009; Knox et al., 2011). In fact, there is some evidence that changing climate has already impacted rice and apple yields. Projections indicate the possibility of losing of 4-5 million tons of wheat production with every rise of 1^oC temperature throughout the growing period (Aggarwal, 2009). Recent simulation analysis has indicated that rainfed maize, sorghum and paddy yields are likely to be adversely affected by the increase in temperature, although increased rainfall and change in management practices can partly offset those losses (Kattarkandi et. al., 2010; Srivastava et al., 2010 and Palanisami et al., 2011).

The projected increase in drought and flood events could result in greater instability in food production and threaten the livelihood security of farmers. The IPCC has indicated significant increases in runoff in many parts of the world, including South Asia due to global warming (IPCC, 2007b). This, however, may not be very beneficial because the increase is largely in the wet season, and the extra water may not be available in the dry season, when needed, unless storage infrastructure is vastly expanded. It may, in fact, lead to increase in frequency and duration of floods. Remote sensing has indicated that several monsoon influenced glaciers are retreating (Scherler et al., 2011) which could further change the runoff scenario. These glaciers are a major source of water for the rivers such as the Indus, Ganga and Brahmaputra in the Indo-Gangetic plains.

Considering the potential impacts of climate change; current state of natural resources and the demand for producing more in such difficult environments, it is important to develop appropriate adaptation strategies. The latter need to take a number of factors into consideration, including globalization, population and income growth, and the resulting changes in food preferences and demand, current state of agricultural production resources, as well as the socioeconomic and environmental consequences of alternative adaptation options. These strategies should be climate smart taking care of not only adaptation but also resilience, mitigation and sustainable intensification (FAO, 2010). Several technological options such as greater use of biotechnology for developing climate-ready crops, hotspot mapping, agricultural diversification, mainstreaming indigenous knowledge, and greater investment in agricultural research have been proposed for adaptation to climate change. Detailed discussion on these in the context of South Asia can be found in literature, including Easterling et al., 2007; FAO, 2008; Aggarwal and Sivakumar, 2010, and Varshney et al., 2011. Some of the policy and institutional strategies needed to address the current state of declining resources and climatic variability as well as progressive climate change are discussed below.

Management of land resources

Land availability per person has drastically decreased in the last few decades due to the rapid rate of population growth. In India, for example, per-capita land availability has decreased from 0.91

ha in 1950 to about 0.32 ha in 2001 compared to the world average of 2.19 ha (NAAS, 2009). Per-capita net sown area has also decreased from 0.33 ha in 1950 to 0.14 ha in 2001 and is projected to decrease to 0.09 ha by 2050. The situation is still worse in extremely densely populated Bangladesh.

In recent times, food insecurity has increased in several regions due to competing claims for land, water, labour, and capital, leading to increased need to improve production per unit of resource. Rapid urbanisation and industrialisation in the last two decades have removed some very productive lands and good-quality irrigation water for agriculture. This has led to increased environmental pressures, compounded by variable and changing climate. Such trends have resulted in fragmentation and decline in size of land holdings leading to inefficiency in agriculture and rise in unemployment, underemployment, and low volume of marketable surplus and therefore, increased vulnerability to global change. Smallholdings limit economies of scale – in procuring inputs and marketing outputs. Transaction costs increase on both production and marketing due to tiny holdings and small marketable surplus. At the same time, almost 60-80% of the price the consumer pays goes to cover costs related to transportation, loading, unloading, storage, wastage, overheads, middleman's profits, etc. Institutional arrangements, such as cooperatives and contract farming that can bring small and marginal farmers together for increasing production and marketing efficiencies, and reduce the long supply chains are needed (Prowse, 2012). Some innovative institutional arrangements are emerging, such as collective or cooperative or contract farming. The successful example of 'Amul' in India is widely cited for cooperative milk production and marketing. Similarly, the poultry sector in India grew by more than 10% per annum mainly due to contract farming with the formal sector. In Bangladesh, the Pran Group of Industries is contracting farmers for milk, fruits and vegetables. The Group processes and sells labeled and branded products. The overall transaction costs were reduced through contract farming by over 90% in dairy, 70-90% in vegetables, and 60% in poultry (Joshi et al 2007). Such institutional innovations need to be up-scaled for sharing the benefits of emerging opportunities with the farmers. Such farming practices have shorter supply chains, and an added advantage of these could be reduced GHG emissions in the future. The latter, however, needs careful assessment because there could be some trade-offs if the supply chain requires refrigerated food storage. Land reform is needed in all the South Asian countries for accelerating agricultural growth and tapping the new opportunities using such cooperative and contract farming approaches.

A large proportion of land in South Asia is affected by some form of degradation. It is estimated that almost 55 million hectare are affected by water erosion, 24 Mha by wind erosion, 80 Mha by desertification, 17 Mha by salinization, 12 Mha by waterlogging, 11 Mha by nutrient depletion and large area by ground water depletion caused by excessive withdrawal for irrigation (Lal, 2007). In addition, there has been a large-scale decline in organic matter and increasing salinity in the Indo-Gangetic plains of South Asia. Such land degradation causes a decline in the quantity and quality of fresh water supplies, and soil productivity leading to greater food insecurities, increased poverty and higher social costs. Land degradation causes about $10 billion loss to South Asia annually. Droughts and flash floods associated with climate change are likely to intensify in South Asia, leading to further land degradation, loss in human well-being, and impacts on food security. Restoration of degraded soils, therefore, has to be a priority which involves afforestation, establishment of pastures and planted fallows, and watershed management. It is estimated that 18 to 35 Tg C/yr can be sequestered by restoration of degraded soils in South Asia (Lal, 2004; 2007). These estimates are of attainable potentials provided the appropriate policies to encourage this are in place. Conservation agricultural practices have been shown to be of large significance in increasing the productivity of land, restricting land degradation, and promoting carbon sequestration (Govaerts et al., 2009). Laser land leveling is another option that improves water and nutrient use efficiencies in irrigated areas. The major problem in its large-scale adoption in South Asia is small landholdings. Though the custom-hire service has become common in western Indo-Gangetic Plain, it is yet to be take-off in eastern Indo-Gangetic Plain. The key constraint is field bunds in place for demarcating farmers' land boundaries as the laser machine removes them. Remote sensing applications in such demarcations may solve the associated problems.

Agro-forestry, especially horticulture based, is another important option that can be used to restore degraded lands and enhance farm profitability and to increase environmental services. The Government of India has launched 'National Horticulture Mission' that provides subsidies as high as 75% for different components. Tissue culture techniques have substantially increased the supply of fruit tree saplings. Promotion of agro-forestry will not only increase incomes of smallholders substantially but also contribute in minimizing risks during extreme climatic eventualities and reducing GHG emissions. It is, however, important to develop regulatory mechanisms for quality planting materials of fruit trees.

Rainwater harvesting, conservation and efficient use can manage the problem of soil and water erosion. Indian government launched watershed programs in rainfed areas. Meta-analysis has revealed that the watershed program gave high dividends in terms of the B/C ratio, internal rate of returns, and increasing employment by expanding irrigated area and cropping intensity. Rainfed areas should receive high investment priority for the watershed development program as it contributes in raising farm incomes, conserving soil and water resources and improving the climate resilient agriculture.

Historically, land use changes have been an important source of adaptation to the climatic stresses. Strategic land use changes are, however, guided not only by the need to cope with climatic stresses but also to adapt to opportunities provided by technology, institutions and markets. Cultivation of almost 13 million hectares of the rice-wheat system in the Indo-Gangetic plain of South Asia is a typical example (Timsina and Connor, 2001). Shifting of the apple belt to higher elevations in Himachal Pradesh as a consequence of inadequate chilling temperatures during last few decades is another example (Rana et al., 2010). The area vacated by apples at relatively lower elevations has now been occupied by vegetables. Such a land use change has not only helped farmers to adapt but also increase their incomes. In future, climatic changes together with such changes in food demand are likely to result in major changes in land use. Scientific tools to assist in regional land use planning that can help farmers and societies to adapt to climate change, meet food demands and environmental goals; and also lead to higher income are needed.

In the context of climate change, policies are needed for land use and settlement in climatic risk prone areas such as coastal regions of southern Bangladesh, and islands such as Andaman and

Nicobar. Land tenure provisions need to be secured to promote preparedness of vulnerable communities to climatic risks. Where and how much rice paddies should be grown is another example where appropriate policies could guide land use.

Management of water resources

South Asia has a large number of water resources, including glaciers, rivers, ponds, lakes, precipitation, and groundwater. There is a large spatial and temporal variability in water resources in South Asia. Much of the rainfall in the region occurs in three months of monsoon and for the remaining period agriculture has to depend on the surface- and groundwater resources. These water resources have been utilized to create a large irrigation potential in the last 5 decades and have been the cornerstone of food security of the region. There is now a very dense irrigation canal system in the Indo-Gangetic plains, the food basket of the region (Figure 1; FAO). To ensure future food security in climate change scenarios the region therefore needs to pay attention to investment in managing and stabilizing the created irrigated potential.

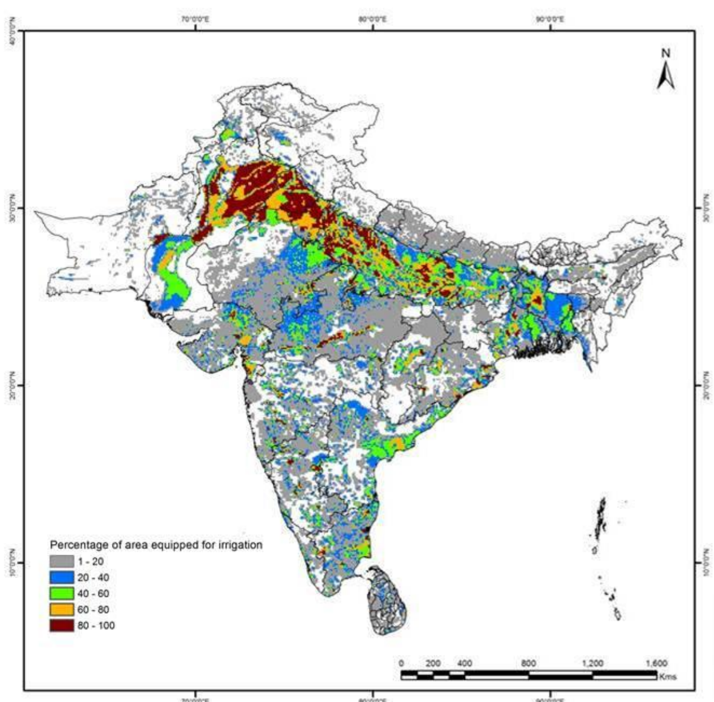

Figure 1: Irrigation map of South Asia

During last few decades, groundwater extraction has become very rampant even in the surface water irrigated regions due to increasing rural electrification, cheap power, availability of credit and assured markets (NAAS 2010). India, Pakistan, Bangladesh and Nepal in South Asia are the major groundwater users in the world, and they pump around 210 km^{-3} ground water every year employing almost 23 million pumps (Shah et al., 2009). This together with a large increase in population has resulted in a decreasing trend of per-capita availability of water resources in South Asia. In India, it was 8192 cubic meters in 1900, decreasing to 5694 in 1990 and to 1704 in 2010 (NAAS, 2009). It is projected to further decrease to 1235 cubic meters by 2050. The intensive groundwater pumping has also resulted in declining water table in several parts of the region, especially in north-western parts. Using satellite-based estimates of groundwater depletion, Rodell et al. (2009) found that groundwater is being depleted at a mean rate of 4.0 - 10.0 cm/y across the states of Rajasthan, Punjab, Haryana, and western Uttar Pradesh. Upper Ganges region of India and Pakistan have the largest groundwater footprint, the area required to sustain groundwater use and groundwater-dependent ecosystem services, in the world (Gleeson et al., 2012).

Irrigation water quality is also becoming a source of concern in many regions. There are considerable discharges of domestic sewage and industrial effluents in many surface water bodies that are used for irrigation. Similarly, groundwater at few places, such as Punjab state where fertilizer use is relatively larger, is showing increasingly higher nitrate concentration. In Bangladesh and in eastern India, the groundwater contains high concentration of toxic arsenic.

Agriculture in South Asia uses more than 70% available water. This fraction needs to be reduced in the future. The efficiencies of water use, therefore, needs to be improved at the farm, community and regional scales. It has been demonstrated that proper leveling of farms could improve water application efficiencies by over 20%. Greater realism in water and energy pricing could also promote an efficient use of natural resources (Shah, 2009). Use of modern irrigation methods such as micro-irrigation could also be promoted to enhance water use efficiency.

Management of climate change requires the creation of additional water storage. Hence, there is a need to make new investments in the water storage structures to store the heavy monsoon runoff since it is not equally distributed. On a regional scale, Managed Aquifer Recharge has large potential to enhance natural recharge rates of groundwater (IWMI, 2009; Shah, 2009). This will also result in lower evaporative losses, which are likely to increase in future due to climate change. Rationing the power supply system as adopted by the State of Gujarat in *Jyotigram* scheme could also result in efficient use of groundwater. The use of efficient water utilization methods such as micro-irrigation coupled with groundwater use may lead to reduction in depletion of groundwater. Conjunctive management of surface and groundwater in Punjab offers large opportunities for improving water productivity as well as for saving energy (Shah 2009). Such resource conserving technologies in a rice-wheat system also have pronounced effects on mitigation of GHG emission and adaptation to climate change (Aggarwal and Pathak, 2009).

In the land constrained, but groundwater rich state of west Bengal, farmers till recently were required to get permit for the government for using tube well pumps. The goal of such a policy was to maintain sustainable groundwater levels, but the cost and time involved in the process prevented vast majority of small farmers from using groundwater. Based on an award-winning research by IWMI, the Government of west Bengal has recently removed the permit system and has also reduced the fee for connecting a tube well to the electricity grid. Such policy initiatives will lead to greater water use in eastern India and also reduce waterlogging, which is likely to further increase in a scenario of climate change.

Improved risk assessment and its management

The increasing probability of floods and droughts and other uncertainties in climate may seriously increase the vulnerability of resource-poor South Asian farmers to global climate change. To manage these risks better, it will be very useful to have an early-warning system of environmental changes and their spatial and temporal magnitude. Such a system could help in determining the potential food insecure areas and communities given the type of risk.

There are several opportunities available today that can facilitate analysis of climatic risks in agriculture and their management from local to global scale such as early-warning systems, and real time agro-advisories for farmers, policy planners, industry, and other stakeholders. To fully exploit their potential, it is however necessary to have a state-of- art infrastructure to measure and record weather variables; standardized data protocols; systems for data storage, assimilation and dissemination; and access to short-, medium- and extended-range weather forecasts and seasonal climate forecasts at desired spatial and temporal scales (Aggarwal et al., 2010). Fortunately, advanced tools such as automatic weather stations, global circulation models, regional climate models, numerical weather prediction models, and downscaling techniques have become more widely available. If reliable and timely seasonal forecasts of weather can be made available there are a number of options with the agricultural research community, farmers and other stakeholders that can be employed to minimize the risks and ensure food and livelihood security.

Value-added agro-climatic products such as the U.S. Drought Monitor (Svoboda, et al., 2002) are a useful example of an operational tool for monitoring drought conditions. In India, the India Meteorological Department is providing weather-based crop advisory services regularly for the whole country through multi SMS/voice based systems to farmers through mobile phones. To implement such schemes in other countries of South Asia, there is a need to strengthen policies and institutions that promote collection, assimilation and dissemination of quality climatic data and products and systematic research efforts to understand their likely impacts on agricultural activities (Aggarwal et al., 2010).

Both current and future climatic risks can be managed better if there are appropriate policies and institutional support together with technological interventions. Several technological options recommended by the scientists are generally not implemented by the governments because of very limited knowledge available today on the costs: benefits associated with these and other competing social and economic activities. Incentives should be provided to the farmers and industry for increasing the efficiency of water, fertilizer, and energy use and sequestration of carbon (FAO, 2008). Rational pricing of surface and groundwater, for example, can arrest its excessive and injudicious use. Integrating perspectives on climatic risks in current national policies and programs in different sectors such as disaster management, water resources management, land use, biodiversity conservation, and agricultural development would lead to increased adaptive capacity to the present as well as future climatic variability (Aggarwal and Sivakumar, 2010).

Poor South Asian farmers are generally risk averse because of their limited capital base and limited availability of credit at a reasonable or low interest rate. This limits smallholder farmers' purchasing power to adopt improved technologies, seeds, fertilizer, machines, and water. In Bangladesh, the non-governmental organizations, namely '*Grameen* Banks' and Bangladesh Relief Action Committee (BRAC) are transforming the rural financial sector. Similarly, in India, *Kisan* Credit Card system and micro-financing are also making easy access to credit for the framers. Such models need to be adapted by other South Asian countries for the benefit of smallholders for easy access to credit, reducing their transaction costs, and enhancing their risk management capacity.

Risk transfer approaches, e.g. crop yield insurance and weather derivatives, are increasingly being used as a viable solution for managing risks associated with climatic variability. While these have been reasonably successful in the developed world, there still is a lot of work to be done before their large-scale adoption in the developing countries. The poor section of the society is either not aware of these tools or does not have the capacity to pay the premiums. One needs to examine and perhaps evolve new models of north-south cooperation in such risk transfers and innovative private–public cooperation for overall global, regional, and local benefits.

Promoting adaptation with co-benefits in mitigation

Globally, direct emissions of GHGs - methane (CH_4) and nitrous oxide (N_2O)- from agriculture (i.e. excluding emissions from agriculture as a driver of deforestation and other land cover change) account for 10-12% of total global anthropogenic emissions (Smith et al., 2007). Overall, Asia contributes some 38% of the global total for agricultural emissions, with the figures lying between 25-35% for most sources of GHGs. However, Asia contributes nearly 90% of the global total for methane from rice cultivation (Figure 2). The highest emissions come from South Asia, followed by East Asia and then South-East Asia.

In South Asia, the agriculture sector is responsible for 20% of its total GHG emissions. These emissions are primarily due to enteric fermentation in ruminant animals, rice paddies, and nitrous oxides from application of manures and fertilizers to agricultural soils (Figure 3; Smith et al., 2007). In future, emissions from soils are likely to increase significantly because of increased intensification of input use required to meet increased food demand.

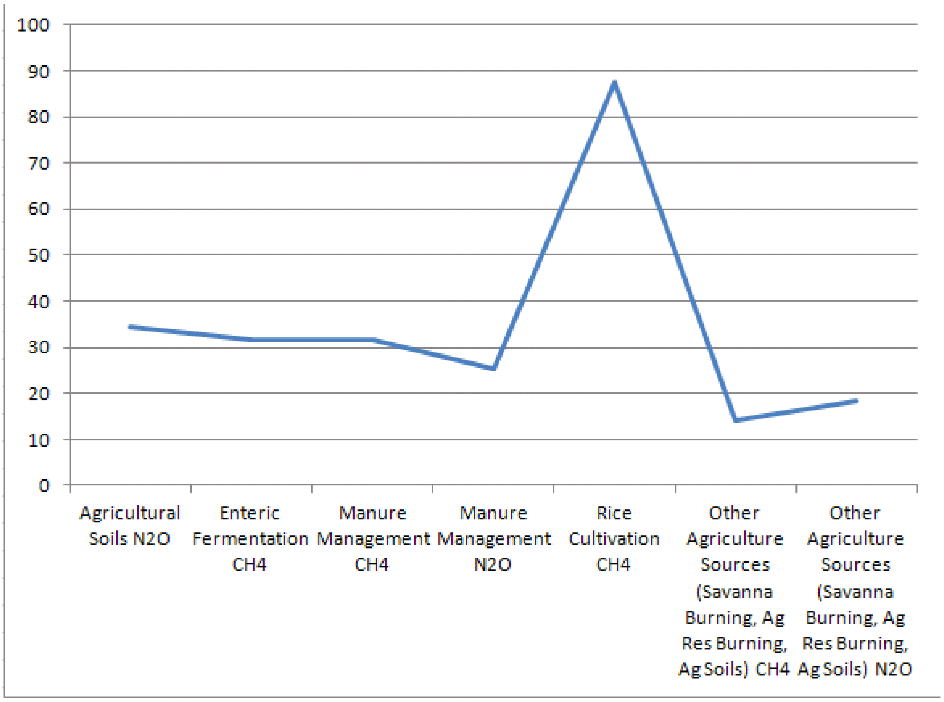

Figure 2. Percentage contribution of Asian agricultural emissions to global agricultural emissions, by category (US-EPA 2011).

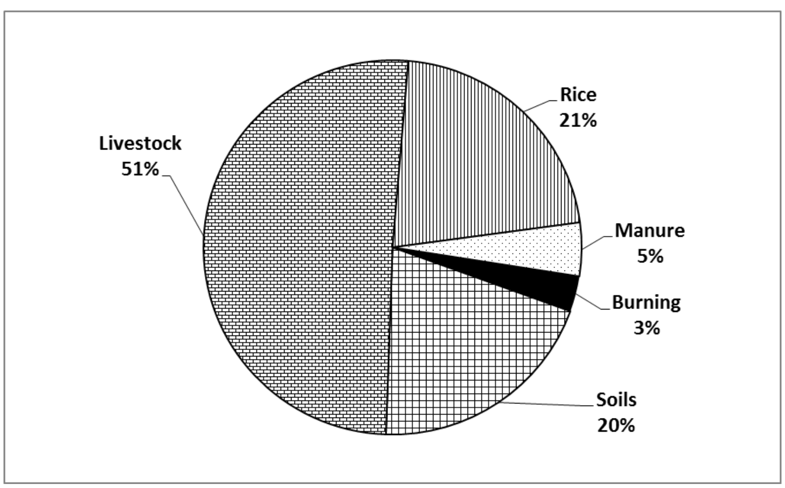

Figure. 3: Contribution of various sectors to agricultural GHG emissions in South Asia in 2005. Source: Smith et al., 2007.

Significant GHG emission reductions, of the order of 10-25%, are possible through changing water management regimes in rice production (Pathak and Aggarwal, 2011). This involves moving from continuously flooded conditions to intermittent flooding and/or a shortened period of flooding, resulting in reduced anaerobic decomposition of organic matter and methane production. It would also improve water use efficiency. Here we have a technology that reduces water use and GHG emissions without compromising yields. However, these reductions do require careful management of the water regime, often involving even greater cooperative behavior amongst farmers.

Fertilizer use efficiency in most of the South Asia is as low as 30-50%. Even if this could be increased by 5-10%, it will lead to not only considerable reduction in cost of cultivation and higher yields but also mitigation of nitrous oxide emissions. Use of the nitrification inhibitors, particularly the cheap, locally available, plant-derived materials such as neem cake and applying appropriate quantities of N fertilizers based on plant requirement are crucial practices. Improving the efficiency of energy use in agriculture by using better designs of machinery, increasing fuel efficiency in agricultural machinery, use of wind and solar power, and use of laser levelers also leads to mitigation. Improved management of livestock diet through use of feed additives, substitution of low digestibility feeds with high digestibility ones, concentrate feeding, and changing microflora of rumen also leads to a reduction in methane emission.

Small changes in climatic parameters can often be better managed by altering dates of planting, spacing and input management. Early planting of wheat, facilitated after rice harvest by surface seeding or zero-tillage may offset most of the losses associated with increased temperatures in South Asia. This reduces costs of production; while it also reduces the use of natural resources such as fuel, and shows improvements in efficiency of water and fertilizers. Other resource conserving technologies such as systems of rice intensification also need to be carefully assessed. If financing mechanisms can be developed to encourage farmers to adopt such resource conserving/efficient practices, the adaptation to climate change for ensuring food security can be accelerated.

Improving governance

Governance reforms are needed to improve rural services, infrastructure and implementation of poverty alleviation programs. For example, use efficiencies of irrigation water and fertilizer remains at less than 50%, which could be corrected to a large extent by designing and implementing scientifically backed policy reforms in water, energy and fertilizer sectors. When the green revolution happened in sixties and seventies, South Asian governments showed very coordinated governance efforts at multiple levels. For India, on the production front, policies were formulated to increase investment in agriculture, and to provide producer subsidies for key inputs (such as fertilizer, power and irrigation). Today, minimum support prices continue to be announced, and guaranteed procurement is ensured to reduce the risk in production of food commodities, especially rice and wheat. On consumption, India's vast public distribution system enables state governments to distribute food (rice, wheat and sugar) to the poor at subsidized prices. Bangladesh has a comparable public distribution system, while Pakistan does not subsidize inputs but does manage a considerable public inventory for staples such as wheat. In the past, these policies have helped in increasing agricultural production and improving food security.

Some stakeholders argue that public funds currently spent on producer and consumer subsidies could be better invested to incentivize the development of markets, cold chains, warehouses and infrastructure for transport and processing. Private and public sector initiatives in weather index-linked crop insurance have been reasonably successful and now reach a few million farmers. Regional private sector investment in biotechnology increased tenfold during the past 20 years, and in future is likely to provide a strong basis for accelerating the development and release of "climate-proof" crop and livestock varieties.

On the other hand, the state has a greater role to play than simply providing conducive conditions for private investment. Governments in the South Asia region will need to continue to invest in assuring fair access for the poor to resources, income-generating opportunities, public services and a basic level of welfare. Under climate change, increasing climate variability means higher risks to farmers' yields and household incomes. Under these conditions, public investment in social safety nets is ever more important, to compensate in the short-term for transitory food insecurity (for example, after floods or droughts) and to enable households to build the assets they need to climb out of chronic food insecurity. The "South Asian Enigma" of sustained economic growth yet persistent malnutrition is perhaps the central challenge for food security under climate change. IFPRI research in Bangladesh and India indicates a weak correlation between household income and nutritional status at the lower end of the income spectrum; other factors are much more important, particularly women's educational status and empowerment (Bhagowalia et al. 2012a & 2012b). Three key entry points for improving the nutritional outcomes of agricultural programs in South Asia are (a) a productivity focus on the poorest farmers, including on-farm diversity (non-staple crops and livestock) and investment in rainfed agriculture, (b) continued management of food prices for poor consumers, and (c) serious emphasis on women's role in agriculture, including stronger land tenure, and access to legal resources, credit, infrastructure and agro-advisory services (Dev 2012).

Several public policy initiatives have been announced to support agricultural development, climate risk management, and poverty alleviation. However, implementation of most of these remains weak. The key reasons for these are policy paralysis and uncertainty due to political uncertainty, weak governance that leads to huge policy gaps of implementation, and powerful bureaucracies that seek excessive controls and regulations. Management of early-warning and response systems for droughts is a typical case. Over the last two centuries, India has responded to droughts by developing and implementing several policies relating to scarcity, drought relief, drought management, water management, and knowledge management. Yet India continues to lose significantly large amounts of its agricultural production to droughts. While increasing water resources availability and their productivity are vital for enhancing adaptive capacity, it is equally important to simultaneously address these socio-economic-political constraints. Experience with water management in both Nepal and India has illustrated the importance of creating real coordination among the multiple responsible ministries and agencies. Equally important is the building of partnerships at the local level to enable locally appropriate adaptation to climate change. For example, the Nepalese experience with participatory plant breeding provides a range of transferable lessons on sustainable, cost-effective, multi-agency partnerships for climate change adaptation.

Capacity strengthening of agricultural stakeholders

Climate change poses new and increased risks for South Asian agriculture but at times may also provide new opportunities. This emerging situation requires that the capacity of all concerned stakeholders- farmers, local governments, NGOs, policy makers and their advisors, and even industry be strengthened.

As indicated earlier, agriculture remains the largest employer in rural South Asia. However, the region has started witnessing seasonal shortage of farm labor and rise in farm wages. Consistent high economic growth (exceeding 6% per annum), investment in infrastructure development, and new opportunities in services and manufacturing sectors are the key drivers for labor migration from agriculture to non-agricultural sectors. In India, social protection program (such as the Mahatma Gandhi National Rural Employment Guarantee Scheme), which ensures 100 days employment in rural areas, is also cited as a contributing factor to labor scarcity for farm operations. Possibilities to address this labor shortage include strengthening small scale mechanization or promoting custom hire services.

Agriculture in South Asia is increasingly feminizing, and the female labor force faces drudgery in agriculture and lacks elementary services, such as health and education. Extension services need to gear up to address gender issues in technology dissemination and its adoption. The gradual transformation of agriculture from subsistence orientation to market-led production systems calls for a more skilled and trained labor force for farm operations, post-harvest operations and marketing of produce. Additional climatic risk management strategies such as a cellphone-based availability of agro-advisories and availability of index-based insurance products also require that the farmer's capacity to utilize such knowledge and products be strengthened. CCAFS has recently introduced 'climate smart villages' to raise the awareness of farmers about various agricultural technologies that can potentially enhance their resilience and adaptive capacity while often providing the co-benefits of mitigation (Figure 4). This concept is currently being evaluated in many sites in South Asia and Africa by farmers in a participatory mode. CCAFS has also started another significant innovation in terms of farmer exchange programs to facilitate farmer-to-farmer learning from visits to sites that are currently experiencing climate conditions that are predicted to happen in the future for their own locations. (referred to as climate analogue sites – see http://ccafs.cgiar.org/our-work/research-themes/progressive-adaptation/climate-analogues) (Ramirez-Villegas et al., 2011).

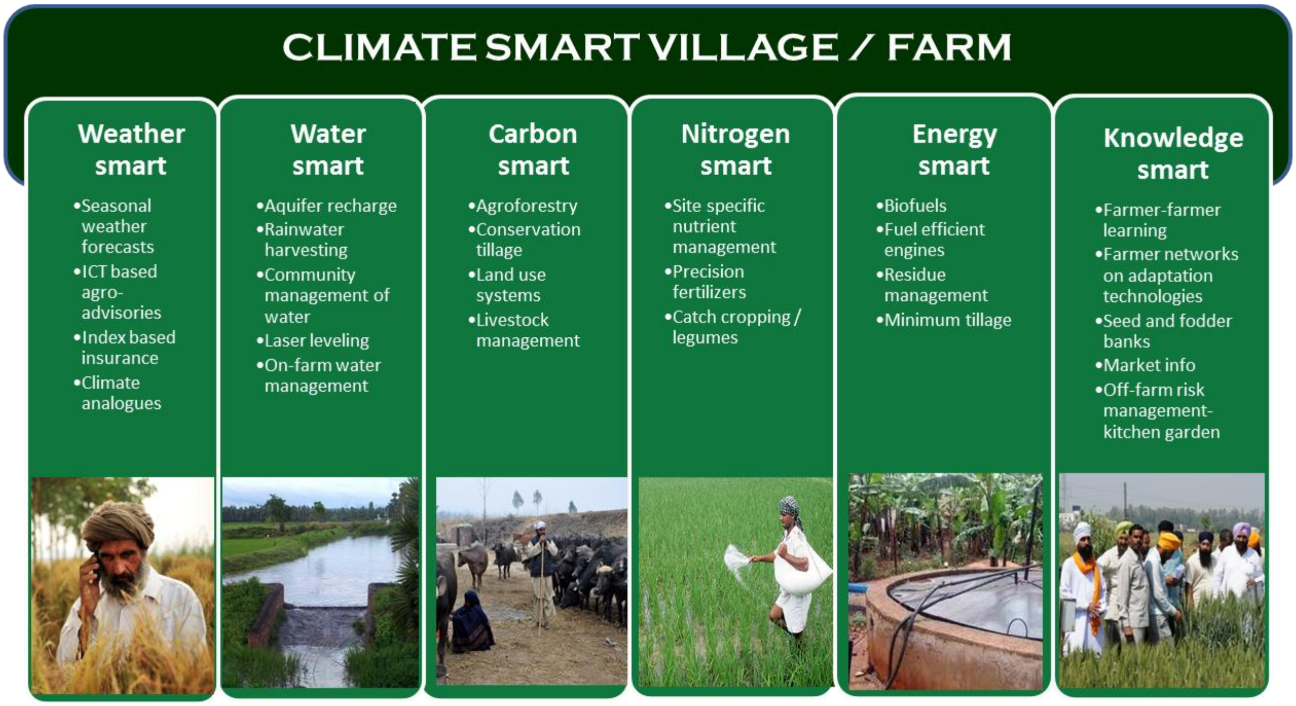

Figure 4. Linking knowledge to action-climate smart villages/farms: Key agricultural activities for managing risks, increasing adaption and mitigation to climate change.

Besides farmers, it is also important to address the capacity strengthening needs of all other stakeholders such as local governments, policy makers and industry. CCAFS is currently focusing on raising the awareness of women Panchayat (local governments) leaders in South Asia about climate change and helping them to better understand and implement various strategies to raise their income, reduce their drudgery and enhance climatic resilience. Soon, a program will be started for the study visit of local government leaders to their climate analogue sites. These leaders also need to be provided support in developing their local adaptation plans for action (LAPAs) especially related to community self-help groups for management of resources such as land and water. Capacity also needs to be raised for the least-developed countries in preparing, negotiating, and implementing National Adaptation Programme of Action (NAPA) and Nationally Appropriate Mitigation Action (NAMA) plans for the UNFCCC.

Globally several new tools such as index insurance have become available that can potentially raise the capacity to address climatic risks. In most developing countries, stakeholders including governments and industry are not fully aware of the opportunities and constraints associated with such schemes and products. Similarly, more effective systems need to be put in place to understand the benefits of local traditional knowledge as well as new seeds to facilitate climate adaptation. New tools that can support policy makers and their advisors for prioritizing investment decisions in climate smart agriculture are urgently needed.

Regional cooperation

History has shown that climatic extremes do not impact the entire South Asian region at the same time. Projected impacts of climate change on agriculture also indicate differential spatial and temporal impacts in South Asia. The regional cooperation through SAARC and other mechanisms in many of the areas proposed above would be useful due to large similarities in agro-ecological features across borders. For example, Punjabs in India and Pakistan, Bengal state of India and Bangladesh, Tarai region of Nepal and Uttar Pradesh and Bihar in India, have similar agro-ecological features and can mutually benefit from a regional early-warning system, especially for monitoring pest movement within South Asia, and for water resource management.

In South Asia, there are several transboundary river basins such as Indus, Ganges and Brahmaputra and Tista. Comprehensive planning and regional collaboration from the perspective of glacier melt, water availability and its appropriate storage and integrated use could help in conserving resources and utilizing them for drought alleviation in stress periods. Having agreements on agriculture related trans-boundary issues such as water and pest's movement would help in managing climatic risks as and when they occur.

Despite being land and food scarce, several countries in the region are pursuing a strategy of storing food in good years to manage food scarcity in bad years, as well as providing support to poorest segments of the population. In India, this, supplemented by the guaranteed minimum support policy for food grains, often leads to accumulation of large buffer stocks (current stocks of 80 million tons are for example substantially more than 32 million tons norm of the buffer stock policy), resulting in very costly food subsidies. Assuming that climatic extremes are not likely to occur all over South Asia at the same time and considering the huge costs of storing food, SAARC countries have proposed establishing a Food Bank to augment regional food security. Each country in South Asia is committed to reserve food grain (rice and wheat) for the SAARC Food Bank. This is a welcome step, and such an initiative needs to be replicated in other parts of the world, especially in Africa. Such a Bank would come in handy when climatic extremes-related crop losses increase in the future.

Several global funds for adaptation and mitigation are now available and some more are likely to be established in future. Collective lobbying for funds by South Asian countries could make these funds available for 'climate proofing' food supplies in their vulnerable regions. Some specific programs where such funds could be used are developing and strengthening adaptation related infrastructure, implementation of weather related risk insurance programs, enhancing research capacity, and for securing 'patented' knowledge/ technologies related to adaptation, including germplasm/ genes from various sources (Aggarwal et al., 2010).

Conclusion

Despite impressive development during last five decades, South Asian agriculture remains highly vulnerable to current climatic risks and is projected to become even more so in the future due to climate change. A range of technological, institutional and policy options have been proposed to help South Asian agriculture become more resilient to a changing climate. It is important to move forward with technologies such as those dealing with conservation agriculture, reclamation of degraded land, and community management of soil and water resources. Appropriate incentives for encouraging these now will build adaptive capacity to climate change as well. Technology intensive adaptation options such as seasonal weather forecasts, early-warning systems, and index based insurance are also necessary but require considerable capacity building of all stakeholders and institutional and policy support. Setting up of a regional/national fund to promote climate smart interventions would be rewarding. It is interesting to note that all of these options are needed for South Asia irrespective of climate change. It must also be noted that most of these adaptation options, if implemented scientifically, will have large co-benefits in terms of reduction in GHGs. Recent analysis has shown that the emission intensity of agriculture in India has been continuously decreasing as production increased during the last few decades (Pathak et al., 2012, personal communication). Promoting good agricultural practices across South Asia is therefore likely to lead to more widespread climate smart outcomes as well.

Management of land and water resources is an important issue for future. Reforms in land ownership rights, investment in creation of water storage, policies to encourage contract and community farming, and availability of credit and extension services are crucial. Several examples of successful Farmer Producer Organizations are now available in South Asia. Regional cooperation through SAARC has to be given priority in order to address transboundary issues of water sharing and pest control, as well as for creating safety nets in the form of food banks.

Recent research has led to evidence in support of a large number of technological, institutional and policy interventions for enhancing the adaptive capacity of agriculture. These interventions have varying costs and economic impacts, and their implementation will require appropriate investment decisions. Farmers, local governments and national policy makers, however, find making decisions difficult because of an overload of information that can sometimes even be conflicting and contradictory. Unless the feasibility of various interventions is scientifically assessed, and these are prioritized based on sound criteria, investment decisions will remain difficult. Tools and methods are needed for assisting different stakeholders in making strategic decisions regarding critical interventions for making South Asian agriculture more climate resilient, efficient, and adaptive at different scales. National and international adaption and mitigation funds are increasingly becoming available. These funds will greatly benefit from the value added, prioritized knowledge that such tools can generate.

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