Environ Earth Sci (2016) 75:412
DOI 10.1007/s12665-015-5127-7

ORIGINAL ARTICLE

The challenge of climate change and policy response in Pakistan

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Received: 13 January 2015 / Accepted: 1 October 2015 / Published online: 24 February 2016

Abstract Climate change is expected to have adverse impact on Pakistan. This is ironical for a country, which ranks 135th in the world in terms of global green house gases (GHG) emissions per capita, but ranks 16th in terms of vulnerability to climate change. Climate change poses a major threat to all dimensions of sustainable development and has widespread impacts across various sectors and ecosystems such as food, water and energy; forests and biodiversity; coastal and marine environment; as well as on the occurrence and intensity of climate related hazards such as floods and drought. It also carries potential for internal and external conflicts. The paper examines the present and potential impact of climate change in Pakistan, and reviews national policies and plans to examine the extent to which climate-related issues have been integrated within these. The paper also discusses adaptation and mitigation measures and identifies the key elements that need to be included in the Climate Change Action Plan of Pakistan and stresses their mainstreaming into the national development policies and plans.

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Keywords Vulnerability · Hazards · Impacts · Climate change policy · Mainstreaming · Development plans

Introduction

Climate change has the potential to seriously harm Pakistan, with its tremendous social, environmental and economic impacts. The effects of global warming and climate change are relatively more pronounced in the country due to its over-reliance on the environment for basic survival, high population growth rate and density, low capacity to adapt to the negative impacts of climate change, and poverty. Realizing the high vulnerability to climate change, the country has developed national policy to combat climate change and is now to embark on developing an action plan to effectively implement climate change concerns in the planning process. This paper reviews the potential impacts of climate change and Pakistan's experience in addressing the related issues. The paper has been divided into five sections. This brief introduction is followed by the section on climate trends in Pakistan. The next section highlights country's vulnerability to climate change, followed by a section on major steps that have been or are being undertaken in the country to address the challenge of climate change as an on-going process. The way forward is next and the concluding section sums up findings of the study.

Climate trends in Pakistan

Substantial work has been conducted on climate indicators and their trends in Pakistan. The studies carried out by Global Change Impact Studies Centre (Shakoor et al. 2009;

Ali et al. 2009) and Pakistan Meteorological Department (Husain et al. 2005; Gadiwala and Sadiq 2008; Zahid and Rasul 2009; Ahmad et al. 2010) in particular are quite significant in this regard. The findings of these studies and analysis reveal that the climate of Pakistan is changing.

Temperature trends

Average annual temperature over Pakistan, in agreement with the global trend, increased by 0.6 °C during the last century. The rate and nature of change, however, had some variation across the country and over time. For example the temperature increase over northern Pakistan was higher compared to southern parts (0.8 vs 0.6 °C). Further, it was higher in second half compared to the first half of the last century. The rate of warming, increased in recent decades reflecting a rise of about 0.24 °C per decade between 1960 and 2007 compared to 0.06 °C per decade earlier (Fig. 1) again, similar to the global trend. The studies conducted at regional and city level (Cheema et al. 2006; Sajjad et al. 2009; Sadiq and Qureshi 2010; Mahar and Zaigham 2010) have also shown increasing trends in temperatures.

The Intergovernmental Panel on Climatic Change (IPCC) assessments based on the projection of future global climate with the help of various Global Circulation Models (IPCC 2000a, b) predict somewhat higher temperature increases in the region where Pakistan is located as compared to average global temperature increase (Cheema et al. 2006). Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen (Pachauri 2014). The research at Global change Impact Studies Centre (GCISC) in Pakistan, based on historical weather data and modeling have shown a strong correlation among the IPCC's predictions, and projections for Pakistan (Islam et al. 2009). The projected changes are shown in Fig. 2, whereby temperature in 2020s, 2050s and 2080s are compared to the base period over Northern and Southern Pakistan using 31N latitude as the boundary. The projected temperature increase in 2020s, 2050s and 2080s for whole Pakistan are 1.31, 2.54 and 4.38 °C in A2 scenario. The results show that rise in temperature throughout Pakistan is higher than the corresponding globally averaged temperature increase at the end of the time horizon. Moreover, the temperature increase in Northern Pakistan is higher than that in Southern Pakistan.

Precipitation trends

The trend in average annual precipitation also recorded increase in Pakistan during the last century. It is estimated to have enhanced by 25 % over the previous century (Shakoor et al. 2009). There is an overall increase in the wet events in the country too. Forty-one out of 54 meteorological stations recorded enhanced trend in precipitation. Regarding projections, current generation of global circulation models (GCMs) is not so reliable for predicting precipitation. Observation of the GCISC using the ensemble outputs of 13 GCMs for the A2 scenario and 17 GCMs for the A1B scenario (Sheikh et al. 2009) indicates that precipitation in both Northern and Southern Pakistan, is likely to increase in summer and decrease in winter with no significant change in annual precipitation.

Vulnerability to Climate change

Pakistan is highly vulnerable to the adverse impacts of climate change. Maplecroft (2010) Index of vulnerability to climate change gives Pakistan 16th rank among 170

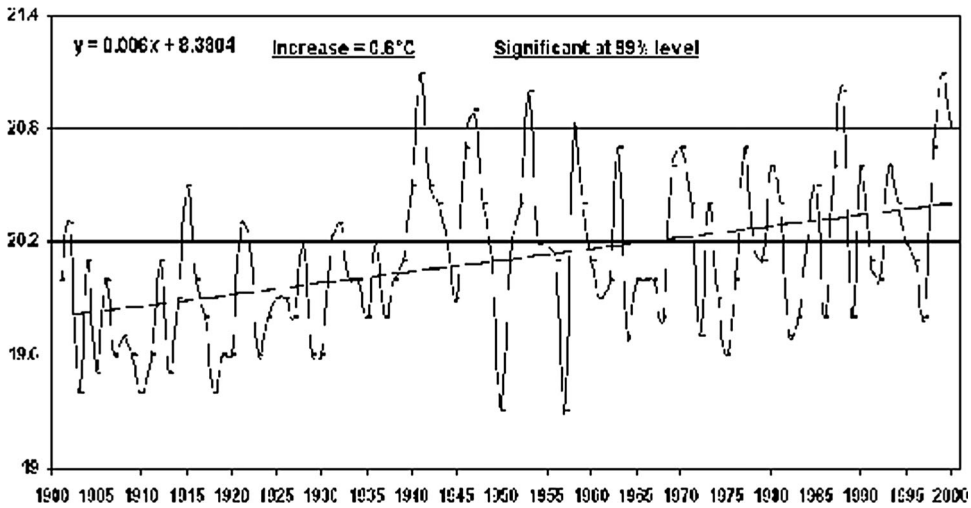

Fig. 1 Pakistan: Mean temperature (°C) trends between 1901 and 2000. Source: Global CHANGE Impact Studies Centre, Ministry of Environment, Government of Pakistan (GCISC, MoE, GoP)

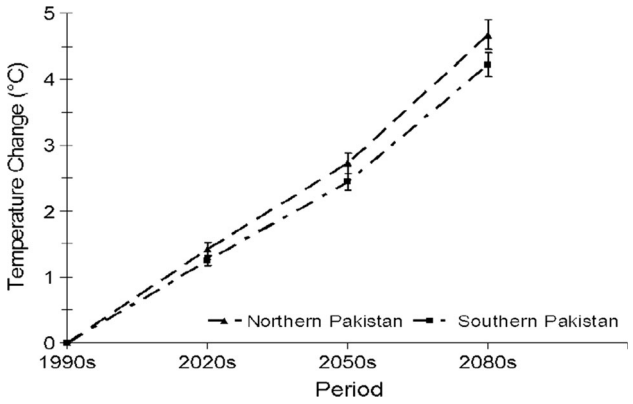

Fig. 2 Projected changes in average temperature of northern and southern Pakistan (coarse resolution results) for A2 scenario, based on ensemble of 13 GCMs (Global $\Delta T = 3.4$ °C in 2100). Source: GCISC, MoCC, GoP

nations of the world. The country has moved up in the vulnerability index since 2010, when it was rated 29th (Maplecroft 2010). The 2012 Global Climate Risk Index of Germanwatch ranks Pakistan as eighth among over 180 nations of the world (Hamering 2012). It had given Pakistan the first rank in 2010. This is rather ironical for a county that contributes very little to the global Greenhouse gases (GHG) and ranks 135th in the world in per capita GHG emissions.

The adverse effects of climate change are already being felt in Pakistan. Two examples of these are the history's worst drought that the country experienced in 1998–2001 and the history's worst flood that hit it in 2010. The later affected 25 million people in all four provinces of the country and resulted in economic loss of 9.5 billion US dollars. These are likely to enhance in the wake of possible drastic shift in weather pattern. The impacts of climate change will be felt in all dimensions of sustainable development—economic, social as well as environmental.

Economic

Economically, the detrimental impacts of climate change will be widespread and have bearing not only on water security, food security and energy security but also on diverse sectors including agriculture, livestock, forests, and fisheries, industries, transport, etc. In view of widespread adverse impacts of climate change on various economic sectors, a major concern of the national planners and policy makers is to translate these into monetary values so as to have some idea on the total costs of these negative impacts on the national economy of the country. Another serious concern is to estimate the cost that the country needs to incur on the coping mechanism, i.e. towards adaptation measures, in order to minimize the risks to the key sectors, i.e. water, food, energy etc. Yet another economic concern arises from the fact that, as a responsible member of the world community, Pakistan is keen to make contribution to the global mitigation effort, most of which are also quite expensive (Cheema et al. 2006). The above concerns are extremely important and most critical in drafting the country's development plans in the most optimal manner particularly in view of the limited available resources.

Water security

Pakistan is already experiencing a shortage in freshwater resources. In the wake of growing population, per capita water availability declined from 5600 cubic meters in 1951–1200 cubic meters in 2003, and is reaching close to the water scarcity threshold level of 1000 cubic meters (Commission Planning 2007). Maplecroft (2010b) index of water security risk already classifies Pakistan as an extremely high-risk country giving it 7th rank among 165 nations of the world (Maplecroft 2010b). The country has two main sources of water; rainfall and glacier and snowmelt. Rainfall is brought by monsoon and westerly winds, which together contribute about 50 million acre-feet or 60 billion cubic meters. Water supply from snowmelt and glaciers of the Hindukush–Karakoram–Himalayas Mountains is another 141 million acre feet or 174 billion cubic meters in the Indus River System (Commission Planning 2010). Both these sources are likely to be affected by climate change. Therefore, in the wake of limited scope for expanding the supplies of water; Pakistan will have to go for improving the efficiency of water use in agriculture sector. The existing irrigation from the Indus River System is highly inefficient. It has been estimated that Pakistan wastes twice the amount of Indus water every year in watercourses than that could be stored at Tarbela dam. 60 % of irrigation water is lost during transmission from source to the field. Almost 50 % of the losses are at watercourse level and 33 % are at canal level, because of inadequate operation and maintenance of a deteriorating canal system (Ahmad et al. 2007).

The area, worst affected, due to climate change would be the lower Indus Plain particularly the deltaic region. Currently on the average, about 106 million acre-feet (maf) of the river flows in Pakistan is diverted to the canal system. The average outflow to the sea below Kotri is about 35 maf (average for 1976–1977 to 2002–2003 period) with the minimum flow being as low as 0.8 maf recorded in 2000–01 (GoP 2005a). In the low-flow years, water going to the sea is less than that necessary to prevent intrusion of seawater into the Indus deltaic region (Gonzalez et al. 2005). Hence besides quantity, the quality of water would also be affected by the intrusion of seawater, which by 2010 had moved 60 km inside the Indus River (Siddiqi 2010). The problem will aggravate with the rise in sea level.

Impacts of climate change on water resources is also of serious concern in all parts of the world. Monitoring programs are underway in karst springs in Wallonia (southern Belgium) to study the discharge behavior of river and the impacts of climate change on groundwater resources due to the perceived rise in temperature of 0.4 °C between 2007 and 2012 (Meus et al. 2014). Yagbasan and Yazicigil (2012) have analyzed the impacts of climate change on Mogan and Eymir Lakes' levels in Central Turkey through lake-aquifer simulation model. They have predicted significant declines in lake levels unless measures are taken for their management. Samper et al. (2014) have predicted impacts of climate change in Iberian Peninsula, especially reductions in ground water resources. The study evaluated the impacts on Plana de La Galera and Tortosa alluvial aquifers in Spain in the simulation periods 2020–2050 and 2069–2099. The impacts are likely in the form of decrease in groundwater recharge mechanism and rise in the mean sea level. Another study by Kabiri et al. (2014) on the Klang watershed in Malaysia has predicted changes in the mean annual discharge. Another study in China has shown changes in the hydrological system due to climatic variability in the upstream and downstream areas (Lu et al. 2014). The authors have pointed out coping strategies by improving the balance of hydrological system by increasing recharge mechanism, implementing water conservation in agriculture and use of treated sewage of urban areas for environmental flows in rivers and restoration of wetland.

Food security and agriculture

Pakistan is not in a happy position in terms of food security. The Maplecroft food security risk index classifies it as a high-risk country, ranking it 30th among 163 nations of the world (Maplecroft 2010c). Agriculture dependent on canal irrigation system is based on diverting water from rivers to farms through the worlds' largest irrigation network. The quantity of water in rivers is declining due to perpetual threats to their watersheds. The climate change will further aggravate the situation. It will impact the food security primarily by reduced agricultural and crop productivity and adverse impacts on livestock health, productivity and reproducibility. Though, there are already substantial existing crop yield gaps in Pakistan (Table 1), the situation will aggravate further due to climate change.

Agricultural crop productivity will be affected due to alteration in biophysical relationships like changing growing periods of the crops or scheduling of cropping seasons, as well as increasing crop stress due to enhanced evaporation–transpiration, changing irrigation water requirements, reduced availability of irrigation water and Intrusion of seawater into deltaic region of Indus affecting coastal agriculture. Changing pattern of rainfall in terms of frequency and intensity may also cause further deterioration of the already cultivated land suffering from water logging and salinity and wind and water erosion. According to estimates about 40 % of irrigated land has been affected by either salinity or waterlogging (GoP 2011 and another 3–5 million hectares has been affected by wind erosion. This limits Pakistan's ability to expand cropped area. The total cost of salinity has been estimated at Rs.30–80 billion, with a mean cost of Rs 55 billion, or 0.9 % of gross domestic product (GDP) in 2004, while the total cost of reduced yields resulting from soil erosion in Pakistan has been estimated at Rs.15 billion per year, or 0.25 % of GDP. The risk of insects, pests and pathogens may also enhance in warmer and more humid environment due to climate change. Production losses may also occur through enhancement of extreme events (floods, droughts and cyclones).

Productivity of livestock is also highly vulnerable to the direct and indirect impacts of climate change. Physiological stresses on animals due to high temperature will lower productivity of milk and meat and their reproduction capacity will decrease at elevated temperatures. Further, climate-related disease epidemics will enhance due to heat and humidity and extreme climate events such as floods, droughts, heavy rainfalls, hailstorms, and cyclones will not only cause their casualties but also affect animal habitats and environment. The indirect impacts will primarily be

Table 1 Pakistan: yield gaps of major crops

Crop	World best yield (2008) (tonnes/ha)	World average (2008) (tonnes/ha)	Progressive farmers' yield (tonnes/ha)	National average yield (Avg. of last 3 years) (tonnes/ha)	Yield gap w.r.t progressive farmer (%)
Wheat	8.3 (UK)	3.09	4.6	2.6	43.5
Cotton	1.9 (Australia)	0.73	2.6	1.8	30.8
Sugarcane Sindh Punjab	121.1 (Egypt)	71.51	200	54.5	72.8
			130	49.9	61.6
Maize	9.7 (USA)	5.11	6.9	2.9	58.5
Rice	9.7 (Egypt)	4.31	3.8	2.1	45.6

Source: Agricultural Statistics of Pakistan 2008–2009, Planning Commission, 2009

through declining rangeland productivity, as well as reduction in quantity and quality of fodder crops. This is extremely serious for Pakistan where the livestock sub-sector maintains over half the value-added in agriculture (53.2 %) and has a great potential for growth in future.

Energy security

Based on historical and current trends in economic growth, Pakistan envisages 8.8 % energy growth, or a total energy need of 361 million tons of oil equivalent (MTOE) by 2030 (GoP 2005b). Provision of long-term energy security by 2030 therefore, means enhancing the production to about six times from the present (2010–11) supply level of 64 MTOE (Fig. 3) (GoP 2011). This requires sustained efforts that should effectively take into consideration the impact of climate change. Other countries in the region are also likely to face similar consequences due to climate change. Impacts in the form of warming trend have been observed in China during the past 50 years varying from 0.2–0.3 °C/10 years (in northern China) to 0.1 °C in southern China (Fig. 4). The study has predicted frequent droughts and floods, which may disrupt the economic, social and environmental settings in the region (Lian et al. 2014). The millennium old profession of grazing livestosck in Mongolia may be at risk due to higher rate of grazing together with conversion of grassland into agricultural land. The practice leads to serious soil erosion and threats to water resources, however, the erosion risk scenarios studied for Kharaa river basin (KRB) in Northern Mongolia are largely dependent on climate factors, besides land use and management measures (Priess et al. 2014).

Climate change will have both direct and indirect effects on energy sector. The direct impacts will include change in the amount and timing of water availability for both hydropower generation and thermal power plant cooling; reduction in hydropower generation capacity due to reduction in river flow rates and higher rate of sedimentation of major reservoirs; decrease in efficiency of thermal power plants as a result of increase in temperatures; damage to the energy infrastructure located along the coast due to sea level rise and increased cyclonic activity; change in renewable energy potential because of impacts on cloud cover, wind resources and agricultural productivity and its by-products; increased Transmission and Distribution (T&D) losses due to increased temperatures, and frequent occurrence of blackouts because of line sagging [present distribution losses in the energy systems tend to be around 23 %, whereas the technical losses should be no more than 3 % (Ali 2008)]. Indirectly, higher temperatures will enhance energy needs because of its impact on other sectors for example increased demand for space cooling in domestic and other sector and pumping of groundwater for irrigation to compensate for evaporation losses in agriculture sector, etc.

Urban and industrial areas

Urban and industrial areas will face problems of enhanced heat island effects, increased air and water pollution, and consequences of increasingly viable disease vectors. The most serious potential impact of climate change on urban settlements would likely be flooding particularly through heat island and high intensity rainfalls as has already happened in Rawalpindi/Islamabad and Masroor Airport base Karachi. On 23 July 2001, Rawalpindi/Islamabad twin cities received 621 mm rainfall during 10 h that caused flooding in Lai Nullah (Cheema et al. 2006) received 621 mm rainfall during 10 h that caused flooding in Lai Nullah (rivulet). Similarly, Karachi received 205 mm of rain at Masroor Airbase and 143 mm at Airport on 18 and 19 July 2009. Heaviest rainfall earlier recorded at Karachi Airport was 207 mm on 1st July 1977. The normal rainfall at Karachi Airport for the 1961–1990 and 1971–2000

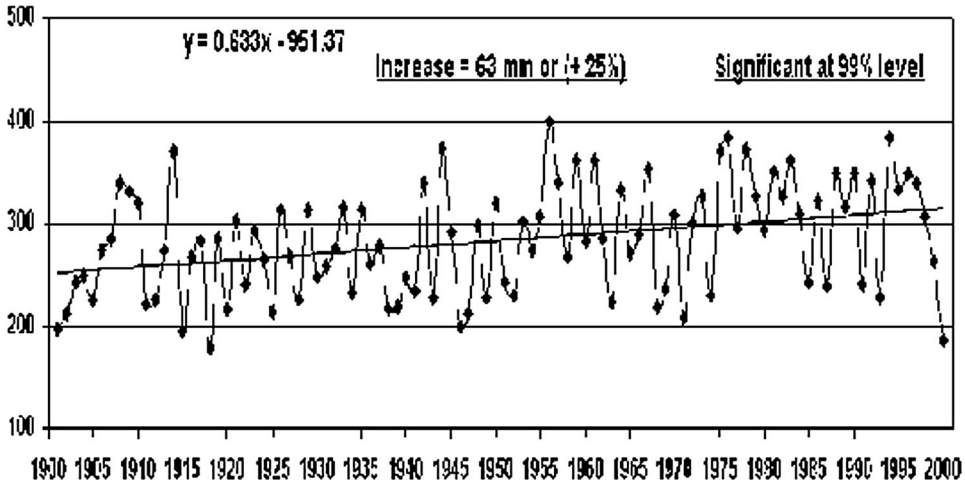

Fig. 3 Pakistan: annual precipitation trends (mm) between 1901 and 2000. Source: Shakoor et al. (2009)

periods were 85.5 and 66.2 mm, respectively. Urban flooding poses a particularly serious problem in Pakistan because storm drains, water supply, and waste management systems are not designed with enough system capacity to cope with them. Such flooding that results from overwhelmed urban storm drains and sewers during extreme rainfall events may take unusually heavy toll in future Floods, cyclones, may also threaten urban and industrial infrastructure and storm surges, and in the long run, by sea level rise would also have detrimental impacts. Karachi, the largest city of Pakistan accommodates 10 % of the total population, and about 40 % of all manufacturing units (Cheema et al. 2006) is the most vulnerable due to its location on the coastline.

Cities would also bear the impact of urban heat islands with affect on human health and energy demand, as well as some of the more severe aspects of air and water pollution. They may also need to accommodate migrant populations or the climate refugees in future.

Social impacts

Climate change will also have social impacts such as adverse effects on health; cause displacement of people and loss of their income due to enhanced extreme natural events such as floods and droughts or sea level rise. As such, it could also jeopardize hundreds of jobs; may result in inflation of food prices and increase number of people at risk of food security and hunger; and result in migration, civil unrest and conflicts. The capacities of individuals, communities, and societies in Pakistan to effectively respond to such hazards will be based on a combination of natural, human, social, financial and physical factors. For example, coastal communities, and small farmers will be at greater risk. The rural houses constructed from mud and makeshift materials will be more at risk compared to better quality houses in urban areas. Poor will also have problems due to increased cost of living as a result of reduced food security, enhanced health related expenditure and increase in the energy prices.

Community-level surveys in three selected areas (Badin District in Sindh, Rajanpur in the Punjab and Khuzdar in Balochistan) show that communities have experienced significant changes in climate (Oxfam 2009). The findings of the surveys depict that climate change is already enhancing the environmental problems in the three districts, and they are likely to increase in magnitude in the future. The report of the survey states, "Poor and marginalized communities tend to be most vulnerable to climate change and least be able to cope with weather-related disasters because of lack of access to information and resources to reduce their risk. The predicted impacts of climate change will increase further existing vulnerabilities, inequalities and exposure to hazards" (Oxfam 2009). Communities interviewed reported hotter temperatures and more erratic rain, and shortening of crop-growing season with serious implications for food security. It is therefore extremely important for policy makers to take these factors into account while framing a climate change policy or adaptation measures. The major climate induced social impacts relate to health, extreme climatic events, and conflicts and security.

Health

Warmer temperatures and greater humidity would increase the months of the year in which mosquitoes are active and hence aggravate malaria. This can be anticipated to be a major new hazard in northern areas of Pakistan where the mosquito season is currently limited by low temperatures in winter. Malaria is only one of the vector-borne diseases expected to expand northwards. Higher air and water temperatures are favorable to reproduction rates of many types of flies and other vectors of disease and thus an increase in infectious diseases are also to be expected, particularly in the northern half of Pakistan.

The recent outbreak of dengue fever in parts of Pakistan might be having its origin in the change of climate. The first case of dengue fever was reported in Pakistan in 1994 but the figure has now passed thousands (Shah 2012). Various other health impacts that can result from the increase in extreme weather conditions resulting from climate change include pneumonia, heat stokes, cholera, and heart attacks etc. Another climate change related impact of particular concern to Pakistan is the 'winter smog', which is the combination of air pollutants (smoke) and fog that has been seriously affecting almost entire Punjab in December and January for the last several years. The winter fog mixes and holds the suspended air particles for a longer duration that can affects plants as well as human being (Ebi et al. 2008). Dengue transmission is critically dependent on climatic factors and there is much concern as to whether climate change would spread the disease to areas currently unaffected. The risk maps indicate that climate change is likely to contribute to increased dengue

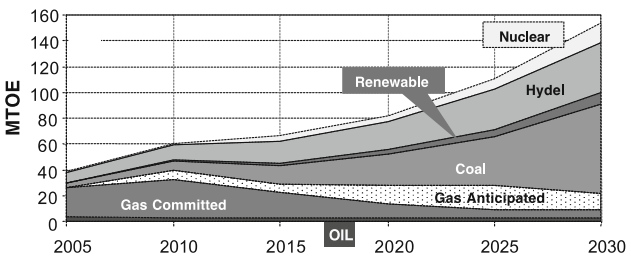

Fig. 4 Pakistan: indigenous energy supply projections. Source: GoP (2005a)

risk in many parts of Europe, especially towards the end of the century. The areas of greatest increased risk are projected to be clustered around the Mediterranean and Adriatic coasts and in northern Italy (Maha et al. 2014). It is believed to be due to the continental scale air pollution known as Atmospheric Brown Cloud (UNEP 2008), it is expected to increase as the use of coal and petroleum increases in India and China over the coming decades.

Extreme climatic events

One of the worst effects of climate change in Pakistan is likely to be on the frequency and intensity of extreme natural events such as floods, droughts and cyclones. According to a recent report (Oxfam 2009), 40 % people in Pakistan are highly vulnerable to natural disasters like floods, drought, cyclones, intense rainfall, and glacial lake outburst floods. Vulnerability of the country to such events is evident from the history's worst flood that occurred recently affecting 25 million people in all the four provinces (More than those hit by 2004 tsunami, 2005 earthquake disaster of Pakistan and 2009 earthquake of Haiti). It resulted in the estimated economic loss of 9.5 billion dollars. Over 1900 people were killed, seven million were rendered homeless and 1.8 million homes and two million hectares of agriculture were destroyed (Thomas and Rendon 2010). Similarly, the floods in 1991–1992 made 1992–1993 agricultural growth rate negative, thereby reducing overall GDP growth rate to only 2 % as compared to GDP growth of 7 % in 1991–1992. Pakistan experienced the history's worst drought in 1998–2001, which affected over 3.3 million people, and 30 million livestock. It made thousands of people refugees, killed hundreds of human being and some 2 million livestock from thirst and starvation (GoP (Government of Pakistan) 2003, 2009). Floods and droughts associated with climate change are areas of serious concerns because Pakistan is primarily a rural country with 62 % of its people residing in villages and deriving their livelihood from agriculture.

Climate change is now inevitable (Shaikh et al. 2010). The poor, living in developing countries, will be the first to pay, and will, unfortunately, pay the most. Climate change were expecting as the Indus is swelling up with the unprecedented monsoon rain and the melting of glaciers (Rose 2001). However, they were unsure of how much additional water there would be. Now, the monsoon rains in the northern parts of Pakistan are described as being the heaviest in the last 80 years (Bezirtzoglou et al. 2011). Similarly, scientists and researchers agree that once the ice in the Himalayas has gone, the Indus will dry up. Floods are among the most major climate-related disasters. In the past decade, reported annual losses from floods have reached tens of billions of US dollars and thousands of people were killed each year. Losses and the number of casualties could be larger in the future. Thus, an assessment of changes with regard to floods is a public concern (Semenza and Menne 2009).

In the current study, we conclude that increased precipitation leads to higher *E. coli* concentrations suggesting that expected climate change like more flooding due to unusual rainfall pattern and increases surface air temperature could also contribute to high *E. coli* concentrations and thus other waterborne pathogens that will ultimately increase the chances of diarrhoea that are already on the rise in the region.

The expected increase in the tropical cyclone activity in the Arabian Sea due to climate change is another issue of serious concern for Pakistan because a large fraction of the country's industrial infrastructure is located in the coastal city of Karachi, which is quite vulnerable to the tropical cyclones generating in the Arabian Sea. In June 2007, two super cyclones originated in the Arabian Sea and hit Makran coast and adjoining areas. No such events occurred twice within a month in Arabian Sea during the last century (Cheema et al. 2006). Glacial dam burst also pose a threat to Pakistan due to climate change and glacial melting. On 4 January 2010, a landslide in Northern Pakistan blocked the Hunza River, creating a 7-mile (11-kilometer) long lake that inundated several villages and submerged 3 miles (5 km) of the Karakoram Highway. The breach of this dam could have flooded several villages downstream and its impact might have reached Tarbela Dam, therefore, an artificial spillway had to be created to avoid a disaster of enormous proportion. Such incidents can also occur elsewhere with 52 such vulnerable lakes present in Northern Areas of the country (Khan 2011). The recent glacial disaster in April 2012, which buried 139 Pakistani soldiers in Giyari sector, Siachin is another warning of climate induced extreme manifestations.

A serious social impact of climate-induced disasters is displacement and migration. More than half a million Pakistanis remained displaced due to the 2011 floods in Sindh Province. Prior to this, the drought of 1998–2001 had displaced thousands. In majority of such events, the most poor and vulnerable are trapped because they very often have a low capacity to move.

Conflicts and security threats

The climate change may also become a threat in terms of both internal and external security in the wake of loss and reduced availability of resources. Increased competition for availing scarce water, food and energy resources could breed both internal and external conflicts. Water issue is the most serious in Pakistan. Internally, the water distribution issue appeared to have been resolved between the

provinces of Pakistan through the Indus Water Accord reached in 1991 (GoP 1991). However, lack of trust among the provinces especially between Punjab and Sindh is at the heart of the water issues in Pakistan. Sindh Province (the lower riparian in this case) questions the upper canal withdrawals and feels that it is either being deprived or will be deprived of its share of water by Punjab. It, therefore, views any new project or plan in the water sector with a great sense of skepticism. It feels that because of the historical events its skepticism is justified (PILDT 2003). Punjab Provincial Government also faces problems with Indus River System Authority on withdrawal of water for Punjab from the Tarbela dam. The issue would get more complicated in the coming years with increasing shortfall in water that has been estimated to reach 30 % by 2030. In order to meet the growing needs, more dams would need to be constructed which is another bone of contention between provinces. For example, while the Punjab Province supported the construction of Kalabagh Dam, both Khyber Pakhtunkhwa and Sindh oppose it, as they are to bear the environmental brunt of the project.

Indus water may also become a recipe of conflict between India and Pakistan. According to Indus Water Treaty brokered between India and Pakistan in 1960, the water of three western rivers The Indus, Jhelum and Chenab were allocated to Pakistan. However, India has already started building Baglihar Dam over River Chenab, which flows from Kashmir to Pakistan with prompt protests from Pakistan (Akhtar 2010). A US Congressional Research Service in its Report on 'Security and the Environment in Pakistan' prepared for members and committees of the Congress said, "Drought can stress water supplies along the Indus River and potentially exacerbate tensions between Pakistan and India and can further lead to reduced hydropower supplies and catalyze protests in areas experiencing rolling blackouts, and of course contribute to economic stresses in Pakistan's agricultural regions, where the majority of Pakistanis live" (CRS 2010). In March 2009, a group of more than 20 different UN bodies warned that, since water has become the latest cause stoking tensions between India and Pakistan, the world might be perilously close to its first water war (WWAP 2009). Nevertheless, cooperation and adaptive capacity development may reduce and even diminish the potential of conflict.

Environmental and biophysical impacts

Climate change will also have serious impacts on Environmental/biophysical conditions such as change in the ecology and habitats. Greater risks will be posed to Pakistan's coastal and marine environment; forest and biodiversity, and other vulnerable ecosystems such as rangelands, degraded lands and mountain ecosystems.

Coastal and marine environment

Pakistan, with a coastline of about a 1000 km, is classified by UNEP' s Ocean and Coastal Area Program Activity Centre as being "particularly vulnerable to the effects of sea level rise (GoP 2003). National Institute of Oceanography (NIO), on the basis of recorded sea level rise data for the last hundred years at Karachi shows that rise in the sea level along the Pakistan coast is approximately 1.1 mm per year, a figure commensurate with global predictions of a sea level rise of up to 90 cm by 2100. The major impacts of sea level rise include risk of erosion. Already islands at the approaches of the creeks in the Indus delta have been severely eroded. Makran coast suffers the same, where erosion poses a serious threat to property, coastal agriculture land and habitats. The impacts of the rising sea do not stop at the immediate coast. As sea level rises, there is an increased risk of riverbanks being overtopped and flooding of adjacent land may occur further up the estuaries. This effect, which would be particularly evident during drought conditions, could affect the whole range of biodiversity and crucial ecosystems such as mangroves, coral reefs, and coastal lagoons. This will have impact on food production due to loss of key nursery areas for fisheries, and also enhance flood and storm damages because storm surges will penetrate further inland, waste treatment and nutrient recycling functions, as well as habitats for wildlife.

Forest and biodiversity

With about 5 % of its area under forest cover, Pakistan is already extremely low in this resource. Climate change may decrease forest productivity, change species composition and reduce forest area for two reasons. Firstly, because the rate of change in the climatic parameters may be too fast to allow forests to adjust through gradual migration of various tree species to neighboring areas with relatively more favorable climatic conditions. Secondly, higher temperature and precipitation are likely to enhance insects, pests and weeds, which may increase damage to forests.

A number of species of unique flora and fauna are also threatened due to change in habitat conditions particularly due to increasing temperature and drought conditions. Of special concerns are mangrove forests, juniper forest of Baluchistan, Chilghoza Pine forest of Suleiman Range, endangered ungulate species like ibex (*Capra aegagrus*) and wild sheep (*Ovis vignei*) that inhabit the dry mountains of Balochistan and Sindh and freshwater fisheries. Particularly vulnerable in plants are mangroves, which provide breeding ground to coastal fisheries and harbor many rare plant and animal species especially the green turtle, an endangered specie in Pakistan. They are unlikely to adapt

quickly enough to the range of sea-level rise predicted by climate models including reduced rate of sedimentation, erosion that may reduce the range of mangrove forests by undercutting roots, a reduction in photosynthesis of tree species that may occur due to inundation, salinity stress that may occur due to intrusion of sea water. Higher temperatures may also affect the composition, distribution and productivity of mangroves.

Other vulnerable ecosystems

These include rangeland, degraded and desertified land and mountain ecosystems. It is the lack of adaptation capacity of these areas, which makes them highly vulnerable to the adverse impacts of climate change. The rangeland covers almost a third of Pakistan's total area and form an important component of its natural resources. Besides supporting two-thirds of the entire population of sheep and goats and over half of the cattle population of the country, they provide livelihood to millions of herders and pastoralists. However, in the absence of proper rangeland management system in Pakistan, heavy grazing pressure and utilization beyond their carrying capacity has been reducing their productivity. It is important to save them, and also desertified land and mountain ecosystems from further degradation due to impacts of climate change.

The climate changes in recent past have significantly altered the surrounding ecosystem functions and, its goods and services. These changes have affected the livelihoods of mass population in South Asia. The Indus basin in Pakistan is one of the most important river basins of the world due to its human dependence that supports around 215 million people. According to the ICIMOD (2015) the climate change and other drivers in the northern areas of Pakistan not only directly affect the region, but also significant impact on downstream areas. There is a need of an urgent regional programme on adaptation to climate change to develop flexibility and to support adaptation by susceptible mountain communities and ecosystems. The programme should enhance its mechanisms and should work with local/regional partner's institution to promote them, which will capture indigenous knowledge on autonomous adaptation and will contribute to the planned adaptation by providing scientific support. The programme should also promote innovative livelihood improvement and sustainable natural resource management strategies to ensure continued ecosystem services and will promote adaptation. Particular attention should be given to the challenges and role of women in adaptation. Building, a range of interrelated strategic priorities at different levels (local, national, regional, and global) should be used as a framework for community-focused ecosystem-based adaptation. Outcomes should include tested adaptation strategies for improved livelihoods and adoption of changed policies and practices for better adaptation in the region.

Policy response

In the light of multisectoral and multidimensional impacts of climate change discussed above, action plan based on climate change policy of Pakistan needs to be multi faceted that should not only cut across a number of priority sectors but also incorporate an interlinked array of economic, ecological and social issues. Moreover, while safeguarding the national environmental imperatives, it should be guided by the international policy framework provided by the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

Studies and policy measures

In terms of response related to multilateral environmental agreements on climate change, Pakistan acceded to the United Nations Framework Convention on Climate Change (UNFCCC) as a Non Annex I Party in June 1994. The country, subsequently, adopted the Kyoto Protocol in 1997 and acceded to it on 11th January 2005. As a follow up to these international commitments, the Government has undertaken climate related studies including the ALGAS study (ADB/GEF/UNDP, 1998). It also prepared the Initial National Communications on Climate Change (GoP 2003, 2009) and produced a high level report called the "Task Force Report on Climate Change" (Cheema et al. 2006). In addition, the Government in collaboration with UNFCCC commissioned a National Economic and Environmental Development Study (NEEDS). The study aimed to identify the priority areas for possible climate mitigation, taking into account Pakistan's future course of growth and the costs in following a low carbon development pathway. The strategic options for adaptation along with their cost estimates were also provided in the study (GoP 2011). The country has also announced and implemented the CDM National Operational Strategy (GoP 2006) as a signal for its entry into the global carbon market. It has also formulated a National Policy on Climate Change.

Pakistan has also remained pro-active in the global climate negotiations right from its inception. As the chair of the G77 negotiating group in 1992 as well as 2007, Pakistan spearheaded consensus building on the basic principles of the UNFCCC. At national level, Pakistan's international commitments regarding climate change finds

expression in its national policy frameworks such as the National Climate Change Policy, Pakistan: Framework for Economic Growth, 2011 (GoP 2011) and Medium Term Development Plan 2010–2015 (under finalization), National Environment Policy (GoP 2005b) as well as the National Energy Conservation Policy (GoP 2005b). These documents provide the steps through which, the Government intends to honor its international commitments.

Many sectoral policies, however, fail to include negative or positive aspects of climate change as the driver of policy instruments and prescriptions such as Agriculture, Water and health Policies and Poverty Reduction Strategies. The Disaster Management is the area that needs biggest attention. The Disaster Management Framework of Pakistan does recognize climate change perspective. However, its scope as mentioned in the document is very limited. Particularly missing are the aspects of displacement or migration and adaptation, thereby leading to shortcomings in setting goals, objectives and targets and achieving success in their implementation.

Agriculture will be most affected, but the only guiding policy document on the sector was framed almost 20 years ago in 1991 and it is silent on climate change impacts that will affect all aspects of agriculture, i.e. production, marketing, processing and transportation. Moreover, the policy measures undertaken in agriculture are sometimes contradictory to climate change mitigation and adaptation. For example, grant of loans for additional sugar mills and increasing area under sugarcane when water shortages are anticipated are contradictory. Likewise, providing electricity subsidy in Baluchistan for tube wells where the aquifers are far beyond recovery is counterproductive in the context of climate change. Such measures need to be rectified and rationalized. National Adaptation Programme of Action (NAPA) launched in 2001, this is only available to least developed countries (LDCs) (thereby excluding Pakistan). Adaptation options for Pakistan is effected due to limited resources available to the government and it depend on private sector to fund the requisite measures (CDKN Asia 2013).The number of adaptation projects and programs for different provinces in Pakistan are underway as supported by different international organization (GoP 2014).

Institutional arrangements

In terms of institutional development, the Cabinet Committee on Climate Change was formulated in 1995 to provide a policy coordination forum for combating the climate change. It was later designated as the Prime Ministers (PM) Committee on Climate Change in 2004. The Committee established a high level inter-ministerial linkage and was quite effective in initiating the country's entry into the global carbon market. The autonomous Global Change Impact Studies Centre (GCISC) was also established to act as the secretariat of the PM Committee on Climate Change. It is now the premier scientific research body that is engaged in conducting research on impacts and adaptation to climate change not only in the country but also at the regional level.

The newly established Ministry of Climate Change which also looks after Environment is the designated national focal point for UNFCCC and Kyoto Protocol. The Ministry has also been coordinating with other concerned agencies/institutions on various technical aspects, including; The National Energy Conservation Centre (ENERCON); Alternative Energy Development Board; and Pakistan Council of Renewable Energy Technologies. The Global Change Impact Studies Centre (GCISC) is also working under the umbrella of the Ministry of Climate Change. Other major relevant organizations working on research in climate change and sea level rise in the country have been highlighted in a survey report conducted by Oxfam (2009).

Mitigation and adaptation action

There are a number of sectors/areas that have a two-way interaction with climate change whereby they not only have implications for future increase in GHG emissions in the country but also are directly affected by climate change. In addition, such areas like energy, water, transport, industries, agriculture/livestock, and forestry together with the natural hazards also hold the key to country's economic development. This section analyzes the status of mitigation and adaptation responses within the country in these areas.

Mitigation

Pakistan's present GHG emissions are quite low but are likely to increase in future with the growing demand for energy to support its developmental needs. Therefore, as a responsible member of the international community, the country has been striving to contribute to the global GHG mitigation efforts within the existing financial and technological constraints (Cheema et al. 2006).

Energy and transport sectors are the largest source of carbon emissions. Therefore, the government efforts have primarily targeted these for GHG reductions. Energy (GoP 2005a) envisages large roles for hydropower, renewable energy technologies (in particular, windmills), nuclear power and imported natural gas fori future energy supplies. The steps taken towards mitigation in the areas of energy, transportation and carbon sequestration were as follows:

- One windmill of 6 MW capacity has been made operational while work is underway on 18 wind power projects of 50 MW capacity each under renewable energy program;
- Construction of a new nuclear power plant is in progress;
- Approval has been accorded for the construction of Bhasha dam that would generate 4500-MW hydroelectricity;
- A number of projects on improvement of energy efficiency, energy conservation and use of decentralized renewable energy technologies are being implemented by National Energy Conservation Center (ENERCON), Water & Power Development Authority (WAPDA), Karachi Electric Supply Company (KESC), Alternative Energy Development Board (AEDB) and Pakistan Council of Renewable Energy Technologies (PCRET);
- Almost two and a half million vehicles have been switched to CNG fuel and the construction of a mass transit system (circular railway) for Karachi metropolitan area has been approved;
- Several afforestation endeavor's like Rachna Doab Afforestation Project are underway for carbon sequestration;
- Tree-plant,ing campaigns are launched each year during spring and monsoon seasons (as many as 541,176 saplings were planted in one day on 15 July 2009, which is a world record for any country.

Adaptation

Candidate areas for adaptation include water resources, agriculture and livestock, coastal areas and Indus Deltaic Region, forests, biodiversity and vulnerable ecosystems. The present adaptation efforts for water resources include:

- At present, on the average 35 maf of water flows to the sea annually during flood season. There is a need to conserve every drop of this water to use it later in maintaining optimal ecological flow into the sea (Commission Planning 2007) and for combating the droughts. 18 MAF of new storage capacity is planned by constructing a series of large hydro projects by 2030 to the to enhance existing 12.5 MAF capacity (which is decreasing by 0.2 MAF annually due to silting).
- Large storage reservoirs are to be complemented by a comprehensive program of small and medium dams' construction as well as measures for recharging underground reservoirs.
- Investigations are also ongoing for using groundwater aquifers as water storage facilities.
- Among water conservation efforts a major program underway is for lining the canals and irrigation channels to save water losses and saving seepage losses.

Adaptation activities in agriculture have concentrated on securing agricultural productivity in a sustainable manner (Tubiello and Velde 2007). For this purpose, it is planned to:

- Develop through biotechnology, heat-stress resistant, drought- and flood-tolerant, and water-use efficient high yielding crop varieties,
- Increase irrigation water availability by reducing losses in the irrigation water supply network,
- Implement "More Crop per Drop" strategy through improved irrigation methods and practices, as well as water saving techniques in combination with the use of high yielding and water-efficient crop varieties, and
- Increase milk and meat production by developing animal breeds which are less vulnerable to climatic change, and by improving animal feedstock (Cheema et al. 2006)

For coastal environment, the following adaptation actions are underway:

- Implementation of the recommendations of a study by local and foreign experts (IPOE) that estimated minimum water flow needed below Kotri Barrage to check seawater intrusion and maintain the ecology of Indus Delta
- Plans are underway to restore the degraded mangroves and marine ecosystem and major interventions are planned to boost fisheries.
- A major intervention underway is to use brackish water for aquaculture.

In the areas of forest, biodiversity and other vulnerable ecosystems, besides the afforestation and reforestation activities, it is planned to

- Improve the rangelands by their proper management, and
- Reclaim nearly 6 million hectare of salt affected waste land and large areas of sandy desert by growing salt tolerant, fast growing grasses, shrubs and trees to be used as fodder.
- Increase the area protected for conservation of wildlife from 11.6 % in 2009–2010 to 12.0 % by 2015.
- Develop national database of threatened and endangered species to encourage their captive breeding for promoting ex-situ conservation of biodiversity.

Way forward

Since action plan is soon to be formulated under the new Climate Change Policy in Pakistan, there is an opportunity to develop it as an overarching framework for addressing

the issues that the country is to face as a result of climate change. The climate action plan should facilitate the government in making effective use of opportunities both financial as well as technical that are available nationally and internationally as well as building institutional capacities to address climate change issues. In addition, it should help develop a mechanism to promote economic incentives to combat climate change issues on the one hand and to enhance the understanding and awareness as well as participation of all stakeholders in tackling these issues on the other. Most importantly, it could pave the way for switching to low carbon economy and achieving long-term sustainability. A proposed framework for the development and implementation of an action plan under the new climate change policy of Pakistan is given in Fig. 5 (Fig. 6).

Collection and assembly of data and information for prediction of possible quantitative impacts, comparison of alternatives, evaluation of preventive measures, and analysis of global research from local perspective should initiate the plan. The next steps in the process should lead to identification of measures on mitigation and adaptation in various realms. Moreover, it should be developed within the overall context of the international policy framework comprising the Climate Change Convention and the Kyoto Protocol while safeguarding the national environmental imperatives.

Mitigation strategies and costs

In terms of mitigation, Pakistan's GHG emissions is likely to increase for two reasons (1) projected growth in agriculture, industry and energy consumption (2) scenario that sees Pakistan's energy future being driven by coal. National Economic and Environmental Development Study (NEEDS) projected overall GHG Emissions (million tons CO_2 eq.) to increase from 347 in 2011 to 4621 in 2050, under Business as Usual (BAU) scenario. Energy sector will remain the leading contributor with its share reaching almost 60 % by the middle of the present century, followed by agriculture sector. The share of industry has been predicted to decrease because of study's underlying assumption of efficiency in production techniques and availability of greener technologies (GoP 2011; UNFCCC 2011).

As advocated in Vision 2030, abatement strategies (nearly 22 % each), should be based (Enquist et al. 2007) on renewable energy for power and better efficiency and cogeneration in the manufacturing industry. An important area

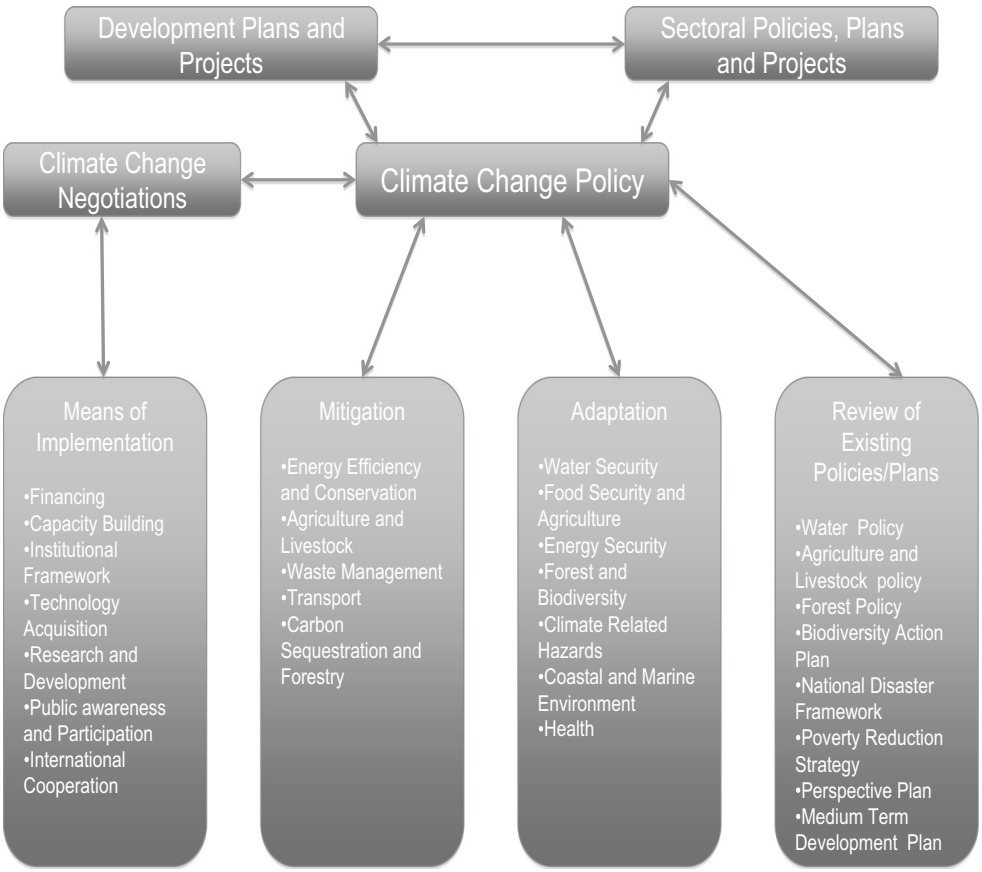

Fig. 5 Proposed framework for the development of action plan based on climate change policy of Pakistan and its integration in the planning process

for intervention was improvement in building efficiencies and transport fuels. The biggest single impact can be expected from preventing deforestation. Some other areas of emphasis include: conversion of existing thermal power stations from fuel oil to natural gas; efficient power generation through combined cycle power plants and integrated coal gasification combined cycle plants; reducing vehicle emissions through accelerating the use of mass transit systems in major cities as well as hybrid vehicles; and making buildings more energy efficient, especially for reduction of air-conditioning loads in summer. In Pakistan, transmission and distribution (T&D) losses as percent of net system energy has reduced from 25 % from 2000–01 to 21 % in 2008–09. There is a need to use more aggressive technical and administrative measures to reduce power losses along with renovation, rehabilitation, capacitor installation and strengthening the distribution system network.

In terms of choices for future energy requirements in Pakistan, the NEEDS indicates that significant financial resources will be required by the country in its efforts to delink its economic growth from, a corresponding growth in emissions. The low carbon development scenarios projected for the country estimate additional investment costs of mitigation ranging between $8 and $17 billion by 2050, as progressively cleaner coal and a higher percentage of renewable energy technologies are employed. It is considered feasible to reduce emissions by 40 % from the BAU scenario by employing cleaner technologies. The country does not have resources for this kind of investment. Nevertheless, it should carry out future technology Needs Assessment to identify the best available technologies for low carbon development path.

Little attention has been paid to address the GHG emissions in agriculture sector. The mechanism recommended by the Task Force on Climate Change for this sector (Cheema et al. 2006) included (1) new methods of rice cultivation that have lower methane emissions (2) new methods for reducing nitrous oxide releases from agricultural soils, (3) new breeds of cattle which are more productive in terms of milk and meat but have lower methane production from enteric fermentation, and (4) new economical feeds that reduce methane production activity of cattle besides providing them with better nutrition.

Adaptation strategies and cost

The area, which needs serious attention for adaptation, is natural hazards. There will be a need for risk mapping, vulnerability assessment, forecasting and early warning as well as raising defense structures. The Disaster Management Framework needs to address the issue within the context of climate change in a holistic manner. The risk mapping also needs to be conducted in coastal areas along with construction of proper engineering structures in order to protect beaches and other facilities along the coast.

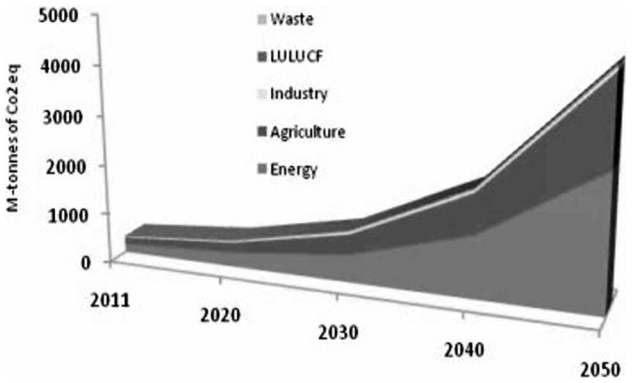

Fig. 6 Pakistan: indigenous energy supply projections. UNFCCC (2011)

Table 2 Pakistan: comparisons of adaptation cost estimates based on three approaches (in billion US $)

Methodology	Time period	cost of adaptation/ annum
Actual (2010)	1 year (2010)	9.7 ++
As a percent of GDP	2010–2050	10.71
Per capita basis	2010–2050	7.12–14.0
Disaster modelling (floods only)* multiplication factor of three	2010–2050	6.09–11.28

Preparation for handling emergencies would also be necessary for relocation of displaced peoples. Existing law and protection possibilities in their case should be reviewed to address potential protection gaps. Further social safety nets should also be extended. The adaptation measures will also need to be strengthened for achieving water, food and energy security as well as in other sectors.

Cost effective and timely adaptation strategies, which are fully compatible with development objectives, are crucial for coping with as well as lowering future climate impacts (Agrawala and Fankhauser 2008; Mishra and Markandya 2010; Oxfam 2007; Parry et al. 2009). In the absence of appropriate measures, Pakistan will be forced to implement reactive unplanned adaptations, which will prove much more costly. Adaptation costs for Pakistan have been estimated by NEEDS (GoP 2011; UNFCCC 2011), based on three different criteria i.e. projected GDP, per capita basis and disaster modeling. The results are summarized in Table 2.

The adaptation costs calculated as a percent of future GDP projections in Table 2, gives an annual average adaptation cost of U$ 10.71 for the period 20,102,050. The per capita-based calculation produced annual adaptation

costs for the country at U$ 6 (in 2010)–14 billion (in 2050) using a per capita estimate of U$ 40. The disaster-based model yielded the adaptation cost ranging from U$ 6–11.28 billion. The study indicates that the adaptation costs to climate change for Pakistan would be quite high ranging from between U$ 7–14 billion/annum.

Conclusion

Pakistan is one of the most vulnerable countries to climate change, despite contributing very little to the global greenhouse gas emissions. Dealing with climate change is no longer an option for the country; it has become an unavoidable reality in the wake of increasing symptoms exhibited through cataclysmic floods and droughts. The potential impacts of climate change identified in this paper are wide-ranging and likely to affect all dimensions of sustainable development with impacts across many sectors and ecosystems. Economically, the detrimental impacts of climate change will be widespread and have bearing not only on water security, food security and energy security but also impinge on agriculture, forests, livestock, and fisheries etc. the sectors vital for Pakistan's economy.

In terms of social dimension, climate change will have adverse impacts on health; cause displacement of people, and result in loss of their income due to enhanced extreme natural events such as floods and droughts or sea level rise. It could jeopardize hundreds of jobs; may result in inflation of food prices and increase number of people at risk of food security and hunger. It could also trigger displacements and migration as well as civil unrest and conflicts. Climate change is also likely to have serious impacts on biophysical conditions such as change in the ecology and habitats; quantity and quality of land, soil, water and biotic resources; rise in sea level and ocean temperature and salinity. It may also exacerbate occurrence of weeds and pests, which in turn may enhance unfavorable environmental changes.

The capacities of individuals, communities, and societies to effectively respond to such changes in the country will depend on a combination of natural, social, financial and physical factors. For example, coastal communities, and small farmers will be at greater risk. The rural houses constructed from mud and makeshift materials will be more at risk compared to better quality houses in urban areas. Poor will also have problems due to increased cost of living as a result of reduced food security, enhanced health related expenditure and increase in the energy prices. It is therefore, extremely important for policy makers to take these factors into account while framing a climate change policy or adaptation measures.

The Government of Pakistan, in response to climate change, has undertaken policy measures at both international and domestic arena. Internationally, it has already acceded to the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. As a follow up to these international commitments, substantial climate related work has been carried out at the domestic front including the ALGAS study of ADB on estimation of GHG emissions, the UNEP country study on adaptation, the first National Communications on Climate Change (submitted to UNFCCC Secretariat in 2003) and recently completed high level Task Force Report on Climate Change (2010). It has also managed to create institutional framework. Moreover, the country announced and implemented the CDM Operational Strategy GoP (2006) as a signal for its entry into the global carbon market and also developed climate change policy recently.

The Government has currently embarked on formulating action plan on climate change. While framing this plan, it is important to make it multifaceted that should not only cut across a number of priority sectors but also incorporate an interlinked array of economic and political decisions. It should also incorporate mitigation and adaptation measures that can be undertaken along with an indication of their costs to ensure a climate sensitive development in the country. Moreover, it should be developed within the overall context of the international policy framework comprising the climate change convention and the Kyoto protocol while safeguarding the national environmental imperatives.

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