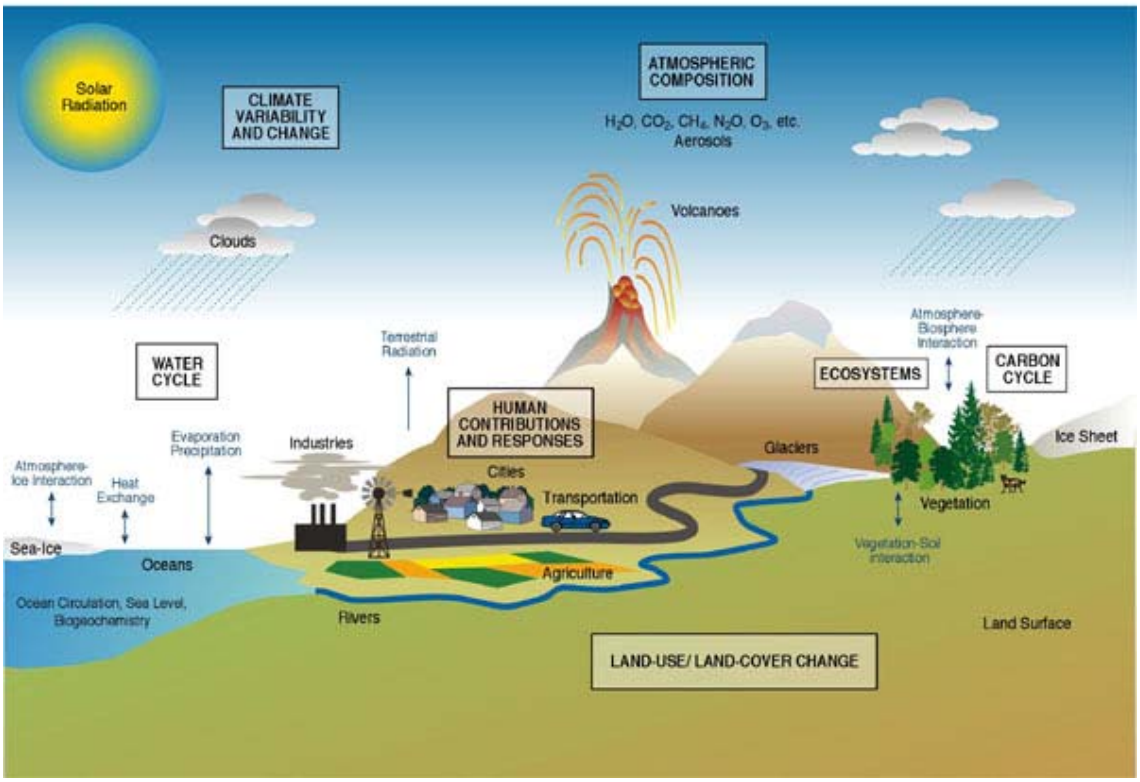
The phenomenon of global warming has reached Pakistan's doorstep. Among the impacts felt and seen are biodiversity loss, rise in the sea level, increased draught, shifts in the weather patterns, increased flooding, changes in freshwater supply and an increase in extreme weather events. These could also lead to alterations in forests and crop yields. Not only that, climatic changes could also affect human health, animals and many types of eco-systems.

Chapter 9 Climate Variation – development with caution

Pakistan's status as a developing country dependent mainly on agriculture makes it particularly susceptible to the effects of climate change. Added to this is the fact that like most other developing countries, Pakistan does not have adequate monitoring systems for the prediction of likelihood of occurrence of extreme events, or the assessment of possible changes in weather patterns, thus making the task of developing short term response or disaster mitigation strategies extremely difficult.



Pressures

Energy and Industrial Growth

The energy sector was by far the highest contributor to CO_2 emissions, contributing 81% of total CO_2 emissions when measured according to the Source Categories Approach. The forestry and land use change sector accounted for 7% of CO_2 emissions, while industrial processes accounted for 12%. In absolute terms, CO_2 emissions from the energy sector

were estimated at 76,775.2 Gg in 1993-94 according to the Source Categories Approach and 84,227.3 Gg according to the Reference Approach.

Agriculture Sector

The agriculture sector was the primary source of CH_4 emissions in the country, accounting for 87% of all CH_4 emissions, while fugitive emissions and emissions from waste management accounted for the remainder of CH_4 emissions. The bulk, or 81% of N_2O emissions also came from the agriculture sector, with the remaining emissions coming from human sewage and the energy sector. NO_x emissions can be attributed almost entirely to the energy sector with the transport sector being the major source. NO_x emissions from the agriculture sector, from field burning of residues, were negligible.

Transport Sector

The primary source of CO emissions was the transport sector, accounting for 81% of all CO emissions. Industrial processes and field burning of agricultural residues also contributed to CO emissions in the country. Emissions of NMVOCs rose primarily from industrial processes.

There are several aspects that are circumstantial to the effects of climate change. In a country such as Pakistan, the pressures generated as a directly result of climate change impact multiple sectors including water, agriculture, forests, biodiversity, livestock, costal zones, etc. Following sub-sections present some of the key sectors directly affected by climatic fluctuations.

State

The Survey of Pakistan classifies the country into eight climatic zones, which roughly concur with the Köppen Geiger classification, where zones are defined on the basis of monthly temperature and precipitation data. According to the Köppen Geiger classification of climatic zones, where zones are defined on the basis of monthly temperature and precipitation data, there are 11 distinct as well as overlapping climatic zones in the country. These range from zones characterized by mild, moist winters and hot, dry summers in the north to semi-arid and arid zones in the west and parts of the south. The north-eastern mountainous and sub-mountainous areas receive more than 1,700 mm annual precipitation with a major share (over 1,000 mm) from the summer monsoon. On the other hand, the extremely arid plains of southwest Balochistan receive only 30 mm during the whole year. Thermal regimes exhibit extreme diurnal, seasonal, and annual variations: temperatures can fall as low as –26°C over the northern mountains and go as high as 52°C over the central arid plains. In the semi-arid plains, temperatures of 42°C are recorded at various stations in the months of May and June. Areas comprising Pakistan have seen several droughts, the most recent of which was the worst experienced for the last hundred years and affected several districts of Sindh and Balochistan from 1999-2000. The drought is estimated to have affected over 3.3 million people and 30 million heads of livestock.

Map of Climatic Zones of Pakistan

Source: Survey of Pakistan

Given the nature of scientific knowledge and the problems associated with the availability, accuracy and reliability of data in the country, the task of a scientifically sound basis for impact assessment and vulnerability assessments becomes all the more daunting. Furthermore, the difficulties of differentiating between impacts caused naturally as a process of climate change from the ones emanating as a result of human induced activities poses additional difficulties in framing the appropriate policy responses.

Impact

Pakistan contributes very little to the overall GHG emissions, but remains severely impacted by the negative effects of climate change. Being a predominantly agriculture economy and vulnerable to extremity of climate, it has a real interest in protecting itself from the adverse impacts of climate change. The recent recurrences of extreme weather events displayed by drought and excessive floods in the Country have raised the enormity of dealing with the issue on an urgent basis.

Similarly, another serious impact of changes in atmospheric and sea temperatures is the increased risk of occurrence of severe cyclones and storm surges. Cyclones are associated with strong winds and heavy rains, while a storm surge is an abnormal rise of sea level caused by a cyclone moving over a continental shelf. The cyclone provides the driving forces in the form of very high horizontal atmospheric pressure gradient and consequent strong

surface winds. As a result, sea level rises and continues to rise as the cyclone moves over shallower waters, and reaches a maximum on the coast near the point of landfall (ie, the point of crossing of land by the cyclone). Seawater inundates vast stretches of coastal area and sweeps away all that comes in its way. Such events can cause widespread devastation and loss of life and property. The islands at the approaches of the creeks in the Indus delta have been severely eroded. The creeks which are near the present outfall of the Indus River, at the concave bulge of the delta are facing erosion due to natural hydraulic forces, such as reduction in the supply of sediments by the river and wave reworking in the comparatively recently formed delta together with the arid condition of the delta itself. On the west (Makran) coast erosion already threatens coastal property, coastal agriculture land and habitats, and such effects may be intensified in the event of further sea level rise. Loose sediments produced by erosion, and in some places accretion, would be a serious threat for the fisheries sector and to navigation.

There is considerable uncertainty regarding the methodologies to be used for conducting socioeconomic impact assessments of climate change, as a universally accepted framework for analysis does not exist in this area. For the purpose of this analysis, socioeconomic impacts are largely assumed to be derived from the impacts occurring in sectors such as agriculture and livestock, forestry and land use change, coastal zones etc. Some direct socioeconomic impacts are also likely to occur, primarily in the form of health impacts. As detailed region-specific scenarios are not available, predictions relating to health effects of climatic changes have to remain general and speculative. Except for a few diseases, there is insufficient data for any kind of projections. Nevertheless, when discussing the various health effects potentially related to climatic change, it is necessary to put them in a population context as many of the conditions discussed hereafter have specific distribution patterns in the population. The poorest sections of society, representing nearly one-third of Pakistan's population, will bear the brunt of adverse health impacts due to the inadequacy of health systems in the country. Within low-income households, women, children, and rural and urban slum dwellers will be at an even higher risk.

There are direct sectoral impacts due to climate change which merit discussion here as it is for these impacts that necessary steps and policies are designed by various stakeholders especially the government.

Water Resources

The effect of climate change on water resources is expected to be significant. An analysis of changes in the Pakistan's hydrological regime provides a basis for estimating the impacts of climate change on water resources. In general, increase in temperature could not only increase water demand because of higher evaporation rates, but may also increase rainfall due to additional moisture supplied to the clouds because of higher evaporation from the sea surface. Similarly, increased rainfall is expected to cause an increase in magnitude of floods.

The results of the analysis for hydropower generation for the year 2020 under the no change in precipitation scenario, suggest an increase in hydropower is 0.03% whereas under the increased precipitation scenario, the increase in hydropower generation is expected to reach 2%. In the decreased precipitation scenario, there is a decrease of 1.5% in hydropower generation. Overall, impacts on hydropower generation, which are based on average base inflows, are expected to be insignificant. In drought scenarios, however, impacts on hydropower generation are likely to be significant.

Changes in Hydropower Generation at Main Dams

Scenarios	Changes in Percent			
Years	2000	2010	2020	2050
0.3 °C & +0% PPT	0	0.04	0.03	0.22
0.3 °C & +1% PPT	0.02	0.86	1.98	4.32
0.3 °C & –1% PPT	–0.01	–0.83	–1.46	–3.85

Agricultural Production

Climate change is also expected to have significant impacts on agriculture. Potential impacts include vulnerability of crops to heat stress, possible shifts in spatial boundaries of crops, changes in productivity potential, changes in water availability and use, and changes in land use systems. Even a fractional rise in temperature could have serious adverse effects such as considerable increase in the growing degree-days. This could not only affect the growth, maturity and productivity of crops but also would require additional amount of irrigation water to compensate heat stress rather cooling of crops might become an essential element of the crop production system. Similarly, temperature increases coupled with variations in rainfall can increase the net irrigation water requirements of sub-humid, semi-arid and arid climatic zones.

Forestry and land Use Changes

In general, a shift in the location of different biomes is likely under the change in precipitation scenarios. Cold and temperate conifers will show a northward shift, pushing against the cold conifer/mixed woodland, which in turn encroach upon the southern and lower edges of the alpine tundra. Similarly, the northern boundaries of warm conifer/mixed forest will also move north, pushing against the southern boundaries of the temperate conifer/mixed forest. This northwards shift of coniferous biomes will increase their size at the cost of the extent of the alpine tundra. A change in species composition may also occur, as those species that are hardier and have a wider distribution are likely to shift to other biomes in the north and south. Due to less severity and frequency in the incidence of frost and rise in temperature because of climate change, the frost tender species, which are at present confined to the southern biomes, will start moving northwards.

Coastal Zones

Pakistan, which has a coast extending over approximately a thousand kilometers, is one of the countries classified as being particularly vulnerable to the effects of sea level rise. Data processed at the National Institute of Oceanography (NIO) shows that sea level rise along the Pakistan coast is approximately 1.1 mm per year, a figure that is in consonance with global predictions of a sea level rise of up to 90 cm by 2100. These results were tabulated using sea level data recorded at Karachi for the last hundred years.

The primary impacts of sea level rise are the direct physical effects on the coastal zone due to changes in coastal dynamical processes because of sea level rise. Such impacts may include the risk of erosion, flooding, inundation and displacement of wetlands and lowlands and salinisation of ground and surface water.

Biodiversity Loss

Substantial data on different aspects of biodiversity and ecosystems necessary for quantitative analysis is currently not available in Pakistan. Moreover techniques such as eco-climatic classification and analysis through climate envelopes and profiles are not applicable due to resource constraints. Nevertheless, it is estimated that an increase in atmospheric CO^2 can have significant impacts on both plants and ecosystems. Various components of the carbon budget like photosynthesis, respiration, biomass accumulation and allocation are

affected by CO^2 concentration. Temperature and CO^2 interact to affect photosynthesis and growth. In general, optimum temperature increases for net photosynthesis. However, if temperature becomes extremely high or low it will retard growth and photosynthesis. Higher CO^2 levels can affect plant responses to different limiting factors including water, light, and nutrient availability positively.

Similarly, changing climate would affect competitiveness of species or groups by altering growth and mortality rates differentially as well as the regeneration success rate.

Extreme Effects

Amongst the possible effects of climate change is the likelihood of increased frequency, and severity of occurrence of extreme events such as floods and droughts. Since Pakistan is particularly susceptible to such events, and has experienced large scale destruction on these accounts in the recent past, the analysis of possibility of occurrence of extreme events, and their impacts becomes all the more essential. This section explores the possible impacts of natural disasters.

Response

Pakistan's vulnerability to the impacts of climate change guides its overall national response in dealing with the issue. In view of limited resources, the level of studies and work undertaken has largely been in the area of mitigation, although a few important studies have also been commissioned on impacts and adaptation.

Pakistan National Communication

Vulnerability and impact assessment studies were conducted for key sectors as part of the research undertaken for the Pakistan National Communication. These studies were undertaken to evaluate the effects of climate change and understand the long run impacts that changes in climate variables such as temperature and precipitation can have on key sectors of the economy.

Impact Assessment and Adaptation

Impact assessment and adaptation studies were carried out sector wise and cover agriculture, forestry, biodiversity, coastal zones, livestock, water resources, energy and socioeconomic sectors. The climate change scenarios used in all the studies were synthetic scenarios, based on incremental changes in meteorological variables, such as temperature and precipitation. The National Study Team, in consultation with experts from the Intergovernmental Panel on Climate Change, reviewed scenarios generated by the Pakistan Meteorology Department (PMD) and formulated scenarios consistent with scenarios generated using the Model for Assessment of Greenhouse Gas Induced Climate Change (MAGICC) – software used extensively by the United Nations Environment Programme (UNEP) and other UN agencies.

Awareness Raising and Capacity Building

Pakistan attaches great importance to the effective implementation of Article 6 of the Convention requiring parties to encourage education, training and public awareness programs, within respective capacities and resources. Such a support is crucial in achieving the ultimate objectives of the Convention. Environmental education has been recognized as an important priority of the Government of Pakistan and has been dealt with both under the National Conservation Strategy (NCS) and the National Environmental Action Plan of the

GoP. The Ministry of Environment in partnership with key stakeholders is spearheading efforts aimed at incorporating environmental education concepts in school curriculums.

In Pakistan, through a mix of public-private partnerships, activities in the domain of education, training and public are being organized on a continuous basis. Most of these activities are part of larger programs and action plans initiated by the government to engender a more sustainable development path. Some of the activities of the Government include organizing workshops, seminars and observing specific international days like Earth day, World Environment Day etc. The government makes use of the electronic and print media in airing environmental messages. However, resources and expertise are required in developing climate change specific modules in the various initiatives being undertaken.

Greenhouse Gas Inventory

In compliance of Article 12.1 and decision 10/CP2, Non-Annex 1 Parties are required to submit a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies agreed upon by the Conference of Parties. Pakistan has prepared its national inventory for the year 1994 using IPCC-recommended methodologies. This inventory has been generated through the Enabling Activity project funded by GEF though UNEP.

Summary Report of National Greenhouse Gas Inventories, Gg

Greenhouse Gas Source and Sink Categories	*CO_2 Emissions*	*CO_2 Removals*	*CH_4*	*N_2O*	*NO_x*	*CO*	*NMVOC*	*SO_2*	*Halocarbons*	
									P	*A*
Total National Emissions and Removals	**94,571.9**	**–**	**2,891.2**	**36.9**	**410.257**	**732.130**	**656.879**	**775.462**	**3.098**	**–**
Energy	77171.80	**–**	**281.4**	**0.606**	**409.908**	**706.126**	**34.273**	**764.487**	**–**	**–**
A. Fuel combustion activities	77171.80	–	4.1	0.606	409.513	705.534	30.191	755.574	–	–
1. Energy industries	21,600.9	–	0.9	0.052	75.715	6.552	0.014	260.778	–	–
2. Manufacturing industries and construction	24,895.9	–	0.5	0.214	60.479	67.794	3.504	375.351	–	–
3. Transport	18,584.4	–	1.9	0.170	172.758	592.150	11.786	94.521	–	–
4. Other sectors	12,090.6	–	0.8	0.171	100.561	39.038	14.888	24.925	–	–
B. Fugitive emissions from fuels	–	–	277.2	–	0.395	0.593	4.082	8.913	–	–
1. Solid fuels	–	–	47.2	–	–	–	–	–	–	–
2. Oil and natural gas	–	–	229.5	–	–	–	–	–	–	–
3. Ozone precursors and SO_2 from refining	–	–	–	–	0.395	0.593	4.082	8.913	–	–
Industrial Processes	**11,269.8**	**–**	**–**	**–**	**–**	**15.750**	**622.606**	**10.975**	**–**	**–**
A. Mineral products	4,350.3	–	–	–	–	–	578.115	2.430	–	–
B. Chemical industry	2,990.5	–	–	–	–	15.750	9.370	1.850	–	–
C. Metal production	3,928.8	–	–	–	–	–	–	–	–	–
D. Other production	–	–	–	–	–	–	35.121	6.695	–	–
E. Production of halocarbons and sulfur hexafluoride	–	–	–	–	–	–	–	–	–	–
F. Consumption of halocarbons and sulfur exafluoride	–	–	–	–	–	–	–	–	3.098	NA
Solvent and Other Product Use	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Greenhouse Gas Source and Sink Categories	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	Halocarbons	
									P	A
Agriculture	–	–	**2,507.9**	**29.916**	**0.349**	**10.254**	–	–	–	–
A. Enteric fermentation	–	–	2,093.0	–	–	–	–	–	–	–
B. Manure management	–	–	191.8	–	–	–	–	–	–	–
C. Rice cultivation	–	–	222.6	–	–	–	–	–	–	–
D. Agricultural soils	–	–	–	29.907	–	–	–	–	–	–
E. Prescribed burning of savannas	–	–	–	–	–	–	–	–	–	–
F. Field burning of agricultural residues	–	–	0.5	0.010	0.349	10.254	–	–	–	–
Forestry and Land Use Change	**6,527.1**	–	–	–	–	–	–	–	–	–
A. Changes in forest and other woody biomass stocks	6,527.1	–	–	–	–	–	–	–	–	–
B. Forest and grassland conversion	–	–	–	–	–	–	–	–	–	–
C. Abandonment of managed lands	–	–	–	–	–	–	–	–	–	–
D. Emissions from soils	–	–	–	–	–	–	–	–	–	–
Waste	–	–	**101.9**	**6.396**	–	–	–	–	–	–
A. Solid waste disposal on land	–	–	92.0	–	–	–	–	–	–	–
B. Wastewater handling	–	–	9.9	–	–	–	–	–	–	–
C. Waste incineration	–	–	–	–	–	–	–	–	–	–
D. Other (human sewage)	–	–	–	6.396	–	–	–	–	–	–

NA = Not Available, - = Not Applicable

For halocarbons, P = Potential emissions based on Tier 1 approach and A = Actual emissions based on Tier 2 approach.

Mitigation Options

On the basis of the GHG inventory prepared for the year 1993-94, the main emitting sectors were explored for viable GHG mitigation opportunities. These options were then analyzed and evaluated to assess their emissions reduction potential and the economic and financial implications of their implementation. The sectors studied for the mitigation options analyses were energy, forestry, and agriculture. For each of the mitigation options essential abatement potential and cost effectiveness indicators were calculated. A total of 21 options were developed for the energy sector, distributed among the various sub-sectors, including the residential and commercial sectors, the transport sector, the industry sector, and the agriculture sector. Options assessment for the energy sector was carried out on the Long Range Energy Alternatives Planning (LEAP) model prepared by the Stockholm Environment Institute (SEI). Six options were considered for assessment in the forestry sector. These options were selected based on suitability, ease of implementation, and potential for carbon abatement. Two mitigation options were developed for the agriculture and livestock sector, both targeting methane emissions.

Energy Sector Options Ranked by Incremental Costs

Greenhouse Gas Mitigation Options	Average Incremental Mitigation Cost US$/Tonne CO_2 Equivalent	Net Present Value Million Dollars	Total CO_2 Abated Million Tons
Energy efficiency improvements in tubewells	–230	574.79	7.15
Energy efficient refrigerators	–160	547	11.53
Energy efficient lights	–139.97	2704.76	56.48
Solar water heaters	–120	569.31	13.60
Solar water pumping	–110	563.28	15.07
Energy efficient fans	–90	890.06	29.23
Cogeneration	–80	1.33	49.35

Energy efficient motors	–70	48.01	1.92
Energy efficient boilers	–44.6	60.48	3.58
Improved wood stoves	–40	211.40	16.20
Waste heat recovery systems	–37.35	40.24	2.95
Reduction in electricity T&D losses	–31.67	1044.54	3.70
Improved engine maintenance practices	–26.08	223.25	23.78
Energy efficiency improvements in tractors	–23.09	97.53	12.34
Improvements in vehicle maintenance practices	–14.25	43.22	8.40
Reduction in gas T&D losses	–0.096	0.42	0.49
Waste-to-energy generation	2.83	–1.16	1.19
Improvements in building design	8.69	–84.78	22.24
Substitution of oil and coal with natural gas	13.81	–452.06	95.64
Improvements in engine design	18.54	–245.33	37.07
Wind power generation	35.68	–9.05	0.74

Forestry Sector Options Ranked by Incremental Costs

Greenhouse Gas Mitigation Options	*Average Incremental Mitigation Cost US$/Tonne CO_2 Equivalent*	*Life Cycle Costs $/hectare*	*Net Present Value Million Dollars*	*Total CO_2 Abated Million Tons*
Agroforesty	–0.011	2.15	5.19	467.863
Reforestation in conifer forests	0.242	126.71	–33.75	139.330
Watershed plantations	0.254	480.00	–5.92	23.285
Reforestation in riverain forests	0.309	72.23	–1.39	4.489
Plantations on agricultural lands	0.677	111.7	–28.05	41.422
Protection of conifer forests	0.808	94.46	–34.79	43.056

Agriculture Sector Options Ranked by Incremental Costs

Greenhouse Gas Mitigation Options	*Average Incremental Mitigation Cost US$/Tonne CO_2 Equivalent*	*Net Present Value Million Dollars*	*Total CO_2 Abated Million Tons*
Water management in rice paddies	–44.21	124.84	42.07
Improved feed for livestock	–30.82	329.38	19.21

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