Climate change, sustainable agriculture and future needs: A perspective of parallel re-thinking

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ABSTRACT

More importantly in developing countries, it will be different for farmers to carry on farmering in the increased temperature (drastic circumstances) of 21st century. Population growth, arable land and fresh water limits, and ability of agriculture to meet this century’s demands while reducing the environmental impact of their productivity. Recognizing this, it is necessary that India should address the issue of climatic change and focus on providing better environment to improve quality of human life. Success depend on the acceptance and use of contemporary molecular techniques as well as the increasing development for agricultural systems that apply salt water (saline) and integrate nutrient cycling flow.

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1. Introduction

Recently concluded United Nation conference on climate change in Copenhagen (South Africa) on 18th December 2009 did not yield the expected results. It is therefore, necessary that each individual country showed formulate its own action plan to reduce the changes of carbon emission to the maximum extent possible within its own resources and capabilities and monitor meticulously on an annual basis on the interest of human survival. It should be concentrate more on research and development effort too. In addition, population experts anticipate the addition of the arable land has not changed appreciably in more than half a century. It is unlikely to increase much in the future because we are losing it to urbanization, salinization and desertification as fast as or faster than we are adding it (Anonymous 2009; Mazid et al. 2011a; Mazid et al. 2011b). Water scarcity is already a critical concern in parts of the world (Anonymous 2007).

Climate change also has important implications for aquaculture. The European heat wave of 2003 killed 30,000 to 50,000 people (Battisti & Naylor 2009). The average temperature that summer was only about 3.5 °C above the average for the last century. The 20 to 36% decrease in the yields of grains and fruits that summer drew little attention. But if the climate scientists are right, summers will be that hot on average by mid century, and by 2090 much of the world will be experiencing summer hotter than the hottest summer now on record. The principle of common but differentiated responsibilities has been occupying a central place in all agreements on climate change (Myers et al. 2011a). In so far as India is concerned the common but differentiated responsibilities should focus sharply on the concern, commitment and accountability of all stakeholders for investing adequate resources to support climate change mitigation, adaptation, technology development, transfer and dissemination to make country’s agriculture resilient, since the Report on
Global Warming sufficiently warning that climate change is likely to affect agriculture adversely and increase the risks of hunger and drinking water scarcity due to enhanced variability and more rapid melting of glaciers. This yield of our most important food feed and fodder and fibre crops decline precipitously at temperatures much above 30 °C (Schlenker & Roberts 2009). Among the other reasons, this is because photosynthesis has a temperature optimum in the range of 20 °C to 25 °C for our temperate crops and plants develop faster as temperature increases, leaving less time to accumulate the bulk of fruits and grains (Qaderi & Reid 2009) (Table 1).

Climate Change

Climate change more particularly harsher weather conditions will have impact on the quality, productivity output and viability of fish and aquaculture enterprises thereby affecting fishing community along with farmers. Climate change affect everyone but worst suffers would be hundreds of millions of small and marginal farmers and people depending upon forests who are already vulnerable. The rise in global temperatures on account of climate change would affect agriculture. While in temperate latitudes a rise in temperature would help countries increase food productivity, it will have adverse effects in India and countries in the tropics. The monsoon accounting for 75% of India’s rainfall significantly impacts country’s agriculture and livelihood of tens of millions of small farmers. Climate change is likely to intensify the variability of monsoon dynamics, leading to a rise in extreme seasonal aberrations such as increased precipitation and devastating floods in some plants of the country as well as reduced rainfall and prolonged drought in other areas. Climate change will further affect agriculture as the sea level rises submerging low-lying crop-land, and as glaciers melt, causing river systems to experience shorter and more intense seasonal flows, as well as are flooding (www.ipcc.ch/publicationsor IPCC, 2007).

Other stress factors

Water use efficiency (WUE) of plants is affected by high atmospheric CO₂ either due to reduction in stomatal conductance and transpiration or photosynthetic enhancement or by increase in transpiration efficiency (Polley 2002; Mazid et al. 2010). Increase in air temperature may increase the rate of transpiration by increasing the vapour pressure gradient and may offset the effects of elevated CO₂ mediated stomatal closure and transpiration. At canopy level, there may be several feedbacks which may reduce the stomatal effects on transpiration. Along with stomatal conductance, there are leaf and canopy boundary layer conductance which together regulate the process of transpiration. If the leaf conductance is high and this ration is large, transpiration is relatively insensitive to changes in stomatal aperture. Impact of high temperature and atmospheric CO₂ on WUE has been reviewed by Polle (2002). He has suggested that increase in crop WUE will be proportionately less than the increase in CO₂ concentration. Similarly in rice, a 56% increase in stomatal conductance occurred under elevated CO₂ (Homma et al. 1999).

Effects of climate change

Much of the world’s food is grown as rainfeed annual crops in the tropics where climate variability plays an important role in determining productivity. The impact of climate change therefore would be particularly severe in the tropical areas, which mainly consist of developing countries, including India. Success of agriculture is dependent on climatic factors like light, temperature and water which are the main drivers of crop growth. During past decades climate change has been one of the important global environmental challenges facing humanity with implications for food production, natural ecosystems etc. Among the various facets of climate change, of particular concern are the expected increase in atmospheric temperature and changes in weather patterns due to rising concentration of GHGs (green house gases). IPCC (Inter Governmental panel on climate change) has projected that the global average temperature of the air of the Earth’s surface would rise by 2.0 to 4.5 °C by the end of this century (IPCC 2007). But CO₂-induced increase in the atmospheric temperature may lead to poor seed quality and lower grain yield and offset the beneficial effect of CO₂. High temperature will also affect development of crop plants through reduction in crop duration, alteration in rate of respiration and photosynthetic partitioning, increased evapotranspiration, hastening the nutrient mineralization in soil and reduction in fertilizer use efficiency due to increased gaseous losses (Agarwal et al. 2001) (Table 2).

Agriculture

According to World Metrological Organization, climate change can adversely impact global environment, agricultural productivity and the quality of human life. More importantly in developing countries, it will be difficult for farmers to carry on farming in the increased temperatures. Recognizing this, it is necessary that India should address the issue of climate change and focus on providing better environment to improve quality of human life (Serra-Majem et al. 2011). Moreover, according to FAO ocean warming, frequent tropical cyclones, flash floods and droughts are likely to bring a devastating impact on food production systems in pacific islands countries. The Report on Climate Change and floral security in pacific Island Countries; says climate change-related disasters have already seriously constrained the development of these islands and reduced food security, especially for
households. Widespread adaptation of more effective and sustainable agronomic practices can help buffer crops against warmer and drier environments (Morison et al. 2008), but it will be increasing difficult to maintain much less increase yields of our current major crops as temperature rise and dry lands expands (Anonymous 2007).

| Table 1. Greenhouse gas assessments carried out in India. |
| Sectors | Gases | | Sectors | Gases | |
| Transport, coal mines, rice and livestock | CO₂, CH₄, N₂O, NMVOC | | Biomass, cement, oil & natural gas, manure, crop residue | All sources | |
| Emission factors | Used published emission | | Rice-extended campaign (organic and non-organic) | All sources | |
| | Developed | | | | |
| | Default and developed | | | | |
| | Default | | | | |
| | Default IPCC | | | | |

**Land and Water**

Recent reports on food security emphasize the grains that can be made by bringing existing agronomic and food science to technology and know-how to people who do not yet have it (World Bank 2008; Royal Society, London 2009), as well as by exploring the genetic variability in our existing food crops and developing more ecologically sound farming practices (Anonymous 2007). This requires building local education technical and research capacity food processing capability, storage capacity, food process sing and other aspects of agribusiness as well as rural transportation and water and countries infrastructure. It also necessitates addressing the many trade, subsidy, intellectual property and regulatory issues that interfere with trade and inhibit the use of technology. Rising sea level owing to climate change would force communities in low-lying coastal areas and river deltas to move to higher ground level. Similarly, increase in frequency of drought due to climate change would force farmers and pastoralists, who rely on rainfall to raise their crops and livestock to migrate to areas in search of land and water (Myers et al. 2011b). This migration/displacement of people would results in dried conflict and competition between migrants and established communities for access to land and water. It may be difficult for displaced communities to maintain their farming at pastoral practices. A broad based policy and program that provide opportunities for the displaced communities to earn livelihood outside the agricultural sector may need to be evolved.

**Biodiversity**

According to the “2005 Millennium Ecosystem Assessment” the climate change will cause loss of diversity by the end of this century. The significance and utility value of biodiversity for food and agricultural purposes well increase as and when climate changes (Ellis et al. 2011). Genetic resources are the living materials that local community’s researchers and breeders use to develop high yields crop varieties/strains that can adapt to changing needs. Maintaining and using this reservoir of genetic diversity well be the foundation for coping with climate change (Tscharnke et al. 2012).

**Live stocks**

Climate change will affect the health, growth and productivity of crops, live stocks, fish and pastures in different ways. It will also have an impact on the incidence of pests and decreases biodiversity and ecosystems. Frequent changes in weather parameters more importantly temperature and precipitation would not only threaten food production but also access stability and utilization of food resources (Sala et al. 2012). Adaptation to climate change will need to focus on strengthening measures such as early warnings systems; systems to identify climate change hot spots and disasters risk management and evolving sustainable and ecofriendly farming systems. Other equally important measures call for sufficiently increase in rural investment to reduce the long term effects of short-term climate variability on food security, through provision of crop and livestock insurance and incentives that encourage farmers to adopt farm and social forestry, conserve resources and better agricultural and land use practices.

**Biotic factors: Pests and diseases**

Climate change is altering the distribution pattern of annual and plant pests and diseases. Changes in temperatures, moistures and
atmospheric gases accelerate growth and generation rates of plants fungi and insects which alter the interaction between pests their natural predators and hosts (Jamieson et al. 2012; Khan et al. 2011a). Changes in land cover, more importantly deforestation/desertification make remaining plants and animals increasingly vulnerable to pests and diseases (Khan et al. 2011b). A World Bank Report on Climate Change impact based on case studies in drought-prone regions of some states of India like Andhra Pradesh and Maharashtra. And flood prone districts of Orissa on the edge of climate tolerance limits high lights the possibility of declining the yields of major dry land crops in Andhra Pradesh, sugar cane yields declining by 30% in Maharashtra and rice production by 12% in flood prone coastal region of Orissa (Galant et al. 2012; Mazid et al. 2011c). The worst suffers would be the poor and marginal farmers who own less than one acre of land mostly populate these regions. What people are talking about today, both in the private and public research sectors is the use and improvement of conventional and molecular breeding as well as molecular genetics modifications (GM) to adopt our existing food crops to increasing temperature, decreased water others rising salinity (World Bank 2008; Royal Society London 2009) and changing pathogens and insects threats (Gregory et al. 2009). Another important goal of such research is increasing crops nitrogen uptake and use efficiencies because nitrogen water way eutrophication and greenhouse gas (GHG) emission (Mazid et al. 2012).

Production of photosynthate (sucrose/starch)
Among the plants, C3 crop species constitutes more than 90% of terrestrial species and most of them respond to increased concentration of CO2. Higher CO2 concentration enhances their rate of photosynthesis by increasing rate of carboxylation reaction of rubisco and decreasing the oxygenation reaction of photospiration (Ghilidyal & Natu 2000). There are various mechanisms which could be responsible for acclimation of photosynthesis (Lawlor et al. 2000; Drake et al. 1997). Photosynthetic acclimation is accompanied by increase in carbohydrates concentration, lowering of concentration of soluble proteins and rubisco, and inhibition of photosynthetic capacity. Some plant species have the limited sink capacity and are unable to utilize the extra assimilated photosynthates under high CO2 environment for plant growth and development (Makino & Mae 1999; Mazid et al. 2011d). However, there are other species which show little or no acclimation of photosynthesis even they are grown for long-term under high CO2. These species accumulate a greater amount of carbohydrates in their leaves, especially as starch in chloroplast which does not affect their photosynthetic response to high CO2 varies with the change in ambient temperature of air and temperature is below the optimum for photosynthesis, a small increase in temperature can result in photosynthetic enhancement.

However, photosynthetic response of elevated CO2 varies among different crop species depending upon the methodology used. In wheat, photosynthetic acclimation was observed when plants exposed to elevated CO2 under controlled environment but no acclimation occurred when grown in FACE (free air CO2 enrichment) (McKee & Woodward 1994a; Garcia et al. 1998). The supply of optimum nitrogen (N) is critical for photosynthesis response under elevated CO2. Pal et al. (2004) observed lower photosynthesis in wheat under limited N supply but application of higher N improved the rate of photosynthesis under elevated CO2. Intactive effect of elevated CO2 and temperature were observed at single leaf photosynthesis in rice where it is stimulated by higher temperature in long-term CO2 exposure studies but at canopy level, very small interaction was observed (Nakagawa et al. 2000). Both short and long term exposure to elevated CO2 were found to increase photosynthetic rate, which showed strong positive response to growth CO2. Similarly increased leaf photosynthesis rates at elevated CO2 has been reported in dry bean (Prasad et al. 2002), peanut (Clifford et al. 2000) and in cowpea (Ahmad et al. 1993). Srivastava et al. (2002) have reported higher photosynthesis and portioning of carbon toward below ground in high CO2 grown mung bean (Vigna radiate L.) plants which resulted in increased nodule number and weight and nitrogenase activity. In soybean, temperature up to 40/30 °C and elevated CO2 shown no effect on photosynthesis rate, total rubisco activity of protein concentration, but decreased initial rubisco activities (Vu et al. 2001) (Table 1 and 2).

Morphology and biomass assimilation
Elevated CO2 enhances rate of photosynthesis and temperature accelerates respiratory losses and net carbon gain of these two processes result in plant biomass. Higher temperature accelerates the growth processes and reproductive development and reduces the crop duration (Kim et al. 2011). Some studies suggest that elevated CO2 may have effect just opposite of temperature and will reduce the leaf or whole plant respiration rates and ratio of dark respiration to net photosynthesis (Ziska & Bunce 1998; Khan et al. 2011c; Mazid et al. 2011e). Rawson (1995) reported 7-36% increase in biomass has been reviewed by Lawlor and Mitchell (1991). At higher temperature, elevated CO2 caused shortening of growth duration in rice (Lin et al. 1997). In the absence of drought and high temperature stress, exposure of elevated CO2 during flowering and anthesis in rice may increased biomass and yield under field conditions (Baker & Allen 1993). The effect of CO2 on soybean developmental stages and growth showed faster vegetative growth and increased number of nodes (Allen et al. 1990; Khan
et al. 2011d). A direct effect increased root growth and mass under elevated CO$_2$ in legumes would be on nodulation and nitrogen fixation. Interaction effect of elevated CO$_2$ and temperature on root growth of legumes has not been well studied (Prasad et al. 2005).

Yield and harvest factors

Poley (2002) concluded that yield benefits of improved WUE at high CO$_2$ are eroded due to decreased harvest index at high temperatures. These reports are of the view that if global air temperature will rise along with CO$_2$ in future, crop WUE will increase especially in arid and subtropical and tropical regions where air temperatures are present at already high point. Several simulation studies have estimated the effect of global climate change on crop productivity using different climate change scenarios (Horie et al. 2000; Tang et al. 2011). These studies predict that global climate change may have substantial positive or negative impact on wheat and rice crops productivity depending on the region of the world under consideration. However, rise in atmospheric CO$_2$ is expected to reduce the negative effect of temperature on yield by enhancing rate of photosynthesis and supply of carbon assimilated to developing grains (Rawson 1995; Wheeler et al. 1996; Camps and Ramos 2011). It has been shown that photosynthetic metabolism responds more positive to rising CO$_2$ than temperature, so it will have more inhibitory effect on photorespiration relatively (Bunce 1998). An increase of 17% in wheat grain yield per 100 μmol mol$^{-1}$ of CO$_2$ enrichment has been reported by Batts et al. (1997) but in wheat grown inside polytunnels warmer temperature than plant biomass. Up to 27% increase in rice yield has been reported by Ziska et al. (1997) under CO$_2$ enrichment at ambient temperature but 4 °C increase in temperature above ambient caused large reductions. Based on various reports in rice, Horie et al. (2000) estimated 39% increase in grain yield in rice grown under double of ambient CO$_2$ in field conditions and at optimum temperature showed reductions. Several reports have shown that increased CO$_2$ levels enhanced seed yield of soybean (Heinemann et al. 2006), dry beans (Prasad et al. 2002) peanut (Clifford et al. 1993; 2000), cowpea (Ahmad et al. 1993). In peanut CO$_2$ enrichment increased total dry matter production and pod yield but not the harvest index (Clifford et al. 1993). There was no interaction between temperature > 36/26 °C (Prasad et al. 2005). Idso & Idso (2001) reviewed effects of CO$_2$ on plant constituents related to animal and human health and viewed/mentioned that elevated CO$_2$ decreased nitrogen and protein in some legume, but the decrease were not found when plant were supplied with sufficient nitrogen.

Keeping in view above facts on response of crop plants to rising CO$_2$ and temperature, it may be concluded that rising CO$_2$ may increase yields substantially through enhanced photosynthesis and improved WUE but the effects of CO$_2$ on crops will depend upon the magnitude of changes in air temperature. Elevated CO$_2$ may ameliorate, but often will not offset negative effects of temperature are above optimum. In areas, where high temperature is already acting as a limiting factor for crop productivity, further increase in temperature in near future, will result in losses in crop yields despite of increase in CO$_2$. In addition, the magnitude of crop response to elevated CO$_2$ and temperature appears to be species and even cultivar specific. Climate change will have an impact on the predictability and variability in the availability of water and also increase in frequencies of drought and floods. Worst sufferers would be farmers of the farm fed agriculture, which cover 60% of ill cultivated land in the country. The risk of crop failures will increase in semi-arid zones with prolonged dry seasons forcing people to migrate when stability of foods production cannot be assured. Irrigated areas in large ever deltas and basins can also be at risk because of a combination of sectors such as reduced rainfall salinity, increasing floods sea level rise urban and industrial pollution.

Indian Scenario among the globe

Climate change and agriculture are interrelated. Agriculture contributes, of course partly to the global warming by spewing GHG and is turn gets affected by its consequences. However, GHG emissions from drought farm sectors and the effect of global warming on the sectors have not been quantified except in few cases, such as wheat. The Indian Council of Agriculture Research (ICAR) has established that annual wheat output may decline by four to five million tons with every one degree Celsius rise in temperature. The impact of climate change will have to be mitigated by modifying farming practices by farmers, for which ICAR has already undertaken various studies. These studies emit some light in the impact of climate change on some crops and other farm sectors like fisheries. They also explain the impact of climate change on some crops and other farm sectors like fisheries. These are a critical need to get beyond popular biomass against the use of agricultural biotechnology and develop forward-looking regulatory frame-works based on scientific evidence (Khan et al. 2011e).

In 2008, the most recent year for which statics are available, GM crops were grown on almost 300 million acres in 25 crops were grown on almost 300 million acres in 25 acres in 25 countries, of which 15 were developing countries (James 2008). The world has consumed GM crops for 13 years without incident. The first few GM crops that have been grown very widely including insect-resistant and herbicide-tolerant corn, cotton; canola and soybean have increased agricultural productivity and farmers incomes. They have also had environmental and
health benefits such as decreased use of pesticides and herbicides and increased use of no-till farming (Brookes & Barfoot 2008; Mazid et al. 2011f). The emission, from the country’s 21-42 million hectares of land under rice cultivation, comprise about 2.07 Tg of CH$_4$, 0.19 Tg N$_2$O and 72 Tg of CO$_2$ annually. However, the emission levels vary from region to region depending on cultivation practices and the inherent carbon content of the soil. The high emission of CH$_4$ is due to the presence of higher organic carbon content in the soil and the traditional practice is keeping rice fields constantly submerged under water. Similarly, emission of N$_2$O is higher in paddy fields in Andhra Pradesh and Northern states because of application of high doses of N-fertilizers. On the other hand, eastern and Southern parts of the country have a relatively high global warming potential because of higher discharge of CH$_4$ and CO$_2$ and the predominance of rice cultivation in the region. Studies on the impact of global warming conducted indicate that the rise in temperature will lead to an increase in water requirement of crops like maize, groundnut, pigeon pea and cotton through their growing duration will decrease by one to two weeks. Despite the excellent safety and efficiency record of GM crops, regulatory policies remain almost as restrictive as they were when GM crops were first introduced. In the U.S case-by-case review by at least two and sometimes three regulatory agencies (USDA-EPA and FDA) is still commonly the rule rather than the exception. Perhaps the most detrimental effect of these complex, costly and time intensive regulatory approaches is the virtual exclusion of public sector researchers from the use of molecular methods to improve crops for farmers. As a results, there are still only a few GM crops, primarily those for which there are a large seed market (James 2008), and the benefits of biotechnology have not been realized for the vast majority of food crops.

In the case of CH$_4$ emissions from the livestock sector, it has been observed that through cross-bred cattle discharge relatively more CH$_4$ per animal, the bulk of the total emissions is accounted for by buffaloes and indigenous cattle because of their far longer population. What is needed is a serious revaluation of the existing regulatory framework in the light of accumulated evidence and experience. An authoritative assessment of existing data on GM crops safety is timely and should encompass protein safety, gene stability acute toxicity, composition, nutritional value allergencity, gene flow and effects on non-targeted organisms. This would establish a foundation for reducing the complexity of the regulatory processes without affecting the integrating of the safety assessment. Such an evolution of the regulatory process in the U.S would be a welcome precedent globally (Table 2).

On the other hand, some crops have already begun adjusting to climate change. It is also critically important to develop a public facility within USDA with the mission of conducting the requisite safety testing of GM crops developed in the public sector. This would make it possible for university and other public-sector researchers to use contemporary molecular knowledge and technologies to improve local crops for farmers (Fedoroff et al. 2010). However, it is not at all a foregone conclusion that our current crops can be pushed to perform as well as they do now at much higher temperature and with much less water and other agricultural inputs. It will take new approaches, new methods now technology—indeed, perhaps even new crops and new agricultural systems. Climate change, more particularly harsher weather conditions, will have impact on the quality and viability of fish and aquaculture enterprises thereby affecting fishing community. The small-scale fishers may be faced with greater uncertainty as availability, access, stability and use of aquatic food and supplies would diminish and work opportunities would dwindle. Aquaculture development opportunities will increase in particular in tropical and sub-tropical regions. The climate change in warmer regions offers new opportunities as production in warmer regions will increase because of better growth rates, a longer growing season and the availability of new fish farming area where it was once too cold.

Aquaculture is part of the answer. A kilogram of fish can be produced in as little as 50 litres of water (Rothbard & Peretz 2002), although the total water requirements depend on the feed source, feed is now commonly derived from wild-caught fish, increasing pressure on marine fisheries. As well, much of the growing aquaculture industry is a source of nutrient pollution of coastal water, but self-contained and isolated systems are increasingly used to buffer aquaculture from pathogens and minimize its impact on the environment (Anonymous 2009c).

Climate change and agriculture research in Indian

The desert is a unique ecosystem, harsh climatic and terrain conditions coupled with an amazing grace that life and practices speak of which conserve the natural resources. Interestingly, the heat generated in the atmosphere actually helps to draw the monsoon in the region. Indian agricultural has witnessed momentous growth during the last 60 years. The food grain production increased by 4 times, horticultural crops and milk by 6 times, fish by 9 times and eggs by 27 times since 1950-51. With a strong base for planning, promotion, execution and coordination of agricultural research and education to meet emergency challenges in the country and wide network of institutes spread across the country of the ICAR has successfully constructed to overall development of farm and related sectors, 45 research Institutes, 4 Deemed Universities, 6 national Bureau, 17 National research Centres, 25
Directorates/Project Directorate, 61 all India Co-ordination research projects and 17 Network Projects, 45 States Agricultural universities one central Agricultural university and 570 Krishi Vigyan Kendras are the part of network of ICAR.

To meet the challenges of climate change in agriculture, National Institute of Abiotic Stress management has been established by ICAR at Baramati, Maharashtra. Two major institutions, “The National Institute on Biotic stress management” and Indian Institute of Agriculture Biotechnology are in the process of establishment to address the impact of biotic stress and harness potentials of emerging tools of biotechnology in Agriculture (Mazid et al. 2011g). Two hybrid varieties and 8 high yielding varieties of rice have been developed and released for different agro climatic ecosystems. Besides this, a new wheat variety PUSA Baker (HS 4900 with a seed potential up to 5t/ha and durum wheat variety Malva kranti (HI 8638) for rained and limited irrigation conditions have been developed for water lodged areas that can enhance not water productivity and net returns in rice.

The standardization of a novel hand guided cloning technique in cattle for the first time in the world and the birth of buffalo calf GARIMA produced through this technique is a significant achievement. Efforts to provide timely support in diagnosis of Avian influenza (AI) has led to international recognition of high security animal diseases laboratory (HSADL) at Bhopal. A comprehensive accreditation system is under implementation to enhance quality of education strengthening of infrastructure and faculty improvement in granted to five SAUs during the years, taking the number to 33 till date. A national core group revised the course curricula and syllabi of 95 courses in Master’s and 80 courses in Doctoral Programs. Introduction of international fellowships during the year was a major milestone in globalization higher agricultural education. Besides, 368 e-courses for degree programme has been introduced and created repository of 3,852-e theses and provided online access to 1,088 research journals in 126 libraries. To promote production to consumption chains for maximizing farmer’s profits 51 models developed for different agricultural commodities. Thirty six models of technological based sustainable rural livelihood initiatives introduced in 102 of 150 most disadvantaged districts, benefited 50,000 farm families.

For the first time non-conventional partners were brought into the partnerships into the partnerships in National Agricultural Research through the National Agricultural Research through the National Agricultural innovation project. They include IITs, IIMs, CSIR laboratories and enterprises of private sectors and NGOs. The project, with its approach and expense, has to become a model for other countries to emulate.

**Mitigation strategies**

Agriculture is one of the major sources of GHGs emissions. Climate change has been a cause of serious concern if the agricultural sector has to grow in the context of country’s overall economic growth, to respond to rural household’s livelihood, country’s food security and poverty alleviation. It may take some years to fully experience the devastating effects of climate change on agriculture but the time is ripe for the government, private sector and public to have adequate concern, commitment and accountability to mitigate the effects of climate change. Another part of the answer is in the scale-up of dry land and saline agriculture (Lantican et al. 2003; Mazid et al. 2011h; Khan et al. 2011f). Among the research leaders are several centre of the consecutive Group on International Agriculture Research. The International Centre for Bio saline Agriculture and the Jacob Bluestein Institute for Desert Research of the Ben-Gurion Universities of the Negev. Moreover, significantly investing expanding, modernizing and equipping agricultural meteorology facilities in all 127 agro-ecological regions to make it world class, thereby continuously improving weather and limited forecasting system. Systems that integrate agriculture and aquaculture are rapidly developing in scope and sophisticated. A 2001 United Nations food and Agriculture Organization Report (Anonymous 2001), describes the development of such systems in many Asian countries. Today, such systems increasingly integrate organisms from multiple tropic levels (Chopin et al. 2008). In this context, we should to diversifying pattern of livelihood and adopting agricultural, fishing and forestry practices to efficient water management and soil conservation practices and growing resilient crops and tress. Also, developing a database on climate soil and water use and crop yields to assess, map and monitor land-use performance under given technology conditions. Assessment of how vulnerable or food system in and how we can adopt agriculture, livestock fisheries and forestry to future climate-related disasters. Increasing coastal inundation, salinization and erosion as a consequence of sea-level rise and human activities may contaminate and reduce the size of productive agricultural lands, thereby threatening household’s livelihood and country’s food security. Steps to mitigate the impact of climate change on agriculture need top priority. An approach particularly well suited for coastal deserts includes inland seawater ponds that support aquaculture, the nutrient efflux from which fertilizers the growth of halophytes, seaweed salt-tolerant grasses and mangroves useful for animal feed, human food, and bio fuels and as carbon sinks (www.seawater foundation.org). Such integrated systems can eliminate today’s flow of agriculturally nutrient from land to sea. If done on a sufficient scale, inland seawater systems could also compensate for rising sea levels.
In addition, evolving policy and programs to manage and mitigate risks due to climate change. Improving early warning systems followed by effective monitoring and evaluating its impact. Developing climate impact modules that give a better understanding of how climate change may affect crop, livestock and fish farming and forestry at local level in order to be well prepared. The heart of new agricultural paradigms for a hotter and more population’s world must be systems that close the loop of nutrient flows from microorganisms and pests to animals as much as possible by subject and sea water. This has the potential to decrease the land, energy and fresh water demands of agriculture while at the same time ameliorating the pollution currently associated with agricultural chemicals and animals wastes. The design and large scale implementation of farms based on non-traditional species in arid places will undoubtedly pose new research, engineering, monitoring and regulatory challenges with respects to food safety and ecological impacts as well as control of pests toward eliminates hunger we must scale up and further build on the innovative approaches already under development, and we must do also immediately.

Conclusion
Agriculture development in India needs to focus on reducing GHG emission through measures, such as significant reduction of deforestation; improving forest conservation and management; effect control of wildfires; promotion of agro-forestry for food or energy; soil carbon sequestration; restoring land through controlled grazing; improving nutrition for ruminant livestock; efficient management of livestock wasteland developing strategies that conserve soil and water resource by improving their quality; availability and efficiency of use. While a National Network Project “Imact Adoptability and Vulnerable of Indian Agriculture of Climate Change” has been launched with a focus on impact of climate change on different sectors of agricultural population’ it is necessary to make sufficient investments to support climate change to adaptation mitigation technology development transfer and dissemination among farmers.

1. Evolving comprehensive climate resilience strategies comprising risk assessment development of varieties that can perform well in stressful conditions, better land water and livestock management and bringing about specific changes in agricultural practices that can respond to climate change.

2. While agricultural research institutes and universities have already been engaged in researching drought-resistant and saline-resistant crop varieties for the arid-regions and rainfall-tolerant and short-duration varieties for flood-prone regions, government and private sector will have to invest substantially in agricultural research on one hand and motivate farmers to take better advantage of the dry rabi season in the flood-prone regions and help them supplement their income through on-farm activities on the other.

3. Developing contingency plans to cover new and evolving risk scenarios.

4. Promotion of best-crop-livestock-fish farming practices through farmer’s capacity building and networking.

5. Conceptualization and Implementation of National Adoption Program of Action on Climate change.

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