International Journal of

Agricultural Research

ISSN 1816-4897

Academic
Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 11 (1): 1-12, 2016
ISSN 1816-4897 / DOI: 10.3923/ijar.2016.1.12

Climate Change-Perceived Impacts on Agriculture, Vulnerability and Response Strategies for Improving Adaptation Practice in Developing Countries (South Asian Region)

[1]Kaizar Hossain, [1]Shlrene Quaik, [1]Norli Ismail, [1]Mohd Rafatullah, [2]Isahaque Ali, [2]Zulkarnain A. Hatta, [3]Maruthi Avasn, [4]Gaurav Pant and [5]Shaik Rameeja
[1]School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia
[2]School of Social Sciences, Universiti Sains Malaysia, Penang, Malaysia
[3]Department of Environmental Studies, GITAM University, Andhra Pradesh, India
[4]Institute of Applied Sciences and Humanities, GLA University, Mathura Utter Pradesh, India
[5]Department of Environmental Sciences, Andhra University, Andhra Pradesh, India

Corresponding Author: Norli Ismail, School of Industrial Technology, Universiti Sains Malaysia, Malaysia

ABSTRACT
Global environmental changes have the potential to exacerbate the ecological and societal impacts of changes in biodiversity. In many regions, land conversion forces declining populations towards the edges of their species range, where they become increasingly vulnerable to collapse if exposed to further human impact. South Asia is home to over one fifth of the world's population and is known to be the most disaster prone area in the world. The high rates of population growth and natural resource degradation, with enduring high rates of poverty and food diffidence make South Asia one of the most vulnerable regions to the impacts of climate change. Temperature rise will negatively impact crop 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 rainfed farmers who constitute the majority of farmers in this region and possess low financial and technical capacity to adapt to climate variability and change. This article will be improved the understanding of the climate change impacts, vulnerability and the adaptation practices to cope with climate change could help this process.

Key words: Climate change, agriculture, vulnerability, South Asian region

INTRODUCTION
Human alteration of the global environment has caused the sixth major extinction event in the history of life and caused widespread changes in the global distribution of organisms. These changes in biodiversity alter ecosystem processes and change the pliability of ecosystems to environmental change. This has profound consequences for services that humans originate from ecosystems. The large ecological and societal consequences of changing biodiversity should be minimized to preserve options for future solutions to global environmental problems. Rising fossil fuel burning and land use changes have emitted and are continuing to emit, increasing amounts of greenhouse gases into the Earth's atmosphere (Hossain and Rao, 2014). These greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (NO_2) and a rise in these gases

has caused a rise in the amount of heat from the sun withheld in the Earth's atmosphere, heat that would normally be radiated back into space. This increase in heat has led to the greenhouse effect, resulting in climate change (Hossain and Rao, 2014). Climate change will have wide-ranging effects on the environment and on socio-economic and related sectors, including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity and coastal zones. Changes in rainfall pattern are likely to lead to severe water shortages and/or flooding. Melting of glaciers can cause flooding and soil erosion. Rising temperatures will cause shifts in crop growing seasons which affects food security and changes in the distribution of disease vectors putting more people at risk from diseases such as malaria and dengue fever (Hossain and Rao, 2014). Temperature increases will potentially severely increase rates of extinction for many habitats and species (up to 30% with a 2°C rise in temperature) (Channell and Lomolino, 2000). Broad scientific agreement now exists that continued accumulation of heat-trapping "greenhouse" gases in the atmosphere will eventually lead to changes in the global climate and in the climates of regions around the world. The agreement is expressed in the 1996 report of the Intergovernmental Panel on Climate Change (IPCC), an international body of leading natural and social scientists sponsored by the United Nations Environment Programme and the World Meteorological Organization. According to the panel's report, an increase in atmospheric concentrations of greenhouse gases equivalent to a doubling of carbon dioxide (CO_2) will force a rise in global average surface temperature of 1.0-3.5°C by 2100. Average precipitation also will rise as much 10-15% because a warmer atmosphere holds more water (Channell and Lomolino, 2000). While plant response to elevated CO_2 is positive, recent studies confirm that the effects of elevated CO_2 on plant growth and yield will depend on photosynthetic pathway, species, growth stage and management regime, such as water and nitrogen (N) applications (Jablonski *et al*., 2002; Ainsworth and Long, 2005). Increased temperatures may also reduce CO_2 effects indirectly, by increasing water demand. Rain-fed wheat grown at 450 ppm CO_2 demonstrated yield increases with temperature increases of up to 0.8°C, but declines with temperature increases beyond 1.5°C; additional irrigation was needed to counterbalance these negative effects (Guoju *et al*., 2005). Temperature rise will negatively impact rice and wheat yields in tropical parts of South Asia where these crops are already being grown close to their temperature tolerance threshold (Kelkar and Bhadwal, 2007). Kumar and Parikh (2001) show that even after accounting for farm level adaptation, a 2°C rise in mean temperature and a 7% increase in mean precipitation will reduce net revenues by 8.4% in India. Wheat yields are predicted to decline by 6-9% in sub-humid, semi-arid and arid areas with 1°C increase in temperature, while even a 0.3°C decadal rise could have a severe impact on important cash crops like cotton, mango and sugarcane (Butle *et al*., 2014; MoE., 2003).

South Asia, comprising of eight countries i.e., Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka, is home to over one fifth of the world's population and is the most densely populated geographical region in the world. South Asia is known to be the most disaster prone region in the world (UNEP., 2003). The agriculture sector continues to be the single largest contributor to the GDP in the region (Table 1). Urbanization is increasing and farm households are diversifying their sources of income beyond agriculture (Hossain and Ismail, 2015; Hossain *et al*., 2015). This relative decline of agriculture is inevitable in countries that experience economic growth, which has been widespread in the region. Nevertheless, a significant percentage of the economically active population is still involved in agriculture in South Asia and agricultural employment is especially important for the livelihoods of the poor (Lal *et al*., 2011).

Table 1: Statistics of various South Asian countries for 2008 (Lal *et al*., 2011)

Country	Area (km^2)	Arable land (%)	GDP growth rate (%)	Agric. contribution to GDP (%)
Afghanistan	652,230	12.13	3.4	31.0
Bangladesh	143,998	55.39	4.9	19.1
Bhutan	38,394	2.30	21.4	22.3
India	3,287,263	48.83	7.4	17.6
Maldives	298	13.33	5.7	7.0
Nepal	147,181	16.07	4.7	32.5
Pakistan	796,095	24.44	2.7	20.4
Sri Lanka	65,610	13.96	6.0	13.4

As three-fifth of the cropped area is rainfed, the economy of South Asia hinges critically on the annual success of the monsoons (Kelkar and Bhadwal, 2007). 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. Cruz *et al*. (2007) concluded that the crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events and that future climate change is likely to affect agriculture, risk of hunger and water resource scarcity with enhanced climate variability and more rapid melting of glaciers. For Asia, the results of recent studies suggest that substantial decreases in cereal production potential could be likely by the end of this century as a consequence of climate change. Cruz *et al*. (2007) stressed, however, that regional differences in the response of wheat, maize and rice yields to projected climate change could likely be significant. Results of crop yield projections, using the HadCM2 climate model, indicate that crop yields could likely increase up to 20% in East and South-East Asia while likely decrease up to 30% in Central and South Asia even if the direct positive physiological effects of CO_2 are taken into account (Lal *et al*., 2011). In South Asia, there could be a significant decrease in non-irrigated wheat and rice yields for a temperature increase of greater than 2.5°C which could incur a loss in farm-level net revenue of between 9 and 25%. One study points out that in Bangladesh, production of rice and wheat might drop by 8 and 32%, respectively, by the year 2050 (Lal *et al*., 2011). Many studies were shown that a 0.5°C rise in winter temperature could reduce wheat yield by 0.45 t ha^{-1} in India (Lal *et al*., 2011). Other studies suggest that 2-5% decrease in Indian wheat and maize yield potentials for temperature increases of 0.5-1.5°C could occur. For countries in South Asia, the net cereal production is projected to decline at least between 4 and 10% by the end of this century under the most conservative climate change scenario (Lal *et al*., 2011). The changes in cereal crop production potential suggest increasing stress on resources induced by climate change in many of the developing countries of Asia (Hossain *et al*., 2015). Climate change could affect not only the crop production per unit area but also the area of production. More than 28 Mha in South and East Asia will require a substantial increase in irrigation for sustained productivity and the demand for agricultural irrigation in arid and semi-arid regions of Asia is estimated to increase by at least 10% for an increase in temperature of 1°C (Cruz *et al*., 2007; Hossain and Rao, 2014).

In Srilanka, half a degree temperature rise is predicted to reduce rice output by 6% and increased dryness will adversely affect yields of key products like tea, rubber and coconut (MENR., 2000). In the hot climate of Pakistan, cereal crops are already at the margin of stress. An increase of 2.5°C in average temperature 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. The National Communication (MoE., 2003) highlighted that crops like wheat, cotton, mango and sugarcane would be more sensitive to increase in temperatures compared to rice. Drylands and mountain regions are likely to be more vulnerable than others (Gitay *et al*., 2001) and ecosystem degradation is largest in these regions (Hassan *et al*., 2005). Climate change is likely to cause additional inequities, as its impacts are unevenly distributed over space and time and disproportionately affect the poor (Tol, 2001; Stern, 2007).

According to Cruz *et al*. (2007), some studies have shown that higher temperatures and longer growing seasons could result in increased pest populations in temperate regions of Asia. Warmer winter temperatures would reduce winter kill and increase insect populations. Overall temperature increases may influence crop pest and disease interactions by increasing pest and disease growth rates which would then increase the number of reproductive generations per season and by decreasing pest and disease mortality due to warmer winter temperatures, would make the crop more vulnerable. The report stated that climate change along with changing pest and disease patterns will affect how crop production systems react in the future (Werrell and Femia, 2013).

Grain is often used as a proxy for all food because it accounts for over half of all food calories consumed in the world. According to the IPCC estimated report, climate change impacts on grain production at the global level with compare to developing country like Asia.

The sources of the IPCC estimates are the three different GCMs, reflecting four different scenarios for estimating climate change impact on grain production (Table 2) (Pimentel *et al*., 2000).

First scenario: Disregards any adjustment that farmers might make to offset the impacts of climate change on grain production and disregards the effects on production of an atmosphere richer in CO_2 (CO_2 is essential to plant growth and much experimental work shows that higher concentrations of it in the atmosphere in fact stimulate such growth).

Second scenario: Incorporates the CO_2 enriching effect on growth (Pimentel *et al*., 2000).

Third scenario: Includes both the CO_2 enriching effect and the effect of modest adjustments that farmers could make using currently known practices, for example, shifting to a different variety of the same crop and changing the planting date by less than one month in response to a change in the length of the growing season (Pimentel *et al*., 2000).

Fourth scenario: Includes the CO_2 effect on growth, the modest adjustments to farming just mentioned, as well as more ambitious adjustments, such as shifting to an entirely different crop, changing the planting date by more than one month and using more irrigation (Pimentel *et al*., 2000).

The IPCC analyses of the four scenarios are summarized in Table 2 to make more clear. The range in each entry reflects differences in the results obtained with the various climate models. Notably, the CO_2 fertilization effect substantially reduces yield losses and may even lead to net increases in grain output in developed countries as a whole. Smaller but significant offsets are obtained by allowing for adaptive behaviour by farmers. Not with standing these adjustments and offsets, however, climate change is indicated by the IPCC report to reduce grain yields in developing nations, underscoring the greater vulnerability of these countries (IPCC., 2012, 2013).

Table 2: Estimated percentage grain production changes from climate change (IPCC., 2007)

Scenario	World	Developed countries	Developing countries like Asia
No offsetting effects considered	-11 to -20	-4 to -24	-14 to -16
Including CO_2 fertilization effect	-1 to -8	-4 to +11	-9 to -11
Including CO_2 fertilization and modest farmer adaptation	0 to -5	+2 to +11	-9 to -13
Including CO_2 fertilization and more ambitious farmer adaptation	-2 to +1	+4 to +14	-6 to -7

The sharp difference in impact that climate change is expected to have on grain production in developed as opposed to less developed countries has two main causes. The first one might be called the "physical" factor. As noted above, the GCMs estimate that the high latitudes will warm more than the tropics. Most of the DCs are in the northern latitudes and their agriculture would benefit from the longer growing seasons that a warmer climate would bring. Most LDCs, on the other hand, include much terrain in the tropics where the negative effects of a warmer climate would not be offset by other favourable trends (Cruz *et al*., 2007). The second reason might be called the "eco-structural" factor. The IPCC notes that, compared with the LDCs, the DCs have much greater economic resources that can be devoted to helping farmers adjust to climate change. In addition, the institutional structures of the DCs appear to be more efficient than those in the LDCs in mobilizing the resources needed to pursue specific social objectives (IPCC., 2012, 2013).

Rosen Zweig and Parry also estimated changes in cereal prices resulting from climate induced changes in production. The direction of change is consistent with well-established knowledge about price-production relationships in agriculture; Prices are what economists call "inelastic," that is, a given percentage change in production is associated with a significantly greater (opposite direction) percentage change in price. That is, a given percentage decline in production because of climate change would result in a greater percentage increase in prices and vice versa for production increases.

Farmer vulnerability: In south Asian region, most of the smallholder farmers live in precarious conditions and are intrinsically vulnerable to any shocks that affect their agricultural systems. Agriculture is the backbone of farmer livelihoods, serving both as the primary source of household food and principal means of income generation. Consequently, the fate of these smallholders is closely interwoven with that of farming (Jones *et al*., 2013; Tubiello, 2005).

The farmers are predominantly vulnerable to any reductions in crop productivity for a variety of reasons. First, the farmers cultivate very small parcels of land (less than 1 ha), dedicate most of their land to crop production for household consumption and obtain low crop yields, which are insufficient to meet household needs, let alone provide surplus for sale. Secondly, the low yields probably reflect the limited use of inputs (fertilizers, pesticides, improved seed varieties), the lack of animal traction, the use of low technology practices, the use of suboptimal land for rice, the prevalence of slash and burn rice production and land degradation all of which have been identified as constraints to agricultural productivity elsewhere (Jones *et al*., 2013; Tubiello, 2005).

Additional factor that increases farmer vulnerability is the remoteness of farm villages and lack of adequate road infrastructure. Across the south Asian region, roads are in a poor state and unevenly distributed, with many villages lacking roads that connect them to other villages. Even the main roads are often accessible only during the dry season. The livelihood insinuations of this isolation are significant, as farmers have difficulties getting their products to markets as well as obtaining agricultural inputs; in addition, farmers generally have to pay higher prices for agricultural inputs in remote areas, reducing their profit margins (Jones *et al*., 2013).

The last and important factor that exacerbates farmer vulnerability is that most households lack access to formal safety nets to which they could turn in times of need. Most of the small holder farmers remain outside a formal credit or banking system, lack capital and are unable to access credit or loans. Farmers are further constrained by having limited access to agrometeorological or market information (only 19% of the households have mobile phones), which could help inform farm management decisions, such as the choice of crops, planting dates and management strategies and which could serve as early warning systems for floods and cyclones (Tubiello, 2005).

Significant vulnerabilities in South Asian agriculture:

- Increased river bank erosion and saline water intrusion in coastal areas may cause 6-8 million people to be displaced by 2050, if SLR is higher than expected and coastal polders are not strengthened/new ones built (MoEF., 2009)
- Risk of crop losses projected to increase due to higher flood frequency under climate change (IPCC., 2008). In Bangladesh about 1.32 Mha of cropland is highly flood-prone and about 5.05 Mha moderately flood-prone (Bangladesh NAPA; Karim, 2009)
- Significant decrease in yields of non-irrigated wheat projected in South Asia for temperature increase above 2.5°C, with projected loss in farm-level net revenue of 9-25% (Cruz *et al*., 2007)
- Projected decreases of 2-5% in yield potential of wheat and maize in India for temperature increase of 0.5-1.5° (Cruz *et al*., 2007)
- Climate changes, especially in temperature, humidity and radiation, may have effects on the incidence of insect pests, diseases and microorganisms. A change of 1°C changes the virulence of some races of rust infecting wheat (Bangladesh NAPA)
- Too much water for crops during the wet season and too little during the dry season projected in Bangladesh. 60% moisture stress on top of other effects might cause as high as 32% decline in boro yield, instead of having an overall 20% net increase. The effect of low-flow on agricultural vulnerability potentially less significant than other climate change effects. The ultimate impacts of loss of food grain production would threaten food security and increase food imports (Bangladesh NAPA)
- CO_2 fertilization may facilitate food-grain production. Doubling of atmospheric concentration of CO_2 in combination with a similar rise in temperature potentially to result in 20% rise in rice production and 31% decline in wheat production. Boro rice would enjoy good harvest under severe climate change scenario with doubling of atmospheric concentration of CO_2 (USAID., 2010; Bangladesh NAPA)
- Climate change projected to increase intensity and frequency of natural disasters, which may lead to 17% decline in overall rice production in Bangladesh and a decline as high as 60% in wheat production, compared to a baseline of 1994/1995. Crop modeling results also suggest that the duration of the growing season could decrease by 2-12 days, which may delay the aman transplantation in December and January (World Bank, 2009; South Asia Climate Change Strategy)
- Increased salinization may have serious impacts on agriculture -0.5 mt reduction in rice production predicted w/.3 m SLR, or of food grain production by as much as 40% in coastal districts (World Bank, 2009; Ahmed and Suphachalasai, 2014)
- In Sri Lanka, an increase in the frequency of droughts and extreme rainfall events could result in a decline in tea yield, a major source of foreign exchange and a significant source of income for labourers (Kelkar and Bhadwal, 2007)

Risks and risk coping strategies: In this region, smallholder farmers face multiple, periodic and significant risks to their agricultural production and livelihoods including risks owing to pest and disease, risks related to weather events and climate change and those related to market access price volatility. Farmers routinely face significant pest (particularly mice) and disease outbreaks (particularly rice blast, *Pyricularia oryzae*) and the accompanying crop and income losses, while highly variable, can be substantial (e.g., 15-20% of farmers reported losing more than half of their crop to pests and diseases) (Harvey *et al*., 2014).

In addition, farmers are frequently subjected to extreme weather events, which result in crop and livestock losses, as well as damage to agricultural fields, roads and homes. Farmers are also affected by problems of market access and price volatility. Despite the fact that most farmers in the study regions do not produce enough rice to feed their families, 80-85% of households sell some of their crop immediately following the harvest to cover the costs of inputs and basic household needs. Rice prices are generally the lowest immediately after the harvest and the highest during the lean season when farmers buy rice back to feed their families, thereby reducing the ability of farmers to purchase food. Related problems include difficulties of farmers getting their produce to market, owing to the lack of road infrastructure as well as low demand for some products (Harvey *et al*., 2014).

However, a few strategies that are common elsewhere such as receiving food aid, participating in food for work programmes, receiving support from local organizations or migrating to another area were only rarely reported by farmers in this study region. While these coping strategies clearly help to mitigate impacts on farmer livelihoods, the fact that most farmers suffer chronic food insecurity suggests that these coping strategies are insufficient. In addition, there are limits to how much different coping strategies can be successfully used. For example, off-farm employment opportunities are often restricted to the months when fields need to be planted and opportunities may be limited. There is therefore an urgent need to provide coping strategies and safety nets, which can better alleviate chronic food insecurity, both in regular years and in times of stress (Harvey *et al*., 2014).

Climate change and adaptation needs: The international community's commitment to helping developing countries to adapt has proliferated through many funding mechanisms including those under the United Nations Framework Convention on Climate Change and a range of bilateral and multilateral venues (World Bank, 2009). For both adaptation and mitigation, fast-start financing under the Copenhagen Accord to secure support for climate adaptation and vulnerability reduction. There is no doubt that financing for adaptation is intensifying: The funding through the Green Climate Fund under Article 11 agreed at the seventeenth session of the Conference of Parties (COP 17) in Durban could even exceed total Official Development Assistance (ODA) (Conway and Mustelin, 2014; Jotzo, 2009).

Adaptation challenges are unfolding as the agenda moves from theory and negotiation to implementation; they are unlikely to diminish in scale or importance, making practice paramount to adaptation (Stern, 2013; Weitzman, 2009, 2015). We identify three broadly defined areas deserving greater scrutiny; addressing priorities through participation, identifying appropriate entry point sand actors and ensuring effective delivery. In doing so, authors provide recommendations for improving adaptation practice and implementation processes with a particular focus on developing countries (Hartzell-Nichols, 2011; Conway and Mustelin, 2014).

Climate change will likely have significant livelihood impacts on the smallholder farmers in all three regions and further exacerbate food insecurity and poverty. The changes will probably place farmers under additional stress, both owing to direct reductions in agricultural productivity and through impacts on human health, infrastructure and availability of firewood and other ecosystem services on which the poor depend (Morton, 2007; Hertel and Rosch, 2010). Most farmers reported that they had noticed changes in climatic conditions over the last 10 years, with more than 90% reporting increase in temperature and changes in rainfall patterns (Xu and Grumbine, 2014; Hulme *et al*., 2011). The limited uptake of adaptation strategies by farmers is probably due to the high levels of household food insecurity, which make it risky for farmers to adopt new strategies that may affect their agricultural production and food availability. In addition, most farmers in developing region simply lack the resources needed to implement adaptation measures, as has been found in other developed regions (Bryan *et al*., 2009). The fact that the use of adaptation measures was positively correlated with farmer education level, use of diversified agricultural practices, diversified cropping systems and livestock ownership indicate that farmers who are better educated and already have more diversified systems are more likely to be willing to adopt new strategies. Other studies have similarly highlighted the importance of educational level, wealth, access to credit and information, extension services, safety nets, resources and adequate agricultural inputs and technologies in increasing the probability of uptake of adaptation measures by smallholder farmers (Bryan *et al*., 2009; Hedger *et al*., 2006).

Policy options for reducing farmer vulnerability in a changing climate: In area, farmers are in a vicious cycle of food insecurity due to low yields, regular shocks that reduce agricultural yields and inadequate coping strategies and this situation is likely to be further exacerbated by climate change. An inevitable question given the bleak outlook is whether farming is really a viable option for improving farmer livelihoods, or whether policymakers should focus instead on developing alternative employment strategies for these rural populations. In the study areas and in most rural areas of the country there are few employment alternatives available to farmers and the poor infrastructure and lack of basic services make it extremely difficult to promote non-farming activities, so farmers will inevitably continue to farm in the absence of other options. In addition, while migration of farmers from rural areas to the urban areas in search of employment does occur, it is unlikely that the cities can successfully absorb the estimated 65-70% of the population that currently depends on farming for their livelihoods. Efforts to improve the livelihoods of smallholder farmers, therefore, will necessarily need to focus, at least in the near term, on increasing agricultural productivity and making farmer livelihoods less vulnerable to climate change and other risks. Particular attention must be paid to raising agricultural productivity, as this could make a significant difference in food insecurity and poverty levels, both by increasing the total food availability to households and improving household income generation (Harvey *et al*., 2014).

The study focused here, instead, is on specific technical options, which we believe hold promise as low-cost, feasible and relatively fast opportunities for improving agricultural productivity on farms, which can be pursued even in the context of unfavourable policies and institutional arrangements (Conway and Mustelin, 2014). Options that have been shown to be effective in increasing agricultural productivity, include facilitating access to improved seed varieties, fertilizers, irrigation and other inputs (Harvey *et al*., 2014), improving road infrastructure and access to markets, providing greater technical support and extension services to farmers (Bryan *et al*., 2009) and facilitating access to timely climate information, which could be used to inform the choice of crops, planting dates and management strategies, among others (Kates *et al*., 2012; Smith *et al*., 2011).

This research suggests four potential areas for policymakers to pursue that could help to increase agricultural productivity and improve livelihoods in the short term.

First, there is an urgent need to improve farmer extension services to provide technical information and training on the best management practices for planting, harvesting and crop storage, to facilitate the adoption of new management practices and to encourage farmer to farmer learning (Reid and Toffel, 2009; Sherman and Ford, 2014; Mortreux and Barnett, 2009; Birkmann, 2011).

The second low-cost opportunity for policymakers and donors is to invest in small-scale infrastructure, such as improved irrigation systems or crop storage facilities, which can help farmers to increase production and better, protect their harvests (Adger *et al*., 2005; Preston *et al*., 2015).

The third option for improving farmer livelihoods is to increase access to credit and safety nets during lean periods and following catastrophic events, such as extreme weather events or disease and pest outbreaks. Moreover innovative solutions are needed to facilitate access of farmers to financial services in terms of need (Mahmud and Prowse, 2012; Eriksen *et al*., 2011). New services, such as mobile telephone payment systems that are beginning to be available even in remote areas, provide an important new, cheap and secure way for family and friends to exchange money even when they are not physically close to each other (Petherick, 2012).

The final priority for policymakers is to safeguard the natural ecosystems that smallholder farmers use as safety nets. Forests, wetlands, rivers and other natural areas provide critical ecosystem services to farmers, including the provision of firewood and charcoal, water, wild yams and materials for house construction, among others (Harvey *et al*., 2014).

CONCLUSION

South Asia is one of the most vulnerable regions in the world to climate change in view of the huge population, the large number of poor facing food insecurity, inappropriate soil and management practices on marginal lands in the semi-arid regions leading to increasing rates of land degradation and the projected impacts of climate change on the agricultural, forestry and fisheries sectors. Projections indicate that climate variations in South Asia will be varied and heterogeneous, with some regions experiencing more intense precipitation and increased flood risks, while others encounter sparser rainfall and prolonged droughts. The impacts will vary across sectors, locations and populations. Temperature rise will negatively impact crop 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 rainfed farmers who constitute the majority of farmers in this region and possess low financial and technical capacity to adapt to climate variability and change. The coping capacity of the rural poor, especially in the marginal areas is poor and there is a need to mainstream the good practices for adaptation to climate change into sustainable development planning in the region. Improved understanding of the climate change impacts, vulnerability and the adaptation practices to cope with climate change could help this process.

ACKNOWLEDGMENT

The authors acknowledge The World Academic of Science (TWAS)-Italy and Universiti Sains Malaysia, Malaysia for providing world class infrastructure and motivations to continue the research work.

REFERENCES

Adger, W.N., N.W. Arnell and E.L. Tompkins, 2005. Successful adaptation to climate change across scales. Global Environ. Change, 15: 77-86.

Ahmed, M. and S. Suphachalasai, 2014. Assessing the Costs of Climate Change and Adaptation in South Asia. Renouf Publishing Co. Ltd., Philippines, ISBN-13: 9789292545109, Pages: 143.

Ainsworth, E.A. and S.P. Long, 2005. What have we learned from 15 years of Free Air CO_2 Enrichment (FACE)? A meta analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. New Phytol., 165: 351-372.

Birkmann, J., 2011. First- and second-order adaptation to natural hazards and extreme events in the context of climate change. Nat. Hazard., 58: 811-840.

Bryan, E., T.T. Deressa, G.A. Gbetibouo and C. Ringler, 2009. Adaptation to climate change in Ethiopia and South Africa: Options and constraints. Environ. Sci. Policy, 12: 413-426.

Butle, J.R.A., W. Suadnya, K. Puspadi, Y. Sutaryono and R.M. Wise *et al.*, 2014. Framing the application of adaptation pathways for rural livelihoods and global change in Eastern Indonesian islands. Global Environ. Change, 28: 368-382.

Channell, R and M.V. Lomolino, 2000. Dynamic biogeography and conservation of endangered species. Nature, 403: 84-86.

Conway, D. and J. Mustelin, 2014. Strategies for improving adaptation practice in developing countries. Nat. Clim. Change, 4: 339-342.

Cruz, R.V., H. Harasawa, M. Lal, S. Wu and Y. Anokhin *et al.*, 2007. Asia. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report of the IPCC, Parry, M.L., O.F. Canziani, J.P. Palutikof, P. van der Linden and C. Hanson (Eds.). Chapter 10, Cambridge University Press, Cambridge, ISBN-13: 9780521880107, pp: 469-506.

Eriksen, S., P. Aldunce, C.S. Bahinipati, R.D. Martins and J.I. Molefe *et al.*, 2011. When not every response to climate change is a good one: Identifying principles for sustainable adaptation. Clim. Dev., 3: 7-20.

Gitay, H., S. Brown, W. Easterling and B. Jallow, 2001. Ecosystems and their Goods and Services. In: Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White (Eds.). Chapter 5, Cambridge University Press, Cambridge, UK., pp: 238-342.

Guoju, X., L. Weixiang, X. Qiang, S. Zhaojun and W. Jing, 2005. Effects of temperature increase and elevated CO_2 concentration, with supplemental irrigation, on the yield of rain-fed spring wheat in a semiarid region of China. Agric. Water Manage., 74: 243-255.

Hartzell-Nichols, L., 2011. Responsibility for meeting the costs of adaptation. Wiley Interdiscip. Rev. Clim. Change, 2: 687-700.

Harvey, C.A., Z.L. Rakotobe, N.S. Rao, R. Dave and H. Razafimahatratra *et al.*, 2014. Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. Philos. Trans. R. Soc. London B: Biol. Sci., Vol. 369. 10.1098/rstb.2013.0089

Hassan, R.M., R. Scholes and N. Ash, 2005. Ecosystems and Human Well-Being: Current State and Trends: Findings of the Condition and Trends Working Group. Vol. 1, Island Press, Washington, DC., Pages: 917.

Hedger, M.M., R. Connell and P. Bramwell, 2006. Bridging the gap: Empowering decision-making for adaptation through the UK climate impacts programme. Clim. Policy, 6: 201-215.

Hertel, T.W. and S.D. Rosch, 2010. Climate change, agriculture and poverty. Policy Research Working Paper 5468, World Bank, Washington, DC., USA.

Hossain, K. and A.R. Rao, 2014. Environmental change and it's affect. Eur. J. Sustain. Dev., 3: 89-96.

Hossain, K. and N. Ismail, 2015. Bioremediation and detoxification of pulp and paper mill effluent: A review. Res. J. Environ. Toxicol., 9: 113-134.

Hossain, K., S. Quaik, G. Pant, S. Yadav and Y.A. Maruthi *et al*., 2015. Arsenic fate in the ground water and its effect on soil-crop systems. Res. J. Environ. Toxicol., 9: 231-240.

Hulme, M., S.J. O'Neill and S. Dessai, 2011. Is weather event attribution necessary for adaptation funding? Science, 334: 764-765.

IPCC., 2007. Climate change 2007: Synthesis report. Intergovernmental Panel on Climate Change, Valencia, Spain.

IPCC., 2008. Climate Change and Water. IPCC Secretariat, Geneva, ISBN: 978-92-9169-123-4, Pages: 210.

IPCC., 2012. Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change, Field, C.B., V. Barros, T.F. Stocker, D. Qin and D.J. Dokken *et al*. (Eds.). Cambridge University Press, Cambridge, UK., ISBN-13: 9781107025066, pp: 3-24.

IPCC., 2013. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Stocker, T.F., D. Qin, G.K. Plattner, M.M.B. Tignor and S.K. Allen *et al*. (Eds.). Cambridge University Press, Cambridge, UK., ISBN-13: 9781139917193, pp: 3-29.

Jablonski, L.M., X. Wang and P.S. Curtis, 2002. Plant reproduction under elevated CO_2 conditions: A meta-analysis of reports on 79 crop and wild species. New Phytol., 156: 9-26.

Jones, R.N., C.K. Young, J. Handmer, A. Keating, G.D. Mekala and P. Sheehan, 2013. Valuing adaptation under rapid change. Final Report, National Climate Change Adaptation Research Facility, Gold Coast, Australia, pp: 1-184.

Jotzo, F., 2009. A perspective paper on adaptation as a response to climate change. Copenhagen Consensus Centre, Copenhagen Business School, Denmark. http://www.copenhagenconsensus.com/sites/default/files/pp_adaptation_jotzo_v.2.0.pdf.

Karim, Z., 2009. Climate change impacts on Bangladesh agriculture and food security: Policy, strategy and management interventions. http://www.nfpcsp.org/agridrupal/content/climate-change-impacts-bangladesh-agriculture-and-food-security.

Kates, R.W., W.R. Travis and T.J. Wilbanks, 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. Proc. Natl. Acad. Sci. USA, 109: 7156-7161.

Kelkar, U. and S. Bhadwal 2007. South asian regional study on climate change impacts and adaptation: Implications for human development. Human Development Report Office, Occasional Paper, United Nations Development Programme.

Kumar, K.S.K. and J. Parikh, 2001. Indian agriculture and climate sensitivity. Global Environ. Change, 11: 147-154.

Lal, R., M.V.K. Sivakumar, M.A. Faiz, A.H.M. Mustafizur Rahman and K.R. Islam, 2011. Climate Change and Food Security in South Asia. Springer, Netherlands, ISBN-13: 9789048195169, Pages: 600.

MENR., 2000. Initial national communication under the United Nations framework on climate change: Sri Lanka. Final Draft, October 27, 2000, Ministry of Environment and Natural Resources, Government of Sri Lanka, Colombo.

Mahmud, T. and M. Prowse, 2012. Corruption in cyclone preparedness and relief efforts in coastal Bangladesh: Lessons for climate adaptation? Global Environ. Change, 22: 933-943.

MoE., 2003. Pakistan's initial national communication on climate change. Government of Islamic Republic of Pakistan, Ministry of Environment, Islamabad, Pakistan, November 2003.

MoEF., 2009. Bangladesh climate change strategy and action plan-2009. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh. http://www.climatechangecell.org.bd/Documents/climate_change_strategy2009.pdf.

Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. Proc. Natl. Acad. Sci., 104: 19680-19685.

Mortreux, C. and J. Barnett, 2009. Climate change, migration and adaptation in Funafuti, Tuvalu. Global Environ. Change, 19: 105-112.

Petherick, A., 2012. Dirty money. Nat. Clim. Change, 2: 72-73.

Pimentel, D., L. Lach, R. Zuniga and D. Morrison, 2000. Environmental and economic costs of nonindigenous species in the United States. Bioscience, 50: 53-65.

Preston, B.L., J. Mustelin and M.C. Maloney, 2015. Climate adaptation heuristics and the science/policy divide. Mitigation Adapt. Strateg. Global Change, 20: 467-497.

Reid, E.M. and M.W. Toffel, 2009. Responding to public and private politics: Corporate disclosure of climate change strategies. Strat. Manage. J., 30: 1157-1178.

Sherman, M.H. and J. Ford, 2014. Stakeholder engagement in adaptation interventions: An evaluation of projects in developing nations. Clim. Policy 14: 417-441.

Smith, M.S., L. Horrocks, A. Harvey and C. Hamilton, 2011. Rethinking adaptation for a 4°C world. Philos. Trans. R. Soc. London A: Math. Phys. Eng. Sci., 369: 196-216.

Stern, N., 2007. The Economics of Climate Change: The Stern Review. Cambridge University Press, Cambridge, ISBN-13: 9780521700801, Pages: 692.

Stern, N., 2013. The structure of economic modeling of the potential impacts of climate change: Grafting gross underestimation of risk onto already narrow science models. J. Econ. Literature, 51: 838-859.

Tol, R.S.J., 2001. Equitable cost-benefit analysis of climate change policies. Ecol. Econ., 36: 71-85.

Tubiello, F.N., 2005. Climate Variability and Agriculture: Perspectives on Current and Future Challenges. In: Impact of Climate Change, Variability and Weather Fluctuations on Crops and Their Produce Markets, Impact Reports, Knight, B. (Ed.). Cambridge Press, UK., pp: 47-66.

UNEP., 2003. Geo Year Book 2003. United Nations Environment Programme, Nairobi, Kenya.

USAID., 2010. Asia-Pacific regional climate change adaptation assessment final report: Findings and recommendations. United States Agency for International Development for Asia, April, 2010. http://pdf.usaid.gov/pdf_docs/pnads197.pdf.

Weitzman, M.L., 2009. On modeling and interpreting the economics of catastrophic climate change. Rev. Econ. Stat., 91: 1-19.

Weitzman, M.L., 2015. Book review-A review of William Nordhaus' the climate casino: Risk, uncertainty and economics for a warming world. Rev. Environ. Econ. Policy, 9: 145-146.

Werrell, C.E. and F. Femia, 2013. The Arab spring and climate change: A climate and security correlations series. Center for American Progress, The Center for Climate and Security and the Center for American Progress, USA., February 2013.

World Bank, 2009. Reducing the risk of disasters and climate variability in the Pacific Islands. Papua New Guinea Country Assessment, Papua New Guinea Country Assessment, SOPAC/GFDRR/World Bank, East Asia and the Pacific Region, Washington, DC., USA.

Xu, J. and R.E. Grumbine, 2014. Integrating local hybrid knowledge and state support for climate change adaptation in the Asian Highlands. Clim. Change, 124: 93-104.