Pakistan's Initial National Communication on Climate Change

November 2003

Government of Islamic Republic of Pakistan
Ministry of Environment
Islamabad-Pakistan

Contents

Exhibits

Foreword

It is my pleasure to present on behalf of the Government of Pakistan, the Initial National Communication to the Framework Convention on Climate Change (UNFCCC). The Communication describes the endeavours of Pakistan to overcome the challenges being posed by climate change. It also outlines the planned efforts and strategies to achieve goals of national development.

Pakistan has been an active member of the international community in its efforts to protect "Global Commons". It was with this spirit that Pakistan joined the group of countries that opted to sign the United Nations Framework Convention on Climate Change at Rio in 1992. Pakistan honoured its commitment by formally ratifying the treaty on June 1, 1994 and is fully obligated to the principles and objectives enshrined in the various articles of the Convention.

Despite its meager resources it does so because of a firm conviction that addressing the issue of climate change sooner rather than later is in the best interest of the global community. Pakistan continues in its domestic efforts to tackle the issue, but feels that the progress made in real and meaningful transfer of technology, financial resources and operationalizing capacity-building in Developing Countries has been slow in forthcoming. It is time to seriously tackle these issues if the world has to meet the objectives of the Convention.

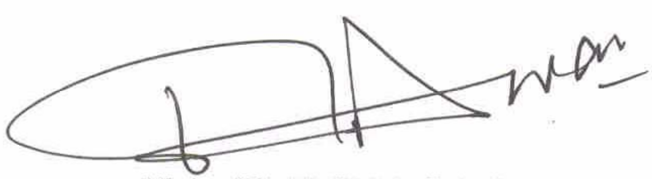
Pakistan contributes very little to the overall GHG emissions, but remains severely impacted by the negative effects of climate change. Being a predominantly agriculture economy and vulnerable to extremity of climate, it has a real interest in protecting itself from the adverse impacts of climate change. 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. Pakistan is a country of over 140 million people and needs a thriving economy to support its population to a reasonable standard of living. The importance of the development operating in a sustainable manner at the global level remains unambiguous. The Government of Pakistan is committed to international action in dealing with issues of sustainable development and poverty-eradication and is taking necessary steps, given its resource and capacity constraints, to honour its pledge to contribute to the targets agreed by the member states of the UN in the Millennium Development Goals. It is the firm resolve of the Government to work with the various stakeholders in the public and private-sector in meeting those commitments.

Pakistan now joins the group of countries that have fulfilled their obligations under article 12 of the Convention to prepare and submit a National Communication containing a National Inventory and detailing the general description of steps taken by the Party to implement the Convention. The process itself that spanned over a period of three years necessitated a challenging task of producing credible information. Like most other developing countries, further work is needed in the area of data availability, reliability and accuracy.

The Government of Pakistan acknowledges the support of GEF and UNEP in not only assisting Pakistan in fulfilling this important national obligation, but in also playing a very important role in assisting international and domestic efforts aimed at protection of the environment.

The INC does not just indicate our compliance to the commitments under the Convention, but also displays Pakistan's firm resolve in addressing the entire issues of climate change. This, we believe is the first step forward providing full disclosure of information that can help the scientific community in better addressing the problems that confront us all. The enormity of this task requires continued technical and financial support to developing countries like Pakistan that are struggling to institutionalize a process whereby such submissions can be based on accurate data.

In the end I wish to congratulate all those involved in the long process of preparing the INC report, which was a task of great magnitude. I specially appreciate the work done by the Project Steering Committee and the Sub-Committee, in providing technical and policy oversight to the project and preparation final version. The timely assistance of GEF, UNEP and the UNFCCC Secretariat, by providing financial and technical support, is also noteworthy.



Major(Retd) Tahir Iqbal

Minister-of-State for Environment

Abbreviations

AEARC	Atomic Energy Agricultural Research Center
AJK	Azad Jammu and Kashmir
AKES	Aga Khan Education Services
ALGAS	Asia Least cost Greenhouse Gas Abatement Strategy
APARM	Agricultural Production and Resources Management
AZRC	Arid Zone Research Centre
BOD	Biochemical Oxygen Demand
CCIA	Climate Change Informatics for Agriculture
CCIS	Climate Change Information Service
CERI	Cost of Emission Reduction Initiatives
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
DSSAT	Decision Support System for Agrotechnology Transfer
EAW	Economic Advisory Wing
EM	Effective Microorganisms
ENERCON	National Energy Conservation Centre
EPA	Environmental Protection Agency
FATA	Federally Administered Tribal Areas
FO	Furnace Oil
GCM	Global Climate Model
GDD	Growing Degree Days
GDP	Gross Domestic Product
HOBC	High Octane Blending Compound
HSD	High Speed Diesel
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification
IUCN	World Conservation Union

KESC	Karachi Electric Supply Corporation
LAI	Leaf Area Index
LDO	Light Diesel Oil
MAGICC	Model for Assessment of Greenhouse Gas Induced Climate Change
MAV	Multi Attribute Value Function
MOE	Ministry of Environment
MNB	Multinutrient Feed Blocks
MSL	Mean Sea Level
MTBE	Methyl Tertiary Butyl Ether
NA	Northern Areas
NACS	Northern Areas Conservation Strategy
NARC	National Agricultural Research Centre
NCS	National Conservation Strategy
NGO	Nongovernmental Organizations
NIAB	National Institute of Agriculture and Biotechnology
NIO	National Institute of Oceanography
NMVOC	Non Metallic Volatile Organic Compound
NPP	Net Primary Productivity
NPV	Net Present Value
NRL	National Refinery Limited
NWFP	North West Frontier Province
P&D	Planning and Development
PARC	Pakistan Agricultural Research Council
PARCO	Pak Arab Refining Corporation
PCRWR	Pakistan Council for Research in Water Resources
PFI	Pakistan Forest Institute
PIDE	Pakistan Institute of Development Economics
PMD	Pakistan Meteorological Department
PRL	Pakistan Refinery Limited
PSDP	Public Sector Development Program

PSF	Pakistan Science Foundation
RSP	Rural Support Program
SME	Small and Medium Enterprise
SUPARCO	Space and Upper Atmosphere Research Commission
SWDS	Solid Waste Disposal Site
T&D	Transmission and Distribution
TRC	Teachers Resource Centre
UBC	University of British Columbia
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
WAPDA	Water and Power Development Authority
WRRI	Water Resources Research Institute
WWF	Worldwide Fund for Nature

Units

Bcf	Billion Cubic Feet
Gg	Giga grams
Ha	Hectares
Maf	Million Acre Feet
Mb	Millibars
Mm	Millimeters
Mha	Million Hectares
MW	Mega Watts
Ppm	Parts Per Million
psi	Pounds per Square Inch
TC	Tonnes of Carbon
tJ	Tera Joules
TOE	Tonnes of Oil Equivalent

1. Executive Summary

The report has been made possible by the support provided by GEF through UNEP under the project "GF/2200-97-57; Pakistan: Enabling Activities for the preparation of Initial National Communication related to UN Framework Convention on Climate Change". The project was initiated in 1999 and the execution and implementation of the project was undertaken by the Federal Ministry of Environment (MOE). The report attempts to provide a detailed analysis of issues confronting the Pakistani climate change planners. The process itself has been very consultative and has spanned a period of three years during which numerous stakeholders from the public, private sector, civil society and academia were consulted.

The preparatory process involved expert work undertaken by a consortium of specially constituted National Study Team for providing the necessary outputs as per laid down technical criteria provided for in the contract agreement between Government of Pakistan and UNEP. The project was provided policy guidance by a high-powered Project Steering Committee (PSC) chaired by the Secretary, Ministry of Environment and comprising government and private sector experts in the area of climate change. The PSC held six meetings during the course of this study and four workshops were organized. A sub-committee was constituted and authorized by the PSC in February 2003 to undertake a consultative process of reviewing the final draft report presented to the PSC and compile Pakistan's initial national communication in light of the comments received from different stakeholders and the guidelines attached to Decision 10/CP2. Pakistan's initial national communication finalized by the Sub-Committee was approved by the PSC in its meeting on 3rd November, 2003.

1.1 National Circumstances

Pakistan occupies a land area of over 880,000 square kilometers and forms part of the South Asian subcontinent. It is bordered by India on the east, China on the northeast, and Iran and Afghanistan on the west. The country is characterized by significant variations in altitude and topography across its territory. Pakistan's diversity extends to its climatic, socioeconomic, and environmental characteristics, which differ significantly from region to region. The country has four provinces, the Punjab, the North West Frontier Province (NWFP), Sindh, Balochistan, and two federally administrated territories: the Federally Administered Tribal Areas (FATA) and the Northern Areas. In addition, the territory of Azad Jammu and Kashmir (AJK), is under the administration of the Government of Pakistan. Each province or territory is further divided into administrative units known as districts.

Pakistan's coastline with the Arabian Sea stretches to over 990 km. It consists of two distinct units in terms of physiographic outline and geological characteristics. The coastal and offshore geology of Pakistan tectonically exhibits both active and passive features.

Pakistan with a population of about 140 million which is expected to rise to 210 million by 2025, is the eighth most populous country in the world.

Climate

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 (Khan, 1993).

Water Resources

Pakistan is divided into three hydrological units: the Indus basin, covering an area of over 566,000 km^2 (70% of the surveyed area in the country), the Kharan desert in west Balochistan with its inland drainage, and the arid Makran coast along the Arabian Sea in the south. The total watershed area of the Indus basin, or the region that drains into the river, as well as the river system itself, is 944,000 km^2, 60% of which lies in Pakistan[1].

Agriculture and Livestock

Agriculture contributes to about 24% of the GDP and provides employment to 48.4% of the labor force (EAW, 2003). Pakistan's area is divided into ten agro-ecological zones based on physiography (PARC 1980). These regions consist of: a) the Indus delta; b) the southern irrigated plain; c) sandy deserts; d) the northern irrigated plain; e) *barani*[2] lands; f) wet mountains; g) the northern dry mountains; h) the western dry mountains; i) the dry western plateau; and j) the Sulaiman piedmont. The ecology and resources in these regions vary considerably.

Almost a third of Pakistan's total area is classified as rangeland (GOP/RCA, 1992). These rangelands support two-thirds of the entire population of sheep and goats and over half of the cattle population of the country. Millions of herders and pastoralists depend on rangelands for their livelihood.

Forestry and Biodiversity

Forests in Pakistan cover 4.224 million hectares, covering only 4.8% of the total surveyed land area of 87.98 million hectares. The percentage of forest area in different provinces and territories is very different. The northern territory of Azad Jammu and Kashmir (AJK) has a forest area that comprises 20.7% of its total land area. This is followed by the North West Frontier Province (NWFP) and the Northern Areas (NA), where forests cover 16.6% and 9.5% of the land area respectively. In the provinces of Punjab and Sindh, about 2.8% of the total land area is under forest. The proportion of forest area in Balochistan is 0.7%.

Pakistan is endowed with diverse biomes and habitats colonized by a multitude of precious animal and plant life. The present diverse and surprising composition of fauna of Pakistan is

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[1] Bhatti, 2000

[2] Rain-fed agriculture.

mainly due to its affinities to two of the major faunal regions: the Palearctic region west of the Indus and the oriental region east of the Indus. The diversity of life forms has been affected by human activities. These activities have caused environmental degradation ranging from pollution to biological invasion from the introduction of exotic species in the region and leading to decrease and loss of biodiversity.

Energy

Primary commercial energy supplies in Pakistan comprise of oil, natural gas, coal, hydro and nuclear electricity. Total primary energy supplies measured in terms of tonnes of oil equivalent (TOE) in 2002-03 were 47.1 million, major contributors being natural gas 44.2% and oil 38.3%. The relative share of oil had been increasing over time in the 1990s mainly due to commissioning of a number of fuel oil based power plants and as a result the share of oil in the energy supplies in 1997-98 had reached the level of 43.5% while gas was contributing 38.0%. However, due to recent policies of the government having a focus on economic as well as environmental considerations, the percentage shares of natural gas and oil have now almost reversed to become more environment friendly.

Economy

With a per capita income of US$ 492 (in real terms) in 2002-03, Pakistan is a low-income economy, which typifies many of the characteristics of developing economies in general, and those of South Asia in particular. The sectoral composition of GDP in Pakistan has not changed significantly over the last decade. The commodity-producing (agriculture, manufacturing, construction, etc.) and services sectors (wholesale and retail trade, transportation, etc.) hold approximately equal weight in the economy, with both contributing close to 50% of the real GDP. Within these two broad categories, agriculture is the single largest sector, with a share of 24% in real GDP, and employs 48.4% of total workforce. This is followed by manufacturing, which accounts for roughly 17%, and wholesale and retail trade, which contributes 14.9%. According to the estimates of the last census, 41% of the employed population over 10 years of age is engaged in agriculture. Manufacturing employs barely 10% of the working population, while the rest is employed in the services sector.

1.2 Inventory and Mitigation Options

The national greenhouse gas (GHG) inventory serves to identify key sources and sinks of direct and indirect GHGs. The GHG inventory for Pakistan for the year 1994 presented in this report has been prepared in accordance with the revised guidelines for preparation of national inventories issued by the Intergovernmental Panel on Climate Change (IPCC). The IPCC recommended methodologies cover five significant GHG source categories, i.e., the energy, industrial processes, livestock and agriculture, forestry and land use change, and waste sectors. Emissions from all categories except solvents are reported in this inventory. The GHG Inventory was to cover the year 1994 but since most of the data published in Pakistan is for the fiscal year, which in Pakistan runs from July to the next June, therefore the Inventory covers the period from July 1993 to June 1994.

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.

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.

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.

The mitigation options assessment covers three sectors: energy, forestry and land use change, and agriculture and livestock. 21 options were analyzed in the energy sector, which included options from both demand and supply side. Demand side options were further subdivided into six sectors: rural households, urban households, agriculture, industry, transport and commercial. Six options were analyzed for the forestry sector and two for the agriculture sector.

1.3 Climate Change Impacts and Adaptation

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. Adaptation, or long term strategies are likewise difficult to formulate unless detailed vulnerability and impact assessment studies, , are undertaken.

Vulnerability and impact assessment studies were conducted for key sectors as part of the research undertaken for the Pakistan National Communication. These studies were completed recognizing the constraints outlined above 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 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. A temperature change of =0.3 $_0$C per decade and a=1.0 percent change per decadein precipitation were recommended. The forecasts were done for the years 2020 and 2050. Agriculture and water resources were given due importance because of the possibility of extensive impacts of climate change in these sectors and the necessity of considering adaptation measures for these sectors. Both these studies provide information on the potential impacts of climate change on these sectors and the possible adaptation measures that can be adopted to counteract these impacts.

Pakistan has a low institutional and financial capacity to adapt to climatic changes; therefore improving the adaptation capability is considered to be of the highest priority at this stage. Suggested adaptation strategies for Pakistan will need to concentrate on reducing vulnerability to current climatic events, as well as adopting policies for ensuring long-term ecological and human development.

1.4 General Description of Steps Taken

Pakistan is a country that contributes very little to the global GHG emissions, but nonetheless views climate change as an issue not only requiring international cooperation but also a pro-active policy at the national level. It is with this objective that Pakistan has embarked upon dealing with an issue that threatens the predominantly agriculture base of the economy and has implications for livelihood and survival of a population of over 140 million people. 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. Most of this work has been largely financed by GEF through one of the implementing agencies.

1.4.1 Existing Policy, Institutional and Legislative Structure

Pakistan's environmental policy and management framework is based on the Pakistan Environment Protection Act 1997 (PEPA), which in turn replaces the Pakistan Environmental Protection Ordinance promulgated in 1983. PEPA has two important responsibilities - the creation of institutions and the regulation of activities covering the environment. This legislation has been responsible for the establishment of Pakistan

Environmental Protection Council (PEPC), and the Pakistan Environmental Protection Agency. The National Environmental Quality Standards (NEQS) finalized in 1993 further provide standards for industrial and municipal effluents and air emissions, including 32 liquid and 16 gaseous parameters. The compliance framework for enforcing the regulations is a mixture of administrative measures, judicial sanctions and active civil society involvement[1].

Major policy initiatives in the environment sector have been the enactment of National Conservation Strategy (NCS) in 1992. Forestry Sector Master Plan and NCS plan of Action and the finalization of a National Environmental Action Plan (NEAP) in February 2001. The NCS lays out the fourteen key priority areas for policy formulation and intervention, while NEAP outlines four priority areas for development and implementation of environmental conservation programs - clean air, clean water, solid waste management and ecosystem management. The NEAP also identifies five additional areas of concern in which additional support is needed to strengthen the base for environmental management in the long run. Both the NEAP and NCS have indirect relevance to climate change issues.

1.5 Education, Training and Public Awareness

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 Government of Pakistan. 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.

1.6 Financial and Technological Requirements

The report provides a detail overview of the analysis undertaken to assist Pakistan in playing its due role as an active partner in international efforts aimed at addressing the issue of climate change and responding to the specific needs of developing countries arising thereof.

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1 Akhund, Nelma and Qureshi, Zainab (1998), "You can make a difference", IUCN publication, Karachi.

Pakistan requires financial and technical assistance in not only meeting its obligations under the Convention but in also helping the country to undertake appropriate measures to respond adequately to climate change impacts and developing sound adaptation strategies. In order to meet its growing energy needs, it requires specific assistance in environment friendly technologies and renewable energy development to embark on a development path that is not only sustainable but also helps the country in meeting the objectives of the Convention. Given the contribution of energy sector in the economic growth and its GHG mitigation potential, it has been recognized that such assistance will be required both technically and financially in the area of renewable energy development. The project identified needs requiring further technical and financial support in the area of inventory preparation, climate change impact assessment and adaptation, institutional strengthening, and disaster mitigation.

The report also documents proposals for research programs for various sectors. It gives possible research programs for agriculture, livestock, forestry, waste, water resources, biodiversity and coastal zones.

2. National Circumstances

Pakistan occupies a land area of over 796,095 square kilometers and forms part of the South Asian subcontinent. It is bordered by India on the east, China on the northeast, and Iran and Afghanistan on the west. The country is characterized by significant variations in altitude and topography across its expanse. Pakistan's diversity extends to its climatic, socioeconomic, and environmental characteristics, which differ significantly from region to region. The country has four provinces, the Punjab, the North West Frontier Province (NWFP), Sindh, Balochistan, and two federally administrated territories: the Federally Administered Tribal Areas (FATA) and the Northern Areas. In addition, the territory of Azad Jammu and Kashmir (AJK), is under the administration of the Government of Pakistan. Each province or territory is further divided into administrative units known as divisions. The country's administrative divisions are shown in **Exhibit 2.1**.

The following sections give a brief, general overview of Pakistan's national circumstances, including climatic conditions, socioeconomic conditions, and environmental issues.

2.1 Climate

The Survey of Pakistan[1], , classifies the country into eight climatic zones, which roughly concur with the Köppen Geiger classification. These zones are shown in **Exhibit 2.2**. 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 (Khan, 1993). 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 northeastern 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.

[1] Responsible for major land surveys and cartographic records in the country

Source Survey of Pakistan

Exhibit 2.1: Administrative Divisions of Pakistan

Source: Surveyof Pakistan

Exhibit 2.2: Climatic Zones of Pakistan

2.2 Water Resources and Irrigation Systems

Pakistan is divided into three hydrological units: the Indus basin, covering an area of over 566,000 km^2 (70% of the surveyed area in the country), the Kharan desert in west Balochistan with its inland drainage, and the arid Makran coast along the Arabian Sea in the south. The total watershed area of the Indus basin, or the region that drains into the river, as well as the river system itself, is 944,000 km^2, 60% of which lies in Pakistan[1].

The Indus river system consists of the Indus River and its eastern and western tributaries. The major eastern tributaries are the Jhelum, Chenab, Ravi, Sutlej, and Beas rivers, while the major western tributaries are the Kabul and Kurram rivers. In addition, there are numerous small tributaries, such as the Soan and Haro rivers, and hill torrents, which drain either directly or indirectly into the Indus basin. The 1960 Indus Basin Treaty with India, which apportioned water from the primary rivers of the province of Punjab between the two countries, allocated the flow of three western rivers, namely the Indus, Jhelum, and Chenab, with occasional spills from the Sutlej and Ravi rivers to Pakistan. The flows in all these rivers are quite variable in different cropping seasons and years. About 84% of flows occur in the *Kharif* (summer) crop season and only 16% occur in the *Rabi* (winter) season. If the population's current 2.1% rate of increase persists, the country's population will double after two decades, which will tremendously increase pressure on freshwater resources. The surface-water resources in the country are constituted by precipitation in the catchment area—or the area that drains into the river—of the Indus river system, and of glacier melt in the upper basin.

The water resources of the Kharan desert (west Balochistan) and the arid Makran coast (southern Balochistan) are limited and the desert areas in the south (Thar and Cholistan) have no appreciable water. Water availability in the rivers that feed the irrigation system is measured at rim stations built on each river upstream from the existing canal system. These stations cover most of the tributary inflows.

2.3 Agriculture

Agriculture contributes to about 24% of the GDP and provides employment to 48.4% of the labor force (EAW, 2003). Pakistan's area is divided into ten agro-ecological zones based on physiography (PARC 1980). These regions consist of: a) the Indus delta; b) the southern irrigated plain; c) sandy deserts; d) the northern irrigated plain; e) *barani*[2] lands; f) wet mountains; g) the northern dry mountains; h) the western dry mountains; i) the dry western plateau; and j) the Sulaiman piedmont (**Exhibit 2.3**). The ecology and resources in these regions vary considerably.

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[1] Bhatti, 2000

[2] Rain-fed agriculture.

Pakistan's agricultural production system is complex and consists of a mix of crop and livestock production. Four major cropping patterns are in practice, namely: a) rice-wheat, b) cotton-wheat, c) sugarcane-wheat, and d) maize-wheat. Farms consisting of an area of less than 5 hectares constitute 39% of the cultivated area, and 81% of all farms in the country fall in this category. About 12% of farms have an area of 5 to10 ha, and such farms cover 22% of the total cultivated area. Only 7% of all farms are over 10 ha in size, but these account for 40% of the farmed area. The variability in size of land holdings ensures that land use and cropping systems differ across farm sizes as they derive from the varying investment capacity of different farmer groups.

Cultivated areas in Pakistan are classified as canal command, tubewell command, *Sailaba*,[1] and *Barani*. The total cropped area in 1999 was 22.96 million hectares (Mha). A further 11.82 Mha is estimated to be under forage and forests. Thus, 34.78 Mha of land is suitable for agriculture and forestry. However, a staggering 96% of arable land does not contain the full spectrum of organic matter needed for optimum agricultural productivity.

[1] Runoff farming.

Source:NARC

Exhibit 2.3: Agro-ecological Zones of Pakistan

2.4 Livestock

Almost a third of Pakistan's total area is classified as rangeland (GOP/RCA, 1992). These rangelands support two-thirds of the entire population of sheep and goats and over half of the cattle population of the country. Millions of herders and pastoralists depend on rangelands for their livelihood.

Livestock farming plays a significant role in the economy of Pakistan. This is because livestock production is deeply integrated with crop production and is dominated by farmers working on small landholdings, as well as landless farmers. In a majority of households where livestock farming is practiced, livestock management is actually the responsibility of the women in the household. In many cases, the women may also have some control over incomes derived from the sale of livestock products. Livestock is still a major source of fertilizer for crop production, power for farm operations, and fuel for cooking, and is an are easily convertible mobile asset in times of emergency. Raw material from livestock (wool, casings, hides/skins) and value-added products relying on livestock products (carpets, leather garments and footwear, etc.) are significant foreign exchange earners. During 1999-2000, the value of these exported commodities amounted to over Rs. 21 billion, or 5.3% of total exports. Rangelands contain more than two thirds of all the sheep and goats and over half the cattle of Pakistan. Most of the buffaloes, however—the primary milk producing animals—are found in the irrigated areas, although in recent years, herds are also being raised in peri-urban areas.

2.5 Forestry and Land Use Change

Forest vegetation in Pakistan is diverse in its structure and composition. This is due to variations in climatic and ecological conditions under the change in latitude from 24 to 37^{o} N and altitude from zero, or sea level, in the south to more than 8,000 meters in the north. These changes also account for a progressive decrease in the mean annual temperature and increase in rainfall from the south towards the north. Forests in Pakistan cover 4.224 million hectares, covering only 4.8% of the total surveyed land area of 87.98 million hectares. The percentage of forest area in different provinces and territories is very different. The northern territory of Azad Jammu and Kashmir (AJK) has a forest area that comprises 20.7% of its total land area. This is followed by the North West Frontier Province (NWFP) and the Northern Areas (NA), where forests cover 16.6% and 9.5% of the land area respectively. In the provinces of Punjab and Sindh, about 2.8% of the total land area is under forest. The proportion of forest area in Balochistan is 0.7%.

By some estimates, about 80% of the area defined as forest in Pakistan actually has tree cover, while the rest is largely denuded (EUAD/IUCN, 1992). Afforestation rates have increased from 70 million saplings per annum in the 1970s to 250 million in the current decade.

2.6 Biodiversity

Pakistan is endowed with diverse biomes and habitats colonized by a multitude of precious animal and plant life. The present diverse and surprising composition of fauna of Pakistan is mainly due to its affinities to two of the major faunal regions: the Palearctic region west of the Indus and the oriental region east of the Indus. Pakistan spans a remarkable number of the world's broad ecological regions because of its interesting zoogeography. The country includes examples of three of the world's eight biogeographic 'realms' (the Indo-Malayan Realm, the Palearctic Realm, and the Africotropical Realm), four of the world's ten 'biomes' (the desert, temperate grassland , tropical seasonal forest, and mountain biomes) and three of the worlds four 'domains' (the polar/mountane domain, the humid temperate domain, and the dry domain). Apart from the two major zoogeographical regions, Pakistan includes within its boundaries four recognized phytogeographical regions, which help to explain the richness and diversity of its flora. Ali and Qaiser (1986) described these as 'Saharo-Sindian' (Sindh, central and southern Punjab, southern Balochistan and plains of N.W.F.P.), 'Irano-Turanian' (Waziristan and North Balochistan, upper regions of Gilgit and Chitral, and adjoining area south east), 'Sino-Japanese' (Kashmir, N.W.F.P., Astor, Naltar, Bagrot Valleys), and 'Indian' (Sub-Himalayan tracts, east and west of the river Jhelum).

2.7 Energy

The vision of the Government for the Energy Sector remains the sustainable exploitation and efficient use of energy resources and power production in order to improve the quality of life of the people. The Government of Pakistan attaches high importance to the development of renewable energy resources and has recently constituted a high-powered alternate energy board to advise the government on cleaner forms of energy. ENERCON, an attached department of the Ministry of Environment is specifically mandated to promote energy conservation and efficiency.

The energy sector is the single largest source of greenhouse gas emissions as detailed in the inventory developed for Pakistan. As such, it is also the sector which is believed to have the greatest potential for development of mitigation options. Pakistan has vast potential for renewable energy development; the three provinces of Pakistan i.e. NWFP, Balochistan and Sindh provide vast untapped resources for hydropower, wind and solar energy. These sectors therefore represent an added opportunity for the corporate sector and foreign governments to undertake viable investments that will also assist Pakistan in utilizing its cleaner forms of energy.

Primary commercial energy supplies in Pakistan comprise of oil, natural gas, coal, hydro and nuclear electricity. Total primary energy supplies measured in terms of tonnes of oil equivalent (TOE) in 2002-03 were 47.1 million, major contributors being natural gas 44.2% and oil 38.3%. The relative share of oil had been increasing over time in the 1990s mainly due to commissioning of a number of fuel oil based power plants and as a result the share of oil in the energy supplies in 1997-98 had reached the level of 43.5% while gas was contributing 38.0%. However, due to recent policies of the government having a focus on economic as well as environmental considerations, the percentage shares of natural gas and oil have now almost reversed to become more environment friendly.

2.8 Coastal Zones

Pakistan's coastline with the Arabian Sea stretches to over 990 km. It consists of two distinct units in terms of physiographic outline and geological characteristics. The coastal and offshore geology of Pakistan tectonically exhibits both active and passive features. The Balochistan coast is active whereas the Sindh coast, Indus deltaic area, and offshore Indus basin are geologically passive. The Sindh and Balochistan coasts have differing climatic conditions and socioeconomic characteristics. The Sindh coast can be further divided into two parts: the Indus deltaic coast and the Karachi coast. The coast near Karachi, which is approximately a 70-km stretch, is relatively more developed than the rest of Pakistan's coastal area.

The most important ecosystems to be found in the coastal belt are the mangrove forests in the Indus delta, which are a rich source of nutrients for a variety of marine species. Eight mangrove species are reported along the coast of Pakistan, with *Avicennia marina* being the most dominant. Some species have been reported to be rare or have disappeared from the delta because of human activities coupled with adverse physical and environmental conditions. Silt and clay deposits elevate land and limit the access of mangrove plants to tidal water, thus retarding plant growth. The mangroves constitute one of the more threatened ecosystems in the country because of reduced freshwater flows, clear felling of sizable tracts of land in the forest areas, and industrial pollution in and around the delta.

2.9 Socioeconomic Conditions[1]

With a per capita income of US$ 492 (in real terms) in 2002-03, Pakistan is a low-income economy, which typifies many of the characteristics of developing economies in general, and those of South Asia in particular. The sectoral composition of GDP in Pakistan has not changed significantly over the last decade. The commodity-producing (agriculture, manufacturing, construction, etc.) and services sectors (wholesale and retail trade, transportation, etc.) hold approximately equal weight in the economy, with both contributing close to 50% of the real GDP. Within these two broad categories, agriculture is the single largest sector, with a share of 24% in real GDP, and employs 48% of total workforce. This is followed by manufacturing, which accounts for roughly 17%, and wholesale and retail trade, which contributes 14.9%. According to the estimates of the last census, 41% of the employed population over 10 years of age is engaged in agriculture. Manufacturing employs barely 10% of the working population, while the rest is employed in the services sector.

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1 All data in this section is from the Pakistan Economic Survey, 2002-03 unless stated otherwise.

Sectoral Share of Various Sectors in Gross Domestic Product[1]

	1969-70	1998-99	2000-01	2001-02	2002-03(P)
Commodity Producing Sector	61.6	51.1	49.7	49.4	49.3
1. Agriculture	38.9	25.4	24.7	23.9	23.6
- Major Crops	23.4	10.3	10.0	9.5	9.6
- Minor Crops	4.2	4.9	4.1	3.9	3.8
- Livestock	10.6	9.2	9.3	9.4	9.2
- Fishing	0.5	0.9	0.9	0.7	0.8
- Forestry	0.1	0.1	0.3	0.3	0.3
2. Mining & Quarrying	0.5	0.5	0.5	0.5	0.5
3. Manufacturing	16.0	17.1	17.7	17.9	18.4
- Large Scale	12.5	12.1	12.5	12.7	13.1
- Small Scale	3.5	5.0	5.2	5.3	5.3
4. Construction	4.2	3.4	3.4	3.4	3.3
5. Electricity & Gas Distribution	2.0	4.7	3.6	3.7	3.4
Services Sector	38.4	49.1	50.3	50.6	50.7
6. Transport, Storage and Communication	6.3	10.2	10.3	10.0	9.9
7. Wholesale and Retail Trade	13.8	15.2	15.3	15.2	15.5
8. Finance and Insurance	1.8	2.5	2.5	2.6	2.4
9. Ownership of Dwellings	3.4	5.9	6.1	6.2	6.2
10.Public Administration and Defence	6.4	6.1	6.4	6.6	6.6
11.Other Services	6.7	9.0	9.7	10.0	10.1
12.GDP (Constant Factor Cost)	100.0	100.0	100.0	100.0	100.0

P) Stands for provisional. Source: Economic Adviser's Wing, Finance Division

[1] In percentage terms

3. National 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[1] has been generated through the Enabling Activity project funded by GEF though UNEP. The Pakistan national inventory for 1993-94 is summarized in **Exhibit 3.6.**

3.1 Methodology

This inventory has been prepared using the common reporting and documentation framework prescribed by the IPCC (see IPCC, 1996*a*) to allow for consistent comparison with other national estimates. The guidelines cover five significant GHG source categories, i.e., the energy, industrial processes, livestock and agriculture, forestry and land-use change, and waste sectors. Solvents and other product use, the sixth GHG source category identified by the IPCC, has been excluded from this inventory because of data deficiencies, i.e., absence of activity and emission data on solvents used in dry cleaning, printing, metal degreasing, painting, and industrial and household uses. The IPCC guidelines use specific terms for certain fuels, which may or may not correspond with terms used in Pakistan.

Developing country-specific emission factors for liquid fossil fuels in Pakistan was not possible because no agency in Pakistan has carried out a detailed analysis of fuel composition for liquid fossil fuels used in the country. However, data was collected on fuel composition for natural gas by field and on carbon content of coal by mine. In addition, data on the sulfur content of coal and liquid fossil fuels in Pakistan were also available. Local emission factors were thus developed for natural gas and coal and for sulfur contents of coal and liquid fossil fuels. **Exhibit 3.1** describes IPCC equivalent of local fuel types.

Exhibit 3.1: IPCC Equivalent of Local Fuel Types

IPCC Terminology	*Terminology Commonly Used in Pakistan*	*Remarks*
Gasoline	High-octane blending compound (HOBC) Motor spirit Methyl tertiary butyl ether (MTBE)	Fuels listed in column 2 are added up under the heading Gasoline throughout the inventory
Jet kerosene	Aviation fuel	-

[1] The inventory preparation builds on the earlier work on Inventory undertaken as part of the *ALGAS* project; "ADB/GEF/UNDP, 1998. *Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS) –Pakistan"*

Gas/diesel oil	High speed diesel (HSD) Light diesel oil (LDO)	Fuels listed in column 2 are added up under the heading Gas/Diesel Oil throughout the inventory
Residual fuel oil	Furnace oil	-

3.2 Summary of Results

Emissions from the energy sector are divided into two main categories, i.e., emissions from fuel combustion and fugitive emissions from a) coal mining and handling and b) oil and natural gas activities. In addition, countries using the IPCC guidelines for inventory preparation estimate emissions from the energy sector using two approaches, the Reference Approach and the Source Categories Approach. The Reference Approach reports the inventory of carbon dioxide (CO_2) emissions by type of fossil fuel. On the other hand, the Source Categories Approach calculates CO_2 emissions at the levels of specific end-use activities, processes or technologies.

Total CO_2 emissions from fuel consumption, calculated by the Reference Approach were estimated at 84,227.3 gigagrams (Gg), with 52 percent of emissions resulting from the combustion of liquid fossil fuels, 36 percent from the combustion of natural gas, and the remaining from the combustion of solid fossil fuels. Within individual fuels, natural gas was the single biggest contributor to CO_2 emissions, accounting for 36 percent of total emissions. Crude oil was the second highest contributor, accounting for 25 percent of total emissions. Gas/diesel oil and residual fuel oil comprised 16.6 percent and 11.8 percent of total CO_2 emissions respectively. Total CO_2 emissions from international bunkering were estimated at 461.209 Gg, 88 percent of which resulted from the combustion of jet kerosene. Other bunkered fuels included gas/diesel oil, which contributed 2 percent of total emissions from bunkering, and residual fuel oil which contributed almost 10 percent.

The Source Categories Approach covers two broad classifications, i.e., emissions from fuel combustion and fugitive emissions from handling, processing and non-productive combustion of fuels. Emissions from fuel combustion are estimated on a sectoral basis and the sectors considered include energy industries, manufacturing industries and construction, transport, the commercial and residential sectors and agriculture, forestry and fishing. Fugitive emissions are estimated for coal mining and handling activities and oil and gas activities including oil refining.

Emissions from energy industries amounted to 21,600.9 Gg of CO_2 in 1993-94. Steam generation units accounted for 50 percent of total emissions from the sub-sector, while emissions from plants run on combined cycle technologies accounted for 29 percent. Emissions from plants run on gas turbines contributed 20 percent of total emissions from power generation, while diesel operated generation stations accounted for barely 1 percent of emissions. CO_2 emissions from manufacturing industries and construction were estimated at 24,895.9 Gg in 1993-94. Approximately 22 percent of these emissions were attributed to the fertilizer industry, while the iron and steel industry (which includes the Pakistan Steel Mill) and the cement industry contributed 15 percent and 14.5 percent respectively. Of the fuels used in manufacturing and construction, natural gas accounted for over 43 percent of all emissions while coal accounted for 2.6 percent, although it is used exclusively in the brick industry.

Total emissions from the transport sector amounted to 18,584.4 Gg, with road transport accounting for 87 percent of all emissions from the sector. Within road transport, gas/diesel oil was the most polluting fuel, accounting for almost 77 percent of total emissions from road transport. For the transport sector as a whole, gas/diesel oil used in road transport comprised 67 percent of total emission—thus highlighting the disproportionately large impact of emissions from this fuel. Emissions from air transport constitute the second largest group of emissions by sub-sector, but these constituted only 7 percent of total transport emissions. Rail transport accounted for 3 percent of total transport emissions, while just over 2 percent were attributed to pipeline transport. Sea transport, which is extremely limited in Pakistan, did not cause significant emission levels.

Fuel consumption in the commercial sector resulted in emissions of 1,948 Gg of CO_2 in 1993-94. Over half of these emissions resulted from the use of kerosene, while a further 41 percent could be attributed to the use of natural gas. Natural gas is very much the dominant fuel in the residential sector, accounting for 85 percent of total fuel consumption, when all fuel consumption is converted into tera Joules (TJ) for easy comparison. Kerosene consumption constitutes 9.8 percent of the total, with smaller shares accruing to liquefied petroleum gas (LPG) and lignite. Emissions from natural gas accounted for 81 percent of total CO_2 emissions from the residential sector, while emissions from kerosene constituted 13.5 percent. In accordance with IPCC guidelines, figures for high-speed diesel (HSD) and light diesel oil (LDO) were combined under the heading "Gas/Diesel Oil" for computation of emissions. Total consumption of fuel in the sector was estimated at 101,860.2 TJ. Estimated CO_2 emissions from the sector amounted to 5,400.5 Gg.

An analysis of emission factors for fuels shows that natural gas is the least polluting fuel with respect to magnitude of emissions per heat unit. Lignite is the most polluting fuel with considerable negative climate change impacts. Fuel oil and diesel have roughly similar emission effects. Residual fuel oil also had an emission factor that was slightly higher than the average for fuels in the energy sector. Gas/diesel oil, which in Pakistan is referred to as HSD, has the highest polluting potential within the fuels used in the road transport sector. As diesel was also the dominant fuel in the road transport and railways sub-sectors in particular, and in transport in general, the relatively polluting nature of the fuel has particularly serious implications.

Methane emissions from coal mining and handling are calculated by multiplying coal production figures by the appropriate emission factor and then by a conversion factor of 0.67 which converts the emissions unit from million cubic meters to gigagrams. Methane emissions from coal mining were calculated as 47.2 Gg of CH_4 in 1993-94. The bulk of these emissions came from mining activities. Methane emissions from oil and gas activities were estimated to total 230 Gg in 1993-94. Over 99 percent of these emissions resulted from natural gas production and from transmission and distribution. Emissions from crude oil production, refining and storage remained negligible. Indirect GHG emissions from crude oil refining activities were negligible. Sulfur dioxide (SO_2) emissions from sulfur recovery plants amounted to almost 2.8 Gg in 1993-94. Non-methane volatile organic compound (NMVOC) emissions from storages in refineries also remained low.

Emissions from industrial processes are distinct from energy sector emissions as they result not from fuel combustion but from the physical and chemical transformation of materials during the production process. The IPCC guidelines specify methodologies to calculate emissions from a variety of industrial processes including cement and lime production, soda ash production and use and production of certain mineral products and chemicals. In addition, emissions from processes employed in industries such as the pulp and paper industry and the food and drink industries are also included in the inventory. Not all of these industrial processes are actually being used in Pakistan. Data availability is another problem in this sector as production from some processes, which are considered part of the informal sector, are largely undocumented. Data on industrial production in Pakistan tend to be patchy and publications such as the Economic Survey only publish production data for selected items.

Emissions from cement production were estimated at 4037.8 Gg of CO_2. SO_2 emissions from the process were estimated at 2.4 Gg. CO_2 emissions can result from heating limestone and dolomite at high temperatures. Emissions from limestone and dolomite use amounted to 230.7 Gg of CO_2 in 1993-94. CO_2 is emitted both from the use of soda ash as an input in industrial production and from the production of soda ash itself. Soda ash is a raw material in industries such as glass manufacture, soap and detergents and the pulp and paper industry. It can be produced from a variety of processes including three which are referred to as natural processes and a fourth, the Solvay process, which is classified as a synthetic process. CO_2 emissions from use of soda ash in industry amounted to 81.8 Gg of CO_2 in 1993-94. Emissions of GHGs and ozone precursors can arise from the production of asphalt roofing materials, from road paving in which asphalt is used and from the manufacture of certain mineral products. Emissions of NMVOC from asphalt blowing were estimated at 0.0084 Gg in 1993-94.

Emissions of NMVOC are likely to result from the use of asphalt in road paving. Emissions from road paving were estimated to amount to 577.9 Gg of NMVOCs. Information on emissions of GHGs and ozone precursors from glass production remains incomplete. However, NMVOC emissions from glass production were estimated and were negligible at 0. 2 Gg. Ammonia production, which in Pakistan takes place in fertilizer plants, is another potential source of GHG emissions. CO_2 emissions from ammonia production amounted to 2990.5 Gg. SO_2 emissions from sulfuric acid production amounted to 1.8 Gg in 1993-94.

The IPCC recommends that emissions from metal production be estimated using information on the reducing agent used. If this information is not available, emissions can be estimated using data on metal production quantities. This is an area where considerable improvement in assessment methodologies is required, and where estimates are somewhat uncertain. The primary metals produced in Pakistan are iron and steel, at the Pakistan Steel Mill in Karachi. A total of 3928.8 Gg of CO_2 were estimated to have been emitted from the iron and steel production process in 1993-94, with a little over half of these emissions coming from the hot metal production process. The IPCC guidelines give a methodology for estimating indirect GHG emissions from the iron and steel industry, but the data requirements for this module were fairly complex which is why this module was not completed for this inventory.

Emissions from the pulp and paper industry arise mainly during the pulping process. SO_2 emissions from the acid sulfite pulping process amounted to 6.7 Gg in 1993-94. The production of certain foods and beverages such as bread, edible oils and alcoholic beverages can be a potential source of NMVOC emissions. Emissions from the food and drink industries considered remained largely negligible in 1993-94, with the sugar industry accounting for about 80 percent of total emissions from the sector.

Halocarbons are also potentially harmful as they have high global warming potentials and long atmospheric residence times. Applications of halocarbons include use in refrigeration and air-conditioning equipment, in aerosols and solvents and in foam blowing. Pakistan does not produce or export halocarbons. However, these chemicals are imported for use in refrigeration, in foam blowing and in fire protection equipment. Halocarbon emissions were estimated at 3.1 Gg in 1993-94.

The agriculture and livestock sectors are potentially significant sources of methane (CH_4) and nitrous oxide (N_2O) emissions. Possible source sectors include enteric fermentation in domestic livestock, manure management practices, flooded rice fields, prescribed burning of savannas, field burning of agricultural residues and emissions from agricultural soils. This inventory calculates emissions from all these sources with the exception of emissions from burning of savannas. This module was excluded from the inventory because there is no prescribed burning of savannas in Pakistan.

Total CH_4 emissions from enteric fermentation amounted to a little over 2 million tonnes or 2093 Gg in 1993-94. Fifty percent of these emissions came from the buffalo population alone, with cattle (both dairy and non-dairy) accounting for a further 28 percent. Emissions from poultry could not be estimated as no default emission factors were given. Total CH_4 emissions from manure amounted to 191.8 Gg in 1993-94. Once again, 50 percent of these emissions came from the buffalo population alone, with cattle (both dairy and non-dairy) accounting for a further 37 percent. Methane emissions from paddy fields can vary considerably depending on the emission factor used—the range of estimated emissions is from 111.3 Gg to a little over 333.8 Gg. If the mean emission factor of 10 is applied as the benchmark, CH_4 emissions are estimated at approximately 222.6 Gg. Emissions from field burning of agricultural residues remained low in 1993-94. Emissions were estimated at 0.5 Gg of CH_4, 10.2 Gg of CO, 0.01 Gg of N_2O and 0.3 Gg of NO_X.

Total direct emissions of N_2O from agricultural soils were obtained by adding direct soil emissions from agricultural fields (i.e., emissions from synthetic fertilizer, animal waste, nitrogen fixing crops and crop residue) and direct emissions from histosols. Thus total direct N_2O emissions were estimated at 16.3 Gg, 96 percent of which were direct emissions from agricultural fields. Total indirect emissions, which included emissions from atmospheric deposition of NH_3 and NO_X as well as N_2O emissions from leaching amounted to only 0.07 Gg of N_2O. Emissions from leaching constituted 52 percent of total indirect N_2O emissions. Total N_2O emissions amounted to 29.9 Gg in 1993-94.

The IPCC methodology for estimating net emissions from the forestry sector rests on two basic themes. Firstly, the flux of CO_2 to or from the atmosphere is assumed to be equal to changes in carbon stocks in existing biomass and soils. Secondly, changes in carbon stocks can be estimated by first establishing rates of change in land use and the practice used to bring about the change. The methodology covers three land use management practices that may result in net emissions, as well as changes in soil carbon. The practices considered include changes in forest and other woody biomass stocks, forest and grassland conversion and abandonment of managed lands. Of these, only emissions from changes in forest and other woody biomass stocks have been estimated in this inventory, as other emission source categories were judged not to be applicable to Pakistan. Total carbon uptake or increment was estimated at 11,451.0 kilotonnes, while annual carbon release was estimated at 13,231.2 kilotonnes. Net carbon release was thus 1780.1 kilotonnes, which translated into net emissions of 6527.1 Gg of CO_2.

Waste disposal and treatment is an important potential source of GHG emissions, particularly methane. The IPCC methodology recommends the calculation of waste emissions from four main categories which include land disposal of solid waste, methane emissions from wastewater handling in the domestic and industrial sectors and nitrous oxide emissions from human sewage. This inventory calculates emissions from all these sources. The figure for Net Annual Methane Emissions was estimated at 101.9 Gg of CH_4. Nitrogen emissions from human sewage were negligible at 6. 4 Gg in 1993-94.

3.3 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 subsectors, 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. The options were analyzed on spreadsheets.

Exhibit 3.2: Energy Sector Options Ranked by Incremental Cost

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

Exhibit 3.3: Forestry Sector Options Ranked by Incremental Cost

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

Exhibit 3.4: Agriculture Sector Options Ranked by Incremental Cost

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

Exhibit 3.6: Summary Report for 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	**11,269.6**	**–**	**–**	**–**	**–**	**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**

Continues…

…Continued

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.

4. Climate Change Impact in Key Sectors

Pakistan like other developing country remains extremely vulnerable to the impacts of climate change. 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.

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[1].

4.1 Climate Change Scenarios

The National Study Team, in consultation with experts from the Intergovernmental Panel on Climate Change (IPCC), formulated a set of synthetic 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 Program (UNEP) and other UN agencies. The temperature rise scenario selected by Leichenko and Wescoat (1992) was also consistent with the scenarios selected for study. The scenarios defined for this Communication are summarized in **Exhibit 4.1**.

Exhibit 4.1: Climate Change Scenarios

Variables	*Limits/Periods*
Temperature	+0.3 ºC/decade[2]
Rainfall	±1.0% /decade
Carbon dioxide	360, 550 ppm
Climatic data baseline	1961-90
Prediction scenario	+0.9 ºC and +1.8 ºC in 2020 and 2050

1 This study builds on the earlier work done on Impact Assessment through the **UNEP** project "***Country Case Study on Climate Change Impacts and Adaptation Assessment"*** completed in 1998 (GOP/UNEP 1998a)

2 Pakistan Meteorology Department (PMD) uses a scenario on an estimate of 0.1 degree/decade temperature increase.

	No change in rainfall (NCR)
	±3% rainfall
	±6% rainfall
Prediction periods	2020, 2050

4.2 Water Resources

The effect of climate change on water resources is expected to be significant. An analysis of changes in the hydrological regime can provide a basis for estimating the impacts of climate change on water resources, and can be used as a tool to recommend changes in the water management regimes. In general, increase in temperature would 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 may cause increase in magnitude of floods.

Impact of Water Resources on Electricity Generation

At present, 34% of total electricity generation in the country is based on hydel sources (HDIP, 1999). The share of hydel generation is likely to increase in the future however, in line with the government's stated policy of increasing hydel power generation to reduce costs of power generation, which have risen significantly due to the increased share of fossil fuel based generation in the total. It is therefore important to study the effects of climate change on hydropower generation.

The results of the analysis for hydropower generation are given in **Exhibit 4.2.** In year 2020 under the no change in precipitation scenario, the increase in hydropower is 0.03% whereas under the increased precipitation scenario, the increase in hydropower generation is 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.

Exhibit 4.2: 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

4.3 Agriculture

Climate change is expected to have significant impacts on agriculture. Potential impacts which were explored in the sector study, were potential 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. The potential impacts of climate change on selected crops in Pakistan are discussed in the following sections.

Potential Vulnerability to Heat Stress

Fourteen crops (eight field crops, three vegetables and three fruits) were considered for evaluating the potential vulnerability of crops to heat stress under a climate change scenario of a rise in temperature of 0.3ºC per decade. All the fifteen selected crops were found to be suffering due to heat stress, but crops like wheat, cotton, mango, and sugarcane are more severely affected, as the prevailing maximum temperature is more than 10ºC higher than the optimal range. Any fractional rise in temperature would therefore have serious adverse effects as would considerably increase the growing degree-days. This would 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.

Potential Shifts in Spatial Boundaries

Pakistan is predominantly an arid country and the maximum temperature in summer exceeds 40°C in the central and southern parts of the country. A small increase in mean temperature can translate into much higher ambient temperatures in the planting and growing periods, which can effect a shift in potential boundaries. A significant increase in growing degree days reduces the growing season length for the crop, and may result in reduced yields. For example the study found that under the chosen scenario, growing degree days for wheat would increase by 8 and 16% respectively by 2020 and 2050. The rice crop would not be affected significantly by the temperature increase expected by 2020. Three harvests of the potato crop are carried out in Pakistan during the spring, summer, and autumn seasons respectively. With the projected rise in temperature by 2020, an increase in growing degree-days of 5 to 11% was observed for the spring crop under different climatic zones.

Changes in Productivity

The simulations showed that a temperature increase in the three selected locations, which consist of semi-arid and arid regions, might result in minor reductions in the grain yield.

Changes in Water Use

The analysis for wheat showed that the irrigation water requirements for the crop vary by climatic zone. Thus temperature increases coupled with variations in rainfall can increase the net irrigation water requirements of sub-humid, semi-arid and arid climatic zones, but no significant effects will be observed in humid zones. Under the scenario where rainfall decreases by 6%, net irrigation water requirements could increase by 29%.

The increase in temperature and changes in rainfall did result in increases in net irrigation water requirements in the cool, hyper-arid climate, and in the hot, semi-arid climate. The analysis for the sorghum and millet crops was similar to that of maize. Significant increases in requirements were observed in the rice-wheat, maize-wheat, and cotton-wheat systems.

Changes in Land Use

The projected increase in temperature by 2050 would reduce the growing season length and productivity of all the three cropping systems, but might provide more time for preparation of land for the next crop and have implications for land use in agriculture

Projected Production of Agricultural Commodities

Changes in climate especially increase in temperature coupled with decrease in rainfall would have a negative impact on the future projections of production of major crops. These effects would occur primarily because of increased irrigation water requirements and hastened maturity leading to shortening of the growing season length The climate change scenario would further affect the resource base in the Indus basin in terms of secondary salinization due to increased use of poor quality groundwater.

4.4 Forestry and Land Use Change

The possible impacts of climate change on the forestry sector include changes in forest area, productivity changes, or changes in species composition amongst others.

Changes in the Location of Optimal Growing Areas

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 encroaches 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.

The size of biomes with considerable economic value (cold conifer/mixed woodland, cold conifer/mixed forest, temperate conifer/mixed woodland, warm conifer/mixed forest and steppe/arid shrubland) increased in general, while the size of biomes of degraded vegetation/scrub (alpine tundra, xerophytic wood/scrub, grassland/arid woodland and desert) decreased. Biome size showed a consistent relation of increase or decrease with rising temperature, but remained independent of changes in precipitation.

Changes in Productivity

Productivity as measured by NPP varied greatly across biomes, ranging from 61 to 653 $gC/m^2/year$. However, on the basis of average NPP, the temperate conifer/mixed forest and warm conifer/mixed forest could be termed as very productive with average NPP of 639 and

653 gC/m2/year, respectively. The increase in temperature scenario tended to increase NPP in all biomes in the year 2020 and 2050. Under increase or decrease in rainfall scenarios, the NPP of all biomes did not show much increase in the years 2020 and 2050.

Changes in Carbon Stored

The total above ground dry woody forest biomass in different forest ecosystems, after correction for commercial and non-commercial harvest, is estimated at 223.50 million tons. The total carbon stored in this biomass is 111.75 million tons (calculated using a carbon fraction conversion factor of 0.5). The average Net Primary Productivity (NPP) increase of different biomes, over the base year of 1990 is estimated as 12% in the year 2020 and 19% in the year 2040-50 (calculated) under the climate change scenarios. Therefore, the carbon stored in the dry woody forest biomass is expected to increase to 125.16 million tons in the year 2020 and to 132.98 million tons in the year 2050.

Changes in Nutrient Retention and Litter Decay Rate

Under the prediction of increase in NPP and forest biomass as a result of climate change, there is likely to be a drain of soil nutrients, which are normally found in woody and non-woody forest biomass. In forests that are used for commercial harvesting, there is no immediate risk of nutrient depletion under climate change scenarios. In coniferous biomes, the soils are shallow but the nutrient balance shall remain undisturbed due to long rotation, low yield and selective cutting, as well as the increased activity of nutrient rebuilding process under climate change. Even for fast growing short rotation (10 years) exotic species like poplar and eucalyptus, soil fertility is not likely to be adversely to the extent of affecting their growth and yield as these species are also housed in rich alluvial soils in the plains of Pakistan.

Forest Pests, Diseases and Weeds

High temperature and increased precipitation reduces the dormant period for insects and increases the length of active period. Moreover, longer summers with early onset of growth may lead to more development of weeds in spring, which in turn can aggravate the spread of forest pests and pathogens. This may result in greater damage to forest vegetation due to the increase in prevalence of defoliating, sap sucking and stem boring insects. The spread of pests and weeds may also pose additional challenges to the relevant departments in charge of forest protection and management.

4.5 Coastal Zones

Pakistan, which has a coast extending over approximately a thousand kilometers, is one of the countries classified by UNEP (United Nations Environment Program) through its OCA/PAC regional seas program, as being particularly vulnerable to the effects of sea level rise. The country's largest city, Karachi, which houses almost 10% of the total population, and about 40% of all manufacturing units, is situated on the coast.

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 salinization of ground and surface water. 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.

Coastal Erosion

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.

Impacts on the Indus Deltaic Coast

It is not clear whether the combined effects of climate change and water development will yield more, or less, water for the Indus delta. If climate change and water development were to reduce freshwater inflows to the delta, the historical processes of economic and ecological degradation would continue. A pressing policy issue related to both immediate problems and climate change is the need to establish minimum flows from Kotri Barrage to the Indus Delta. Fresh water inflows to the delta are an economic and ecological problem today. While these problems would be aggravated by some types of climate change, they would worsen with all scenarios of future water development. In light of the progress made in reaching an inter-provincial water allocation agreement to facilitate water development, it is especially important to move toward a policy on minimum river discharge into the delta.

Inundation of Coastal Areas

Sea level rise can cause significant flooding impacts in the coastal zone, particularly in the low-lying deltaic regions. These areas would become more vulnerable to flooding because a higher sea level provides a higher base for storm surges to build upon. Higher seawater levels would also increase the risk of flooding due to rainstorms, by reducing coastal drainage. A rise in sea level would raise the water table, further reducing drainage in coastal areas. All these effects could have possibly devastating socioeconomic implications, particularly for infrastructure in low-lying deltaic areas.

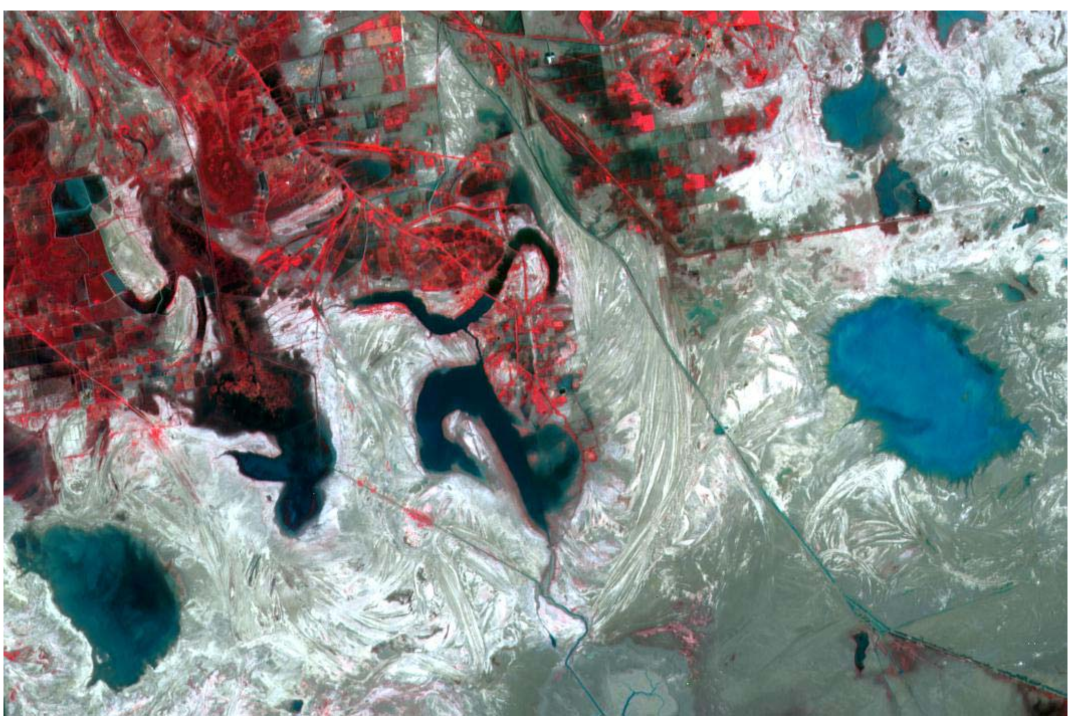
Salinization of Surface and Ground Water

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. Saltwater will penetrate further upstream and inland, as was the case in the lower Indus plain (see **Exhibit 4.3**). This effect would be particularly evident during drought conditions.

Sea level rise would also enable saltwater to ingress farther inland, and upstream in to the rivers, wetlands, and aquifers, which would be harmful to aquatic flora and fauna, and would threaten human uses of water. Increased salinity has already been cited in most of the coastal areas especially in the lower deltaic plain region. A rising sea level, combined with decreased river flow and sediments dispersal, would mean a land ward penetration of the salt water wedge within the groundwater column, which would have significant implications for communities living in the coastal regions.

Indiscriminate exploitation and deterioration of the coastal resources due to hypersalinity, decreased alluvial flow, pollution, soil erosion and dredging have seriously endangered the mangrove forests in the Indus delta. These adverse effects may be added to sea level rise and increased salinization.

Exhibit 4.3: Sea Water Intrusion Observed from Satellite



Cyclones and Storm Surges

The Indus deltaic creeks are critically located on the path of cyclones of the Arabian Sea. One cyclone is expected in a year in the Arabian Sea. About 75% of these cyclones end up at the Omani Coast on the Western Arabian Sea and the remaining 25% curve clockwise and cross the coast near the Rann of Kutch. Sometimes the cyclones cross the Indus deltaic coast. Generally cyclones have strong winds over 100 knots with central pressure as low as 986 millibars (mb). The frequency of cyclones in the Arabian Sea was 0.86 per year for the period 1891 to 1960 and 1.25 per year for the period 1967 to 1970. In the recent five year data 1992 to 1996 the frequency has increased significantly to 2.2 cyclones per year. In the last seven years, two cyclones have crossed the Indus deltaic coast, whereas in the period from 1891 to 1960, only six crossed the Indus deltaic coast.

Climate change is postulated to increase the frequency and severity of cyclones and storm surges along the coast. **Exhibit 4.4** gives the maximum surges at different sites. The model was calibrated using this basic data.

Exhibit 4.4: Maximum Surge at Selected Sites

Location	*Coastal Surge (feet)*
Gwadar	2.7
Pasni	4.6
Ormara	3.3
Sonmiani	5.6
Karachi	8.4
PQA	7.9
Keti Bander	6.6

Impacts on Natural Resources and Biodiversity

In coastal areas, deposits of shells and calcareous sand have always been used for construction and for making lime. Erosion of coastal terraces by strong impounding waves can increase both shell deposits and deposits of calcareous sand, which can be used as building materials. Frequent storm surges and floods can affect salt deposition and harm the salt industry.

Sea level rise and increased temperature might enhance their biomass, but the nutrient availability in coastal waters will deplete at a much faster rate, thus adversely affecting seaweed formation. Sea level rise will also increase the risk of bleaching in the small coral communities, which are found in patches on the Balochistan coast.

Vegetated wetland systems might be submerged during a tidal cycle for progressively longer periods, and may die due to water logging. Loss of wetlands will impact many sectors including food production (loss of key nursery areas for fisheries), flood and storm protection (storm surges will penetrate further inland), waste treatment and nutrient recycling functions, as well as habitats for wildlife.

4.6 Livestock

The livestock sector and rangeland management are most likely to be vulnerable to the impacts of climate change in countries like Pakistan with high population growth rates that compel expansion of grazing into areas of marginal productivity, thereby further stressing the already stressed ecosystem. Thus the traditional pastoralist system of livestock management is likely to suffer under extreme climate change scenarios, as their capacity for adaptation is low. The IPCC has also predicted that increased concentration of CO_2 is likely to alter the carbon and nitrogen ratios of some forage plants. This would result in decreased palatability and nutritional quality of the forage. This is more likely to occur in lower latitude rangelands where forage quality is already inadequate, like in the central and southern regions of Pakistan.

4.7 Impacts on Biodiversity

Substantial data on different aspects of biodiversity and ecosystems necessary for quantitative analysis is currently not available in Pakistan. Pakistan's Biodiversity Action Plan (BAP)[1] also acknowledges data deficiencies as a major issue. Moreover techniques such as eco-climatic classification and analysis through climate envelopes and profiles are not applicable due to resource constraints. Expert judgment would be the most appropriate method for assessment of climate change impact on natural communities and ecosystems in Pakistan.

Ecosystems that were already under extreme pressure from human activity are discussed in this study, as a detailed study of all ecosystems would require considerable resources.

Response of Ecosystems to Increased Atmospheric CO_2

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.

Response to Change in Temperature and Moisture

Changing climate would affect competitiveness of species or groups by altering growth and mortality rates differentially as well as the regeneration success rate. Synchronous functioning of the life cycles of plants, animals, and soil organisms could be potentially

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[1] BAP was prepared by the Ministry of Environment in collaboration with IUCN and WWF as part of the PDF study for Protected Areas Management Project (GEF-World Bank)

affected also. Decomposition and decay of surface litter and organic matter is greatly influenced by climatic factors that in turn affect nutrient cycling.

4.8 Impacts on Important Ecosystems

Actual impacts of climate change on ecosystems are hard to predict. It is necessary to try to generalize about the potential ecological limits to climate change in order to reach basic conclusions. Impacts of climate change on different ecosystems are detailed below.

4.8.1 Marine Ecosystem

Climate change has effects on a whole range of marine life, from phytoplanktons and zooplanktons to predators like seabirds and marine mammals. Climate change may alter the composition, abundance, and concentration that would affect the whole range of marine life. It is expected that warmer waters will decrease phytoplankton biomass and alter their composition as nutrients become limiting and nutrient availability to deeper waters becomes limited.

4.8.2 Mangroves

Mangroves are very productive ecosystems, providing breeding grounds for many varieties of coastal fish and harboring many rare plant and animal species especially the green turtle, an endangered species in Pakistan. Mangrove ecosystems are unlikely to adapt quickly enough to the range of sea-level rise predicted by climate models. The main limiting factor would be build up of sediment level. Sedimentation rate may further be reduced due to changes in water flows. Erosion can also reduce the range of mangrove forests by undercutting roots. A reduction in photosynthesis of tree species may occur due to inundation. Furthermore, a rise in sea level is likely to increase salinity that will impart salt stress to the forests, causing further damage mangroves. Higher temperatures may affect the composition, distribution and productivity of mangroves, while lower precipitation can contribute to salt stress.

4.8.3 Indus Riverain Wetlands

Freshwater wetlands will face fundamental changes in temperature, water flow, salinity, and geographical patterns due to climate change. Climate warming could result in higher surface water temperatures and extended intervals of thermal stratification. Higher groundwater temperature could increase the river water temperature throughout the year, with adverse effects on freshwater fisheries. In general, the survival of wetland populations would depend upon the severity of climate change and availability of escape routes to more suitable habitats. The distribution range of many species would increase and that of others would be squeezed, essentially altering their population status.

4.8.4 Mountains of Pakistan

The mountains of Pakistan are of special concern, given that they support a variety of critically threatened ecosystems, like the juniper forests of Balochistan and the '*Chilgoza'* pine forests in the Sulaiman range. Climate change can affect mountain areas in many ways.

The more direct effects are such that mountains are likely to get warmer and their soils drier, and the frequency of droughts is likely to increase. Increased ice melts at higher latitudes can loosen frozen soil and stones, making landslides and avalanches more common.

Endangered ungulate species like ibex (*Capra aegagrus*) and wild sheep (*Ovis vignei*) that inhabit the dry mountains of Balochistan and Sindh are facing extreme drought conditions for the last three years and are living at the limits of tolerance. If such drought conditions continue to prevail or become more frequent, a drastic reduction in population of such species is expected.

4.9 Socioeconomic Impacts

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 mentioned earlier, the socioeconomic impact assessment of climate change is based on the analysis of impacts in main sectors. Impacts connected to each sector are discussed in the following sections.

4.9.1 Impacts Related to Agriculture and Livestock

Decreases in production of major crops can adversely impact the incomes of a number of farm households. Over 1.3 million farm households, or 30% of the total reporting establishments, reported having some area under cotton in the 1990 agricultural census (ACO, 1999) and 53% of these were farms up to 3 hectares in size. Similarly, 27% of reporting households had paddy fields, and 57% of such households were those having less than 3 hectares of land (ACO, 1999). Decreased cotton yields may have particularly adverse impacts on the earnings and incomes of rural women in cotton growing areas that are traditionally employed on daily wages to carry out the cotton sowing and picking activities.

Linked primarily, with the agricultural sector, livestock predominantly affects the livelihoods of rural dwellers with either small land holdings or none at all. Moreover, availability of meat and dairy products falls almost totally in this domain again with a positive rural (or semi-urban) bias. The impact of climate change on livestock is most pronounced in case of extreme events such as floods and droughts.

4.9.2 Impacts Related to Forestry

Wood is the primary fuel used for both cooking and heating in rural areas in Pakistan. Though, climate change, may have a generally positive impact on the size and location of most biomes, but with product extraction rates estimated to be as high as 2 tons per hectare (according to estimates prepared for the mitigation options analysis) for certain categories of forests, the pressure on woodfuel extraction will continue to grow. Biomes, the size of which is expected to decrease significantly include the alpine tundra area, as well as dry scrub and dry thorn forests. Since productivity in these biomes is relatively low, and the dependence of surrounding communities on such systems is limited, the socioeconomic impacts of changes in size of such biomes are not likely to be significant.

4.9.3 Impacts on Coastal Zones

Sea level rise can have serious long term impacts on communities in coastal areas. Effects may include threats to food production capacity due to decline in irrigation water quality as well as degradation of crucial ecosystems such as mangroves, coral reefs, and coastal lagoons. Degradation of drinking water quality may also have serious health effects. In cases where some permanent inundation may occur, displacement, relocation, and cultural stress may occur, accompanied by a decline in land and property values. In general, economic losses that may occur in coastal areas basically fall under three categories, the direct losses of economic services from land and capital caused by shore-line retreat and storm damage, cost of protection, mitigation and response measures taken to minimize the losses, and lost opportunities due to sea level rise. If coastal areas are developed without anticipating sea level rise, than there is a threat of damage and relocation in the future.

The coastal areas of Pakistan have great potential to develop as tourist resorts. However, many of the coastal resources, which meet recreational and tourism needs, are already under significant pressure from pollution, industrial and residential development, ports and shipping. Climate change effects such as sea level rise and erosion may serve to exacerbate such risks. Sandy beaches may become less sandy with an increase in erosion, the scenic value of the coast may be diminished, more coastal defense protections like concrete sea walls and rock armor may become necessary to defend against the rising tide—all measures that can affect the scenic beauty of the coast and hinder potential tourism development.

The coastal zones of Pakistan have a rich history and culture. A number of prominent archaeological sites can be found scattered along the coast, some of which may be under threat from temporary or permanent inundation. The loss of cultural heritage may thus be another consequence of climate change effects.

4.9.4 Migration, Urbanization, and Human Distress

During the last 25 years, Pakistan's urban population has been growing at more than 3% per annum (HDC 1999b). Urban settlements have grown at such a rapid pace that today nearly 30% of Pakistan's population is contained in less than 0.75% of its area (HDC 1999b). While these settlements have blossomed, basic infrastructure facilities have not kept pace. With the result that about one third of Pakistan's urban population lives in squatter settlements (*Katchi Abadis*) that lack clean drinking water, sanitation, health, education, and employment opportunities (HDC 1999b). According to estimates the proportion of houses in urban areas that have access to piped drinking water has actually gone down from 68% in 1989 to less than 60% in 1997 (FBS, 1998). As climate change is likely to have a detrimental impact on rural livelihoods, therefore more people are likely to be forced to seek employment in urban areas. Thus, human migration towards urban areas is expected to rise, and such settlements are expected to proliferate in the future.

4.9.5 Health

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.

4.10 Extreme Events

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.

4.10.1 Impacts of Floods

Potential flood damages indicated in earlier studies show that the magnitude of the area inundated is especially large in the lower Indus basin. There are also indications of significant damages in urban areas (eg, the Shahdara-Balloki reach). The recent vulnerability of Pakistan's economy to floods is evident from the fact that the 1991-92 floods rendered overall agricultural growth rates for 1992-93 negative, thereby dragging overall GDP growth from 7% in 1991-92 to a mere 2% in 1992-93 (EAW, 2000).

Increased intensity of such exogenous shocks combined with a growing population may lead to increased displacement of rural communities, human migration, and rapid, unplanned urbanization. Hundreds of thousands of people particularly from the low lying areas are uprooted during floods, houses are destroyed/damaged, means of communications are damaged and disrupted, standing crops are wiped out and thousands of livestock are drowned. The people and animals that survive are faced with starvation because foodstuffs and forage may not be immediately available in sufficient quantities. The displacement and upheaval has significant health impacts, with diseases such as cholera and dysentery generally becoming rampant in temporary shelters and camps set up for the homeless.

4.10.2 Impacts of Droughts

Areas now comprising Pakistan have experienced several droughts, of which the most recent and perhaps the most severe occurred in 1999-2000. The drought occurred in several districts of the provinces of Sindh and Balochistan, and is estimated to have affected over 3.3 million people, including thousands who became refugees and hundreds who died of thirst and starvation. It was also reported that about 30 million livestock were affected, including over 2 million that have died. An emergency relief plan, involving an amount of Rs1.6 billion, was carried out as part of the disaster mitigation effort, under which measures were adopted to strengthen logistics support, provide drinking water and material supplies to the drought-hit areas, medical cover to the affected population and treatment to endangered cattle. Food and fodder were also distributed.

5. Adaptation

Climate change impacts and adaptive response strategies have been analyzed in this Communication through an integrated approach that considers possible impacts, both within and among sectors.In this chapter we look at the adaptation strategies, both planned and autonomous, that would help in adjusting to the changing climate. Autonomous adjustments are generally referred to as those that are carried out irrespective of knowledge of climate change, while planned adjustments refer to specific adjustments that are made in order to address the expected impacts of climate change. Planned adjustments are those that are external to the system. In other words, autonomous adaptation means adjustments made within the system, initiated by the stakeholders themselves, while planned adaptation refers to adjustments that are initiated by public policy. However, for certain sectors, some of the planned measures may also be classified as autonomous adaptations. For example in the livestock sector, the livestock, rangelands and the people who derive their livelihood from these systems have some degree of inherent adaptability. However, the degree to which these systems can adapt and remain productive for their defined use depends on the magnitude, timing, frequency and duration of the climate change induced alterations.

Pakistan has a low institutional and financial capacity to adapt to climatic changes; therefore improving the adaptation capability should be of the highest priority at this stage. Suggested adaptation strategies for Pakistan will have to concentrate on reducing vulnerability to current climatic events, as well as adopting policies for ensuring long-term ecological and human development.

5.1 Water Resources

Adaptation strategies for the water resources sector may be developed in response to results of the water resources management models, or be suggested as general guidelines to enhance the overall efficiency of the water resources operation. The sector has much scope for adaptation and has also shown capacity to adapt in the past.

5.1.1 Measures to Improve System Efficiency

The overall efficiency of water resources system is very, due to losses in the system, system constraints, and inefficient farm practices, and also due also to the constraints of funds and inflow patterns. In the precipitation increase scenario, adaptation measures to increase efficiency may include the adoption of better farm management and irrigation practices. Special care will have to be taken to control the high waters in the root zone which considerably reduce the acreage of the crop. Precision land leveling and proper field sizing may be required.

5.1.2 Watershed Management

An effective and economically beneficial adaptation option lies in the construction of dams over the tributaries and *nullahs* to check sediment transport into the Indus basin. Watershed management ought to be an integral part of investment in new storage, particularly surface storage, in view of its local environmental and agricultural benefits. Watershed protection would also have benefits for groundwater storage and flood alleviation. As well as investing in flood protection works (or remedying flood damage) and delayed action dams, there has to be an investment in arresting the degradation of catchment works. Silting from hill torrents is a major problem in the areas where managed flood irrigation is practised. Watershed management works can cover this area also.

5.1.3 Urban Water Use

There is an urgent need to devise policies, both economic and structural, to practise water conservation in the urban areas to lower the rising pressure on the drainage and supply systems and to lower the pressure on sewage treatment, which has become essential for the preservation of water quality.

5.1.4 Water Quality and Environmental Protection

The scenarios of temperature rise coupled with no change or decrease in rainfall are going to affect the quantity of inflow to lakes, ponds and the sea, especially in the low flow years. This is going to trigger environmental degradation in these areas. The problem is to spare enough water to provide optimal regimes both for the delta and riverain areas and for the wetlands throughout the year. Saline drainage into the wetlands and deltas is an added problem and is difficult to solve. Techniques will have to be developed for sophisticated management of reservoir filling, reservoir and barrage releases, and canal abstraction to make more effective use of available water and to mitigate the hazardous effects on the environment.

5.1.5 Flood Control

Floods have a varied impact on different areas. Proper risk and vulnerability analyses for each flood prone area need to be carried out in the changed climate. For the vulnerable areas, current topographic maps are needed. The flood control authorities should keep up-to-date records of settlements and infrastructure development. A clearance from the flood protection agency may be required for erection of settlements and infrastructure in the new areas. Other measures for flood controls include the following.

Flood Mitigation

Reservoir operations, bunds and spurs are the current means that are being used to overcome flood hazards. However, hydrological solutions need to be emphasized for a sustainable long-term policy to deal with flood issues. Strengthening of the vulnerable sections of the bunds damaged due to heavy rains or changes in river regimes, relocation of the bunds is a preferred adaptation strategy. Similarly at sites where damage is being caused by transportation, either alternative roads may be provided or safer passes may be constructed.

Flood Protection Structures

There is a need to set up a permanent cell comprising fully trained persons who have necessary equipment and material for dealing with flood protection structures. Further a fully researched strategy has to be devised about the usage of material and types of structures in the specific areas with respect to the available filling material. Possibilities of usage of materials like geo-textile and synthetic material mats should be explored. In addition to the regular and emergency repair of breaches, this cell should carry out pre-flood surveys of the bunds as well. Usage of remote sensing and aerial surveys is needed as the reliable monitoring of the bunds is not possible through manual inspections only. Availability of regular and sufficient funds is critical to implement a consistent flood protection operation. Relief operations need to be carried out by well trained staff with the necessary powers to coordinate with federal and provincial authorities and carry out such operations.

5.1.6 Weather Forecasting and Information Network for Farmers

Weather forecasting requires immediate action on two fronts. The first is the development of centralized real time forecasting using satellite communication reaching down to the planners and water users. The second need is to develop phenomenological models for the upper Indus basin. The agricultural economy of the *barani* area to a large extent, and of the irrigated area to some extent, requires proper estimation and prediction of rainfall both for the farmers and for the planners for crop management and predictions of the crop intensity.

5.1.7 Adaptations in Policy Planning

Water resource planning, development and management in the Indus is ecologically, technically, and socially complex. Adjustments to climate impacts will be effective only if these complexities are properly understood. Water planning should concentrate on the dynamics of the water resource system, or the approaches which are responsive to short-term fluctuations, medium-term shocks and long-term trends, in hydroclimatic processes. Climate-imposed considerations can be incorporated within medium and long-term water investment planning and project appraisals. Given the importance of the Indus river, it would be advisable to broaden the scope of water planning to address the long-term impacts of climate change in conjunction with pressing water problems. A comprehensive approach to adaptation in the water resources system is necessary to ensure that system efficiencies are maximized without adversely affecting any one sector.

5.2 Agriculture

In Pakistan, the agriculture sector has been generally adaptive to changing technology, resource conditions and increasing demand. Farmers have adopted various measures over the years to cope with these challenges. There has been a shift in the potential boundaries of cotton during the last 30 years due to a rise in the water table in cotton growing areas. In order to cope with this situation, the areas of central Punjab and Sindh province, which previously produced cotton, shifted to other crops. Food crops in Pakistan are normally grown on flat surfaces using basin irrigation. However, due to shortage of water and change in plantation and irrigation methods, the farmers are now growing onions, potatoes, tomatoes, cauliflower and cabbage on ridges using furrow irrigation. The most common and widely accepted adaptation method was the use of high yielding cultivars of wheat, rice, maize, cotton crop, and chemical fertilizers during the Green Revolution period.

Extreme variability due to monsoon causes droughts and floods, and has damaged agricultural crops in the past. These events also forced agricultural scientists to adjust their crop breeding programs, so that the crops could become drought tolerant, and develop resistance to excessive wetness.

5.2.1 Changes in Cropping Patterns

A rise in temperature and reduction in rainfall could increase the net irrigation water requirement of crops, thereby forcing farmers to make changes in the existing cropping patterns, in order to adjust to climate change. Some of the progressive farmers have already started adjustments by reducing the area under sugarcane. These farmers are also considering the option of replacing sugarcane with sugar beet. The sugar industry is also seriously looking at adjusting the industry for use of both cane and beet and is responsive to this change. The recent experiments made for cultivation of sugar beet in the Sindh province have shown highly promising results. This crop has been grown successfully in the NWFP for the last 50 years and the industry is already crushing both the cane and the beet. It is expected that the crop will also be suitable for cultivation in the Punjab province.

5.2.2 Adjusting Cropping Pattern with Water Availability

Changes in the availability of water since 1975 have resulted in a significant shift in cropping patterns. There has been an increase in cropping area for high water demanding crops like rice, cotton, sugarcane, and a decrease in low water demanding crops like coarse grains and fruits and vegetables. If net irrigation water availability decreases, farmers are likely to switch to low water demanding crops.

5.2.3 Improved Productivity and Production Management

Sound management and more efficient water use are the most effective long-term strategies for dealing with water scarcity. In view of the importance of water for economic development in general, and, agricultural development in particular, options have to be formulated to manage water for sustainable agriculture, and further adaptations planned to adjust to impacts of climate change. The non-water management options required are tillage, precision planting, plant nutrition, drainage, and salinity management.

5.2.4 Changes in Land Use

Due to changes in resource conditions, technology, and changes in demand, there have been changes in land use in Pakistan during the last 30 years. The increase in demand of fuelwood, paper and pulp has resulted in a change in agroforestry systems, providing a market pull for farmers to introduce and integrate block and boundary plantations of plants. Furthermore, salinization of lands, due to the use of poor quality groundwater, forced farmers to grow eucalyptus species to provide surface cover to fallow lands, and raise fuelwood or timber.

Land use must be sustainable so that existing resources are not degraded in the process of productivity enhancement. The expanded use of organic composts and integrated pest management would lead towards more sustainable land use. The use of effective microbes for enrichment of organic materials seems an appropriate technology for the future, because the organic acids produced by the effective microorganisms (EM) would also reduce methane emissions.

5.3 Livestock

The livestock sector, aided by prudent human management decisions, has demonstrated the capacity to adapt to extreme events in the past. The government's policies and sound interventions would, however, serve to support the autonomous adaptations carried out by the livestock farmers.

Autonomous and planned adaptation strategies for livestock farmers are suggested as under. Although these programs are more relevant and applicable to the range livestock production system in Pakistan, they are also equally applicable to non-range animals, as well.

5.3.1 Adaptations in Rangeland Ecosystems

Depending upon the severity and the nature of the impacts, shifts in species composition and distribution are the most likely autonomous adaptations in the rangeland ecosystem in Pakistan. Due to the effects of climate change on temperature and rainfall, farmers alter the location, timing and duration of grazing of their animals. That, however, is the extent of the autonomous adjustment in the sector. There is also no significant change in supplemental feeding unless drought conditions prevail. Similarly, breeding management is also not changed nor is there any change in rangeland management practices. When feed and water begin to become scarce, stocks are sold even when the prices are not attractive.

5.3.2 Fodder Banks

Use of feed conservation techniques and fodder banks is applicable to livestock systems in the arable areas. On the rangelands, haymaking is perhaps the only technique possible. Elsewhere, silage making can be another technique for conservation of fodder. Although, cooperatives have not been a success in Pakistan, this system could be tried for developing feed/fodder banks.

5.3.3 Improved Feed

Improving nutritional plane may be possible through the use of multinutrient (MNB) blocks prepared from urea, molasses, vitamins and minerals. Such improved feed systems can reduce the animal's reliance on fodder crops to a significant extent. Altering distribution of animals by using mineral blocks and watering points may also be possible.

5.3.4 Restoration of Degraded Areas

Although difficult in practice, weed management and restoration of degraded areas is very important and may be supported by NGOs through their network of community mobilization. Increasing native rangeland vegetation and planting adapted species should form part of range development programs.

5.4 Forestry

The forestry sector is very vulnerable to climate change as far as forest distribution, composition and productivity are concerned. Climate change scenarios and impacts on forest biomes may require changes in forest management. Suggested adaptation strategies for the forestry sector are as under.

5.4.1 Pest Control

The biological control of forest pests is a very important adaptation measure. Viable populations of predatory birds and insects shall have to be maintained through restricted use of chemical insecticides and encouragement of both natural and artificial conditions conducive for their fast breeding and multiplication. Practical measures will be needed for the identification of pathogens for forest insect pests. Use of attractants (light and pheromone traps) and chemical and botanical repellents for forest insect pests could be a cost effective and environment friendly control measure.

5.4.2 Changes in Species and Varieties

In order to meet the needs of people for timber, fuelwood and fodder for livestock, multipurpose fast growing indigenous and exotic tree species shall have to be planted on farmlands. Special attention shall have to be given to those tree species which have poor seed production and dispersal, which occupy ecological niches, have small populations and restricted ranges and are peripheral. Genetically impoverished species or those that have important ecosystem functions will also need more care. These species can be assisted by providing natural migration corridors, but many may eventually also require assisted migration to keep up with the speed with which their habitats shift with climate change and change in land use.

5.4.3 Preservation of Watersheds

People living in mountain areas tend to be heavily dependent on forest ecosystems. Over use of land and vegetation in these watershed areas can seriously impact water management systems downstream, with serious consequences for irrigation in the Indus plains, and for power generation. Given the key role of watersheds in the national economy, policy options need to be considered whereby the costs of watershed development are shared by key sectors of the economy, which benefit from improved management of watersheds.

5.4.4 Control of Wastage

The national timber demand could be reduced if there is more production and use of composite wood products (plywood and particle board) based on wood waste, undersized pieces and low quality timber species. Besides value addition to the wood products, this measure would also generate additional job opportunities for the local people.

Energy efficiency measures need to be adopted in fuelwood use, particularly with regard to improvement of efficiency of fuelwood use in household energy. Energy efficient cooking technologies should be introduced especially in mountain areas where the fuelwood demand is already very high. Modern timber harvesting should be adopted to maximize recovery of timber.

5.5 Coastal Zones

Adaptation strategies for coastal areas may take the form of protective measures such as the construction of structures like dikes and seawalls at strategic points, and more long term measures to relocate communities and infrastructure in threatened zones. While more detailed information would be needed to make any recommendations regarding long term measures such as possible relocation, measures such as the construction and maintenance of coastal defence systems should be looked at immediately.

5.5.1 Coastal Defence Structures

The vital importance of defending coastal towns and large tracts of valuable land cannot be overemphasized. On the west (Makran) coast, erosion already threatens coastal property, coastal agriculture, land and habitats. Coastal erosion, to some degree is noticeable at the ports of Gwadar, Pasni and Gadani. The sandy beaches are almost flat and are eroded by southwest monsoon waves. However, at Pasni, erosion has been controlled to some extent due to the construction of Pasni fish harbor. Protection measures have been taken through stone pitching at Gadani. Proper engineering works such as groynes, however, should be constructed to protect beaches from excessive erosion of beach sediment.

Existing defences should be revisited to ensure that they can withstand possible effects of sea level rise in the medium and long term, while vulnerable regions along the coast should be identified and plans for coastal defence systems in these areas be finalized. Ecosystems such as mangrove forests provide a natural defence system along the coast, and the protection of mangrove forests becomes doubly important in this regard.

5.6 Biodiversity

Natural adaptation in biodiversity can take a number of forms, including acclimatization, evolution or migration. There is poor information on the first two, but it is possible to make rough quantifications for migration rates. Climate changes in the past caused major alterations in biomes and ecosystems. Plant and animal species responded by either adapting to the changes or migrating from the area (Davis, 1983), thereby becoming restricted to islands or specific habitats. The current situation appears to be very different for two reasons. Firstly the rate of climate change is unprecedented, and a wide range of species is unlikely to adapt or migrate fast enough and secondly, natural habitats are now patchy and isolated and species are often blocked from successful migration.

A number of options to cater to climate change impacts and to adopt effective management techniques are reviewed here.

5.6.1 Migration as Autonomous Adaptation

Migration is an issue for fauna as well as for flora. Migration efficiency of a species and also the migration routes could be potentially affected by climate change. Migration rates of some plant species have been estimated from paleoecological evidences. But human land use patterns and the increasingly fragmented nature of forests now present barriers to migration (Peters and Darling, 1985).

Birds are highly mobile; but in a changing environment some species will not cross open clearings even as small as tree-fall gaps. Required habitat species may fail to migrate, such as a Jack pine in the case of Kirtlands Warbler (Botkin et al., 1991). Annual migrants depend on the availability of specific habitats for 'refueling' stops on their journeys, and may migrate in synchrony with the availability of transient food resources. For example several species of shorebirds rely on synchronous timing of crab spawning or on insect emergence. Alternative sites with predictability of timing and supply of food probably do not exist (Skagen and Knopf, 1993). Insects too may face migration problems. The migration rate required to adapt to climate change could be easy for some species and impossible for the others.

Despite the species being highly mobile and possessing strong migratory tendencies, the physical distribution of rivers and lakes strongly limits the movement of fresh water fish. Most fish species have limited tolerance for changes in water temperature and therefore face significant threats as they are unable to find their way to cooler waters, when water temperature rises.

5.6.2 Preservation of Ecological Process

Classical conservationists strongly emphasize the importance of species protection (Walker 1992) and protected area management. But in changing climate scenarios when ecozones are shifting to certain spatial scales and species have to adapt to a new environment, conservation tools need some additional consideration. Recent advances in the development and management of marine protected areas have been stimulated by the realization that many concepts derived from terrestrial conservation are of little relevance in the marine environment. And just as the marine conservation debate is now centering on issues of ecosystem process, so is multiple use and interaction of wide-ranging forms of environmental degradation and stress. This gradual shift in priorities in recent years from structurally based, species-oriented conservation to an approach rooted in preserving ecological processes and complexity (Agardy 1994) will require increased attention to the climate issue if it is to be successful.

5.6.3 Protected Areas Management Under Climate Change

Protected areas management is one of the widely used tools in conserving biodiversity. However, after reviewing climate change impacts it is felt that for effective functioning of managed areas in changing climate certain strategies are required.

5.6.4 Corridor Management

Under the climate change scenario, it is assumed that species will have to shift their distribution and migrate to other areas where a suitable habitat exists. Human beings have strongly affected the habitats, causing fragmentation in some habitats. Therefore it is strongly recommended that certain corridors between important habitats and ecosystems should be identified and managed.

5.6.5 Buffer Zones

Due to change in climate, biomes could shift at certain spatial scale. In order to deal with this situation, the area outside the protected area needs to be designated as a buffer zone. This zone will then be managed sensitively in order to protect the core area and also take over the function of reserves in future. This will not be possible in many areas because of prior land use, but where possible, steps should be taken to manage buffer zones in a way suitable for subsequent development into full reserve status.

5.6.6 Ex-situ Conservation

This is an important tool basically adapted for preserving genetic diversity. Gene banks, seed banks, zoos and botanical garden are the options to conserve species out of their natural environment.

5.7 Energy and Industry

Adaptation strategies for energy and industry are closely linked to developments in coastal zones, and in water resources management.

Energy and manufacturing infrastructure may be threatened by floods, cyclones and storm surges or, in the long run, by sea level rise. Background studies for this report show that while increased incidence of floods and cyclones is a distinct possibility in the medium to long term, sea level rise poses relatively little danger to energy and industry installations. While relocation of existing infrastructure is certainly not recommended at this stage, it is necessary to carry out a detailed mapping of areas that could be at increased risk from natural disasters in the medium to long term, and to discourage the establishment of major infrastructure installations in such areas.

5.8 Socioeconomic Adaptation Measures

The viability of socioeconomic adaptation to climate change is determined by the strength of the economy, the quality and coverage of health services, and the integrity of the environment. Societies with relatively greater economic resources and robust adaptive mechanisms suffer less severely from the unexpected impacts of climate change. Improvements in access to basic health care, clean drinking water, and sanitation facilities will increase the population's resistance to climate change and reduce the impact of disease vectors spreading into new areas.

6. General Description of Steps Taken

The climate change issue embodies certain unique and challenging features that make it inherently different from other environmental issues, turning the task of formulating an appropriate policy response into a daunting and complex task. To start with, the issue transcends across the globe, which necessitates a collective and concerted response encompassing a wide diversity of policy measures framed by a multiplicity of decision-makers around the world. In addition, being linked to the concentration of greenhouse gases, the nature of the problem is a long-term one thereby making, inevitable, the intergenerational consequences of any policy decisions.

These complexities are further accentuated by limited knowledge and a pervasive uncertainty surrounding the issue pitted against an open-ended risk of potentially catastrophic and irreversible consequences. Finally, there are very strong linkages of climate policy with other broad socio-economic policies because of which climate related decisions are embedded in a complex array of economic and political decisions. Any national climate policy has to have a multi-sectoral nature cutting across many important domestic policy areas of priority such as energy, transport, agriculture and forestry.

The Chapter begins by laying the national and international context within which climate change action is being undertaken in Pakistan and then goes on to provide specific steps and actions taken in supporting the implementation of the Convention.

6.1 Policy and Legislative Structure

Pakistan's environmental policy and management framework is based on the Pakistan Environment Protection Act 1997 (PEPA), which in turn replaces the Pakistan Environmental Protection Ordinance promulgated in 1983. PEPA has two important responsibilities - the creation of institutions and the regulation of activities covering the environment. This legislation has been responsible for the establishment of Pakistan Environmental Protection Council (PEPC), and the Pakistan Environmental Protection Agency. The National Environmental Quality Standards (NEQS) finalized in 1993 further provide standards for industrial and municipal effluents and air emissions, including 32 liquid and 16 gaseous parameters. The compliance framework for enforcing the regulations is a mixture of administrative measures, judicial sanctions and active civil society involvement[1].

Major policy initiatives in the environment sector have been the enactment of National Conservation Strategy (NCS) in 1992. Forestry Sector Master Plan and NCS plan of Action and the finalization of a National Environmental Action Plan (NEAP) in February 2001. The NCS lays out the fourteen key priority areas for policy formulation and intervention, while NEAP outlines four priority areas for development and implementation of environmental conservation programs - clean air, clean water, solid waste management and ecosystem

1 Akhund, Nelma and Qureshi, Zainab (1998), "You can make a difference", IUCN publication, Karachi.

management. The NEAP also identifies five additional areas of concern in which additional support is needed to strengthen the base for environmental management in the long run. Both the NEAP and NCS have indirect relevance to climate change issues.

6.2 Institutional Framework

Environmental issues being interdisciplinary cut across a number of sectors like forestry, agriculture, etc, and hence both the Federal and Provincial Governments have responsibilities over its execution. Ministry of Environment (MOE) is the Federal focal Ministry for policy planning, formulation and coordination on environmental issues. It houses the PEPC – the highest environmental policy making body in the country chaired by the Prime Minister or his nominee. The PEPC comprises professionals, civil servants, and private sector executives, members of academia and civil society and high-level political representatives drawn from the four provinces. MOE is supported by the Federal EPA, which provides legal and technical support to the Ministry. Provincial EPA's have been created to deal with environmental issues in the provinces and have been delegated powers by the Federal EPA to enforce the Pakistan Environmental Protection Act in the provinces. Environment Protection Departments have also been established in some provicinces. Additionally, an environmental wing in the Federal Planning Ministry, and environmental cells in the provincial Planning and Development Departments, have been created for incorporating environmental concerns into developmental planning. There are other support agencies, departments and organizations both in the federal as well as provincial governments that share some environmental responsibilities like the Forest Department in the Provinces dealing with nature conservation issues.

6.3 International Cooperation

In tandem with Pakistan's resolve in contributing to the international efforts aimed at protection of "Global Commons" Pakistan is signatory to major environmental management conventions and protocols. These conventions are listed below along with the dates on which they were signed/ratified.

- Convention on High Seas (31 October 1958)
- The Convention on International Trade in Endangered Species of Wild Flora and Fauna - CITES (20 April 1976)
- The Convention on Wetlands of International Importance, especially as Waterfowl Habitats -RAMSAR (23 November 1976)
- United Nations Convention on the Law of Sea (10 December 1982)
- Convention on Conservation of Migratory Species of Wild Animals (01 December 1987)
- The United Nations Convention on Biological Diversity (5 June 1992)
- The United Nations Framework Convention on Climate Change (13 June 1992)
- The Vienna Convention for the Protection of Ozone Layer and the Montreal Protocol (18 December 1992)
- The United Nations Convention to Combat Desertification and Drought (15 October 1994)
- The Basel Convention on the Control of Trans-boundary Movement of Hazardous Waste and their Disposal (26 July 1994)

- Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of Sea relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (15 February 1996)
- Stockholm Convention on Persistent Organic Pollutants (6 December 2001)
- Cartagena Protocol (04 June 2001)

Such a support and participation also provides Pakistan with an international context with which it can comfortably work to design its overall national environmental planning, conservation and implementation mechanisms.

6.4 Key Climate Change Initiaives

Climate Change is a cross-sectoral and interdisciplinary subject and hence many projects and programmes can be tapped under the umbrella of climate change. At present, there is paucity of data and figures surrounding the cataloging of projects with climate change projects. Being a signatory to UNFCCC and a member state of World Bank, Pakistan qualifies for assistance under GEF climate change focal area. In terms of the overall GEF portfolio for Pakistan, climate change represents a very small percentage in real terms. This has been recognized by the Government and efforts are being made to mobilize support for enhancing the climate change portfolio. At this point, two major activities under the GEF climate change focal area are as follows:

Fuel Efficiency in Road Transport Sector Project[1]

The "Fuel Efficiency in Road Transport Sector" project is the only major GEF funded project in the area of climate change, being implemented by Ministry of Environment through ***ENERCON***[2] (PAK/92/G31 UNDP-GEF; approved in the pilot phase of the GEF). The objectives of the project are to reduce GHGs and other pollutants by improving fuel efficiency in road transport sector projects. The project also aims to build institutional capacity to review transport options, expand pilot projects to tune-up urban vehicles, and develop options with regard to technology transfer, regulations and pricing. The main activities include 1) setting up of 30 tune-up stations throughout the country; 2) training of mechanics to conduct computerized tune-ups; 3) establishing and operating a revolving loan fund to extend loans at nominal charges to workshop owners for establishing additional tune-up centres in the private sector; and 4) conducting policy studies for further improvement of fuel efficiency in the road transport sector. Due to substantial savings realized in the implementation, the Project is preparing a plan for enhancing the activities[3].

Commercialization of Wind Power Potential in Pakistan (Preparatory Phase)

Pakistan has significant potential for investment in the renewable energy sector and in view of the government's resolve in promoting such a technology in Pakistan, a PDF-B study has been initiated with the assistance of UNDP and GEF (PAK/97/G42 UNDP-GEF)

[1] http://www.ENERCON.gov.pk/ferts/index.htm

[2] http://www.ENERCON.gov.pk

[3] Source: http://www.un.org.pk/undp/energy/ongoing-proj.html

to support the GEF Climate Change Objective for stabilizing Green House Gases (GHGs) concentrations. The project aims at promoting the commercialization of wind power in Pakistan through establishing commercial feasibility for wind energy in the country, identifying and overcoming barriers to future investments in renewable energy, and scaling up the practical demonstration of the technology to attract potential entrepreneurs. A feasibility study is being carried out through monitoring and analysis of wind data for assessing wind power potential in the coastal areas of Pakistan. It would set in place a complete package of resource assessment, evaluation of economic viability and marketability, and effective implementation arrangements for future applications. A GEF full Project Brief for large-scale demonstration of wind power project in the coastal areas of Pakistan, including cost sharing from potential investors will also be developed on the basis of the feasibility study[1]. The work has almost been completed and a project brief is under preparation for submission to GEF Council.

Increasing Natural Gas Share in the Energy Mix

Natural gas is the cleanest of the fossil fuels. Pakistan is fortunate to have large resources and well developed infrastructure for the supply of natural gas. During the last four years, the Government has, therefore, followed a policy of increasing natural gas supplies in the country which have increased by more than 50% from 2 to over 3 billion cubic feet per day.

Pakistan took initiative of introducing CNG as an alternate transport fuel in Pakistan by commissioning a demonstration CNG station at Karachi in the public sector in 1982 to replace gasoline in road transport sector. In 1990s, the government emphasized its commitment to the environment friendly CNG program by providing incentives to private sector including totally deregulated consumer price. As a result, the CNG industry started developing during late 1990s and now Pakistan is the largest CNG user country in Asia. Currently, 430 CNG stations are providing CNG to more than 400,000 vehicles all over the country.

After a successful CNG program for petrol replacement, the Government is now embarking upon a program to replace more polluting diesel fuel in road transport sector. Under this program, some more incentives will be offered to the investors and initially dedicated-CNG-buses will be introduced in major cities of the country. Another area having significant impact on environment in Pakistan is the power sector, where a number of fuel oil-run power plants have now been converted to run on natural gas.

6.4.1 Major Studies Completed

Pakistan has undertaken some research studies for climate change that will be used in formulating a national action plan on climate change. Most of the resources for undertaking the studies were provided by GEF, although some studies were co-financed by bilateral and multilateral donors also. All these studies provided valuable tools both to the country and international donors interested in investing in climate change in the country. It is important to point out however that these represent only a small portion of the overall effort in addressing the issue of climate change in the context of sustainable development. Given the

[1]Source: http://www.un.org.pk/undp/energy/ongoing-proj.html

wide nature of the subject, the report has not been able to fully capture all of the activities of the Government as well as the private sector in Pakistan that have climate change implications.

Some of the studies undertaken by the Ministry of Environment are listed below:

***Asia Least Cost Abatement Strategy (ALGAS)*:** ALGAS project completed in 1998, and, funded largely by Asian Development Bank (ADB), involved 12 Asian nations including Pakistan. The report included the formulation of national GHG abatement strategies consistent with national development priorities, and the preparation of a portfolio of GHG abatement projects and national action plans embodying national development objectives.

***Climate Change in Asia - Regional Study on Global Environmental issues (1992-1994)*:** The report supported by funding from the Asian Development Bank (ADB) and finalized in 1994, provided an analysis of Pakistan's vulnerability to climatic events and recommended the technical and economic feasibility of options that could be undertaken to adapt to climate change and also limit GHG emissions or enhance their sinks[1]. A national response strategy was also proposed as part of the study.

Country Case Study on Climate Change Impacts and Adaptation Assessment (1996-1998): Completed in 1998 through the assistance of GEF-UNEP was a major study on assessing the impacts of climate change on four major sectors of the economy –agriculture, forestry, water resources and meteorology. The present climate change study in the area of impacts and adaptation has benefited from the work undertaken in the project.

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1 Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere (UNFCCC text).

7. Education, Training and Public Awareness

The Government is fully cognizant of the necessity of educating and creating awareness among the general public about climate change factors, parameters, impacts, adaptation strategies and other related issues and of prioritizing the thrust areas for the development of information dissemination modules. This is not only important in meeting the objectives as enshrined in Article 6 of the UNFCCC , but also in engendering the citizenry to a more sustainable development path.

In Pakistan both public and private sector institutions have been involved in the planning and development of programs for education and public awareness, with the understanding that comprehending climate change issues are not only the responsibility of experts in the field, but of people in general, who need to be educated regarding the impacts and possible adaptation measures.

The Chapter builds on the earlier Chapter on "General description of steps taken" by summarizing initiatives being undertaken by Pakistan in further promoting the objectives of the Convention and meetings its obligations under Article 6 of the Convention given Pakistan's resource and capacity constraints.

7.1 Education

Environmental education has been recognized as an important priority of the Government of Pakistan which has been dealt with both under the National Conservation Strategy (NCS) and National Environmental Action Plan of the Government of Pakistan. In this connection, the NCS Unit in the Ministry of Environment specifically organizes activities in collaboration with various schools and education community that are not just meant for awareness raising but inherently imbibe the concept of engendering environmental components in the school curricula. The Ministry of Environment, with the support of Swiss Government plans to implement a project "Promotion of Environmental Education at school and college level". The project aims at integration of environmental concepts in relevant textbooks from class 1-12 throughout Pakistan.

The various government entities and civil society organizations are also active in environmental education activities both as active partners and in individual organizational capacities. This has generated a series of events that are being organized as part of programs, projects and activities of the various organs of State and Civil Society.

7.1.1 GLOBE[1]

Pakistan participates in the Global Learning and Observation to Benefit the Environment Program (GLOBE). Pakistan signed the GLOBE Agreement on November 18, 1997 and became the sixty-second country and the first South Asian Country to join the GLOBE Program. The Ministry of Environment is the responsible agency for Program coordination and implementation in Pakistan. To date, Pakistan has 12 GLOBE schools and 18 GLOBE teachers and has reported over 8,800 scientific measurements to the data archive of GLOBE Program.

7.2 Training

Building necessary expertise to provide the technical and scientific knowledge remains a goal of the government. In view of pressing requirements to fund priority sectors in support of human development, the fiscal space to provide resources for training and education for the next generation of environmental leaders remains limited. The Government has nevertheless managed to initiate several scholarships and made funding available to local scientist for further education and research in different scientific disciplines. As yet, a policy or support aimed at generating a cohort of scientists or professionals in the field of climate change has not specifically been undertaken due to funding constraints..

7.2.1 GEF- Pakistan website

One of the many initiatives of the Ministry of Environment is the website for the Global Environment Facility Programme in Pakistan[2]. The website is not specifically meant for providing on-line access on climate change issues only, but rather attempts to provide an information gateway to provide all GEF- stakeholders, project proponents and citizens at large with information and intellectual resources focusing on the focal areas of GEF. The website attempts to meet the needs of GEF stakeholders in better project development in all focal areas by providing an information gateway to GEF issues.

7.3 Workshops, Seminars and Observing Specific International Days

The Ministry of Environment organizes workshops and seminars regularly to educate and raise awareness around the climate change issue among the various strata of the society. Some are specifically organized in conjunction or in support of observing important international days like "Earth Day, World Environment day etc" to create a more general environmental awareness. Additionally, targeted high-powered and expert-level workshops and events are organized around key themes on a continuing basis. These activities serve to

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[1] GLOBE (www.globe.gov) is a US-based international environmental science education and awareness program that aims to enhance environmental awareness throughout the world; contribute to scientific understanding of earth; and improve student achievement in science and mathematics. The Program involves school students in grade one to twelve that conduct a set of experiments in the area of Atmosphere, Land Cover, Biology, Hydrology, and Soils, according to their skill level, and report the data via the Internet. Currently the Program is being implemented in 102 countries and involves 12,000 schools and more than 20,000 GLOBE trained teachers.

[2] www.gefpak.gov.pk

meet the three pronged objectives of education, training and public awareness and hence have cross-disciplinary impacts.

7.3.1 International Symosium on Energy and Environment Conservation[1]

A two day international symposium on Energy and Environment Conservation is being organized by the Ministry of Environment in collaboration with ***ENERCON*** in December 2003. The purpose of the 6th International Symposium on Energy and Environment Conservation 2003 is to highlight the relationship of energy and environment conservation in the context of Sustainable Development. The symposium will be a means for creating business opportunities to seek institutional support and financing for affordable environment and energy conservation projects. It will help foster a closely integrated programme to disseminate information, create awareness and educate the people in the area of energy and environment conservation. Through a specifically organized technical exhibition, the symposium attempts to highlight Pakistan as a regional hub for energy and environment conservation projects.

7.4 Mass Awareness

Mass awareness was first identified as an important component of environmental conservation and protection programs when the National Conservation Strategy (NCS) was prepared. Some mass awareness programs were therefore launched for environmental programs and projects to propagate awareness of environmental issues amongst stakeholder groups including the government, communities, youth groups and school children. Climate change concerns are being integrated into some of these ongoing programs as a first step.

7.4.1 Electronic Media

The Government recognizes the power of the electronic media in influencing public attitudes and behaviour and utilizes the media periodically through specially designed environmental messages. This has been done though a professionally drafted media strategy by a consultative process.

7.4.2 Print Media

The Government regularly publishes environmental messages through the print media by specific targeted advertisements around certain themes and supplement in major newspapers. The Sindh EPA publishes a quarterly magazine 'Sindh Environment', which talks about environmental issues and degradation. It also prints leaflets, brochures, booklets and posters in Sindhi, Urdu and English about various environmental concerns. Under the mass awareness component of the National Conservation Strategy, a monthly environmental magazine is also published.

[1] http://www.ENERCON.gov.pk/Symp/default.asp

7.4.3 Additional Interventions

The following lists some of the activities that have been designed not just to create climate change awareness but to create environmental awareness in general. The focus of our efforts would be to create more climate specific awareness programs in the coming years.

General

The Ministry of Environment has promoted the concept of "Green Journalist" award to encourage reporting on environmental matters and promoting environmental awareness. The Environmental Protection Agency (EPA) of Sindh gives out awards such as the Green NGO award and is considering the setting up of the 'Federation of Environmental NGOs of Sindh.' It also awards funds to NGOs, educational institutions and youth groups for small projects such as street theater, speech competitions and solid waste management through traditional methods.

Energy Conservation and Efficiency

Agencies such as the National Energy Conservation Centre (ENERCON) in Pakistan have been active in promoting energy conservation programs in industry and transportation for some time. Energy use in the country remains sub-optimal, primarily due to the nature of the equipment used. The import of used equipment such as industrial boilers is frequent—imported secondhand boilers are estimated to constitute 50% of the total number of boilers in use—as this serves to reduce capital cost (ENERCON, 1993).

Forestry

To increase public awareness of forestry sector issues, a tree-planting campaign is carried out by MOE twice a year, in spring and in the monsoon season. Publicity campaigns are also conducted to explain the importance of tree planting and to get people to participate, which include messages released by the prime minister and president in the print and electronic media.

Biodiversity

For the biodiversity sector, wildlife distribution maps were published at national and provincial scales by MOE with the help of the Pakistan Agricultural Research Centre (PARC) and the Pakistan Forestry Institute (PFI) for the national and provincial wildlife and forest departments. Booklets on the diversity of fauna in the country have also been published with the help of the World Wide Fund for Nature (WWF) or by the Ministry itself in both Urdu and English. A scientific journal produced by the Zoological Survey Department, called the 'Zoological Survey of Pakistan' regularly publishes articles and information about wildlife and biodiversity in Pakistan.

Agriculture

For the agriculture sector, the Water Resources Research Institute (WRRI) of the National Agricultural Research Centre (NARC) intends to strengthen its existing facility of Space Informatics by adding a Climate Change Informatics for Agriculture (CCIA).

8. Financial and Technological Needs and Constraints

The compilation of national communication through an indigenous preparatory process has built awareness around the challenges associated with not only formulating an appropriate policy response on climate change but also in realizing the limitations of the existing financial and technical capacity in the country to adequately assist policy makers in responding to the climate change problem. This does have implications for Pakistan's preparedness as an active member of the international climate change community. Pakistan remains determined to deal with the issue utilizing its limited resources and expects the necessary technical and financial support from Annex 1 parties in developing its capacity to respond to the climate change issue.

The present chapter tries to summarize in what should not be considered totally exhaustive elucidation of Pakistan's financial and technological needs and constraints highlighted during this phase of climate change enabling activity. It is believed that with more scientific understanding and increasing awareness around the issue further areas of work will be identified. Chapter 9 provides further areas that were identified for building research capacity in the country as part of the preparatory process for national communication.

8.1 Preparation of Inventories

Although, Pakistan has been able to prepare an emissions inventory most recently as part of this national communication and also as part of the group of 12 countries conducting the *ALGAS* study, the capacity in the country for an institutionalized system of inventory preparation is still lacking. Major problems of data quality (availability, accuracy and reliability) in various key socio-economic sectors remain unresolved. There are situations of both lack of data or problems of highly uncertain data in many situations. The emission and conversion factors pose significant challenges for inventory experts to undertake an appropriate analysis compatible to local conditions. The IPCC default emission factors also pose additional challenges and there is a need for development of appropriate emission factors for respective sectors with a view to improving estimates of national GHG emissions. There is also a need to develop GHG inventory methodologies to suit local conditions and development of local emission factors to improve the reliability of emissions data.

There is also an important need to improve the reliability and availability of data through active cooperation between various organs of the State, private sector, academia, and civil society. Access to adequate training is an important element in enhancing local technical capacity in data collection, management and dissemination. Financial and technical assistance is required to address these issues over a sustained period of time, building both individual and organization expertise in Pakistan to prepare more accurate and reliable inventory estimates and an inventory database system.

8.2 Vulnerability to Climate Change

The need for building capacity around climate impact models was recognized. There is a need for assistance in improving socio-economic scenarios, improve the development of sea-level rise scenarios and monitoring, and assessing the relationships of climate change impacts, impacts of extreme weather events and climate variability events. There is a need for enhancing existing methodologies and capacities to undertake integrated assessment of climate change impacts in different sectors. There is a very limited understanding at present of analyzing weather the extreme weather events occurring periodically in the Country are due to climate change or natural variability in climate. Pakistan's economy being so heavily dependent on agriculture requires that necessary capacity be built in the country to understand the implications of climate change on agriculture. Limitations of data and global circulation models may require specific interventions to address these deficiencies in future.

8.3 Adaptation

Pakistan recognizes that improving and completing vulnerability assessments is only the first step in assisting countries in identifying and implementing appropriate adaptation options. Such a capacity of built would have direct bearings on the quality of adaptation measures and responses generated. There is a strong need for improving information sharing, education and training, technical and scientific research inorder to articulate an effective adaptation plan. There is a requirement for identifying appropriate technologies for adaptation well-suited to local conditions and builds on the indigenous knowledge of the area. Pakistan needs support in implementing the various adaptation measures identified in the report. Assistance is needed to undertake research to enhance local capacity and infrastructure for planning for integrated coastal management.

8.4 Disaster Mitigation

Pakistan needs to develop capacity in dealing with natural disasters and extreme weather events like floods and droughts. Disaster preparedness is closely linked with the efficacy and efficiency of data collection and monitoring systems, communication systems and the development of early warning systems in the country. The development of a cross-sectoral disaster mitigation and relief system is crucial for the country.

8.5 Institutional Support

Pakistan needs technical and financial assistance in undertaking the following institutional capacity enhancement measures:

(1) Financial and Technical Assistance is needed to strengthen the national institutional framework for undertaking tasks related to the implementation of Convention. The need for a functional and independent **Climate Change Cell** under the Ministry of Environment has long been recognized. This cell would coordinate all climate change activities at the Ministry of Environment and ensure that climate change issues are addressed in various policies of the Government.

(2) Enhancing capacity to prepare projects and programs in the climate change area.

(3) Enhancing the national capacity for policy formulation and planning and integration of climate change concerns into various activities of the government is a recognized limitation for which adequate financial and technical support is required.

(4) Enhancing technical capabilities, and improving infrastructure and equipment for better data collection and monitoring, to enable development and maintenance of proper databases.

(5) There is also a need for establishing and upgrading stations for systematic observation of the climate system as well as to establish environmental monitoring system.

(6) Enhancing the analytical capacity of experts, policy-makers and decision-makers to better understand the linkages and interactions that exist between political and technical dimensions of climate change.

(7) Promoting the participation of key stakeholders, such as public and private sectors, non-governmental organizations, academia and scientific and technical personnel as well as local communities.

(8) Raising public awareness and incorporating climate change issues into national formal education systems at all levels in order to facilitate effective implementation of climate change measures.

(9) Establishment of a national clearing house for information sharing and networking on climate change.

9. Proposals for Research

It is not possible to implement climate change response strategies in the face of gaps in knowledge, information and technology. Therefore, it is important to develop and implement climate change impacts and adaptations research programs to address priority research thrust areas. Research is also necessary to understand and quantify the impacts of climate change and the viability of possible adaptation measures, and these findings then need to be disseminated to the public through mass awareness programs.

This Chapter details suggestions and possibilities in the fields of research for some of the sectors that have been under study for the national communication. Such research work would help to fill the gaps in knowledge required to better prepare Pakistan in dealing with the impacts of climate change and developing sound adaptation strategies.

9.1 Water Resources

The finite nature of renewable fresh water makes it a critical natural resource to be examined in the context of population growth and climatic changes. Fresh water availability is dictated to a large extent by climate, and particularly by the timing and location of precipitation and by evaporation rates and varies tremendously from season to season.

9.1.1 Research Programs

Natural resource planning for the future is difficult without more significant and reliable data keeping in mind demographic variation and without an understanding of the phenomenological response of the biological ecosystem to climatic changes. There is a need for the development of mathematical models and research to find out the phenomenological responses of various subsystems of the environment in order to assess the impacts of climate change on sectors such as water resources.

Water Resources Development

Development of dams in Sindh is necessary in order to curb the degradation in the estuarial and delta environment. This option will be more significant in the scenario with the increase in temperature and decrease in rainfall. A comprehensive and integrated study is required to reclaim the lost environment and required funds should be made available through grants for the reclamation. Research needs to be conducted to ascertain the feasibility of a major dam on the Indus at an agreed location, a smaller dam at Jhelum, and small reservoirs in Sindh. There is an also urgent need to conduct a detailed study on the development of new dams in areas outside the Indus basin and to evaluate the existing potential of the developed dams with changing global climate scenarios.

Conservation of Water Lost Through Evaporation of Groundwater

Some countries have attempted to use chemical forming monomolecular films to reduce the evaporation of groundwater, but with little success. However, research efforts for cheaper and effective evaporation retardants are required. In agricultural fields, about 2.36 maf of water (approximately 4 percent of the total water used by crops) is lost due to evaporation. There is a need to conduct studies to reduce the evaporation losses from fields through agronomic methods and different irrigation practices like night irrigation. This saving of water lost through evaporation will not only increase the total water availability but also enhance the overall efficiency of the irrigation system.

Water Distribution System

Irrigation canals, with the exception of a few, are unlined and designed to flow in regime with different sediment loads. Even though there are major losses/seepage from the canal system, the costs of lining are great. Research to study the impacts of lining on the seepage and groundwater systems should be carried out region or area-wise, so cheaper lining options have to be studied and developed. Efforts for improvements in the hydraulic sections and regular dredging by various methods will have to be carried out to maintain capacity of the canals. The rate of losses in the outlets and minors are lower than those in the canals, therefore the lining of the canals takes priority, but the costs of this practice are very high. In the decreased inflow scenario, it may become feasible. A phase wise remodelling and regulation of the water distribution system is required, from minors to watercourses. The available manpower in the rural community should be utilized and economical methods of carrying out these improvements need to be discovered.

Watershed Management

An increase in temperature will destabilize the watershed regimes and an increase or decrease in rainfall or snow and snowmelt is going to affect the sediment load of the watershed. The pattern of sedimentation in the major rivers shows that both the clay content and the erosion rates in the watersheds are dependent upon the intensity and timings of the rainfall. In case of increased rainfalls in the *Rabi* season, the inflows at the lower regime will result in enhanced silting in areas above the reservoirs and other unregulated channels and a larger increase can have a profound effect on the current operation of the water resources system. Studies on hydel power generation and watershed management schemes, especially in terms of reservoir design, should be conducted keeping in mind possible climate change scenarios.

Urban Water Use

The demand for water in urban areas is likely to increase, as urbanization increases and more people are covered by water supply schemes. Area-wise surveys need to be carried out in urban areas to assess water requirements under various climate change scenarios. At present, the urban water supplies are deficient due to limited capacity of the supply system but at the same time large amount of supplies are wasted. There is an urgent need to devise policies, both economic and structural, to practise water conservation in the urban areas to lower the rising pressure on the drainage and supply systems and to lower the pressure on sewage treatment, which by now has become essential for the preservation of water quality. For this purpose, studies are necessary to find out the optimal methods for water use, adapted to the local environment.

Adaptations Required for Waterlogging, Salinity and Drainage Sector

With larger evaporation from water bodies, higher soil evaporation, and decreased inflows, there will be some decrease in seepage and water logging. Better management of the ground water system will be required to control mining. Due to higher temperatures and less seepage, the effects on the soil quality may be detrimental. Salinity may rise to some extent. A comprehensive study has to be carried out to determine the exact adaptation measures needed to address these problems.

Water Quality and Environmental Protection

The concerns about environmental degradation in the Indus delta stem from the increased intrusion of seawater, continued decline in the delta mangroves and decline in the migratory fish numbers in the rivers. The Pakistani fish industry depends upon shrimp and fish nurseries in the mangroves in the delta, which have been in decline for some time, ever since construction of the Kotri Barrage, when the flows into various creeks were brought under control. The problem is to spare enough water to provide optimal regimes both for the delta and riverain forests and for the wetlands throughout the year. Saline drainage into the wetlands and the delta is an added problem. When requirements for these water demands are fully understood, techniques will have to be developed for sophisticated management of reservoir filling, reservoir and barrage releases, and canal abstraction that could make more effective use of available waters.

Development of Hydrological Models

A detailed meso-scale atmospheric model and a regional hydrological model for the upper Indus basin are required to accurately quantify the long term effects of increased temperatures on the melting of glaciers and behavior of the westerlies in the hotter climate. Such data would be invaluable when future water management strategies are being planned, and would also be useful in the prediction of floods.

Efficiency

In view of the increase in population, changes in the living standards and the stressful global warming projections, the optimization of water usage, structural changes in and around farm and scientific irrigation practices are part of the comprehensive strategy to meet water demands in the future. A comprehensive study by scientific experts should be carried out to assess the structural and management changes needed to achieve water management targets in terms of productivity.

Data Collection and Compilation

For enhancement and implementation of any operation for the water resources, varied data is required to make judgments but such data are not readily distributed currently. A regular supply of on-line data and results of various research efforts is necessary to keep the workers in the water resources research up to date with the new scenarios.

9.2 Agriculture

Agriculture is a key sector of the economy, and one that is likely to be significantly affected by climate change. Developing research and mass awareness programs in this sector is also particularly important, and is an exercise that has to be undertaken very carefully, given that information dissemination amongst the rural population is a complicated process.

9.2.1 Research Programs

Pakistan houses considerable expertise in agricultural research, but there is limited experience of dealing with climate change issues in agriculture. Some of the possible areas in which research programs need to be initiated in this regard are as follows.

Integrating Resource Use Planning with Climate Change Measures

Need for site-specific interventions would increase with climate change impacts, as heat-stress and droughts might demand more comprehensive planning and management of natural resources. Thus appropriate strategies have to be developed and evaluated for management of natural resources for enhanced agricultural production. Therefore, integration of agricultural production and resources management (APARM) systems would be essential, which is possible through the use of spatial and temporal information. Geographic Information Systems and Image Processing techniques provide an option for formulating appropriate strategies for the integrated APARM systems.

Integrated APARM systems demand development of spatial databases, analysis, and mapping for building 'Decision Support Systems'. The research activities identified in this regard include the following.

- Development of spatial and temporal digital databases of natural resources (climate, land, water, vegetation, topography, etc.)
- Characterization and classification of agro-ecological zones with and without climate change and their impact on land use systems for different agro-environments
- Development and evaluation of adaptation strategies to address issues related to climate change impacts
- Systematic monitoring of effects of adaptations on land-use systems under different agro-environments.

Development of Crop Varieties Responsive to Climate Change

Recent awareness created by the efforts of the United Nations Environment Programme (UNEP) and other international/national agencies has resulted in discussions among the scientists to consider heat-stress and drought tolerance as objectives of crop improvement programs, in addition to high yields and resistance to diseases and insects. Furthermore, water ponding and excessive wetness should also be considered as objectives of breeding programs, to help crop cultivars adjust to the vagaries of changes in monsoons and floods. Thus, increased resistance to salinity and waterlogging is another important dimension of the breeding program. Farmers are aware and capable of adopting new varieties of crops if these suit their conditions and fulfill the purpose of the farming system. The research activities identified for the development of crop varieties responsive to climate change include

- Development of varieties for crops such as wheat, rice, maize, sugarcane, cotton and oilseeds with increased resistance to drought, heat-stress, salinity and water-logging
- Development of cotton varieties with increased resistance to insects and diseases and
- Development of rice and sugarcane varieties, which require less water

Development of Improved Agronomic Practices Responsive to Climate Change

Successful introduction of improved varieties in the country was followed in the past by the development of appropriate and improved agronomic practices for crops, fruits and vegetables. The commodity research program in the country was designed to develop a) improved cultivars b) improved agronomic practices and c) water use crop production technology.

Emphasis was initially placed on research related to aspects like seed rate, planting date, distances between rows and plants, fertilizer use, etc. During the last decade, researchers started developing water use and crop production practices considering leaching requirements. In addition, practices have been developed to reclaim salt-affected soils (saline, saline-sodic and sodic) using leaching and amendments. Incorporation of organic manure along with chemical fertilizers also started gaining importance. Appropriate tillage practices like minimum and deep tillage have been developed for different soils and farming systems.

Existing programs and policies are conducive to adaptations for climate change. However, there is a need for increased interaction between water management experts and agronomists to more clearly understand options available for adaptation. Irrigation with sprinkler systems can be used for cooling or frost control under climate change scenarios. There is a need to initiate research in operating systems to develop improved agronomic practices considering the farmers' framework of potentials and constraints. The research activities identified in this regard include

- Water use and crop production technology for water demanding crops like rice, sugarcane, fruits, vegetables and fodder for different ecological zones and socioeconomic environments
- Effects of planting dates on growing season length and productivity of crops sensitive to heat stress like wheat, potato, maize, sugarcane, fruits and vegetables
- Minimum tillage to reduce the effect of temperature rise on the increase of soil temperature and improve soil structure
- Effects of natural or organic farming using effective microorganisms (EM) for crop tolerance to drought and heat stress including reduction in methane emissions from rice fields
- Effects of sprinkler irrigation for cooling and frost-control of crops like sugarcane, banana, tobacco, potato, etc.

Managing Water for Climate Change Impacts

The overall irrigation efficiency of the Indus basin system is around 36%. Therefore, only 1/3rd of surface water is available for crop consumption requirements. Irrigation system losses are the main cause of waterlogging and salinity, as around 35% area of the Indus basin is now affected by this menace (WCD, 2001). Furthermore, the use of marginal/brackish groundwater in the Indus basin also causing secondary salinization, and the problem is worse with the use of sodic groundwater, which is turning soils into saline-sodic or sodic. These soils are difficult to reclaim and sustainability of soil health is a serious concern.

The research activities identified are listed below.

- Development and commercialization of low-cost geo-membrane liners for lining of canals and watercourses
- Development of water and energy efficient irrigation systems
- Adjusting cropping patterns with water availability to increase productivity of water in terms of land and time
- Development of skimming wells and energy efficient pumping systems and
- Management of saline and sodic groundwater, and re-use of drainage effluents to understand their long-term impacts on soil health.

Sustainable Development of Irrigation Schemes for New Areas

Expansion of irrigation to new areas (rain fed, runoff farming and riverine) is essential to add sustainability and profitability to the non-irrigated farming systems. The yield of food grains (wheat, sorghum and chickpeas) in these systems is about 1/3rd of the yields in irrigated areas. There are about 6 million hectares under non-irrigated agriculture in Pakistan (ACO, 1999). The increase in population, resource degradation and change in demand would require provision of irrigation facility to these areas through diversion of runoff and storage in earthen reservoirs. The demand for expansion of irrigation facilities to other areas is also likely to increase due to climate change, especially in case of increased warming and aridity.

Impacts of climate change would demand more sustainable development of new irrigation schemes, as there will be higher demand for water in the arid environments. The research activities identified are:

- Conjunctive use of water from various sources and integrated land use for sustainable development of irrigation schemes
- Water and energy efficient sprinkler and drip irrigation systems and adaptations to suit local environments
- Impacts of climate change on runoff, net irrigation water requirement and land use systems of fragile environments

9.3 Forestry

Research on the forestry sector climate change impacts, adaptation strategies and mitigation options needs to be conducted on the forests of the study area as identified by Siddiqui, et al., 1997. This study area covers 13.1% of the total area in the northern part of the country. The vegetation in this area comprises of moist and dry temperate Himalayan mixed vegetation of conifers and broad leaves. The ecological importance of the study area forests lies in the protection they afford to the fragile mountain ecosystems, provision of habitat to important wildlife mammal species and their water regulatory function. About 8.450 million people and their livestock also live in and around the forests of the study area and their livelihood directly or indirectly depends upon these forests because of their poor socioeconomic conditions and lack of alternate means of sustenance (Siddiqui, 1997).

The Pakistan Forest Institute based at the University of Peshawar is the premier forestry research institute in the country, which is well equipped to carry out the research activities outlined here.

9.3.1 Research Programs

Research programs for the study area include the following.

Research on Characteristics of Biomes

There is a need to conduct research on the actual changes in the size and location of different forest biomes under various climate change scenarios by the regular monitoring of meteorological data and ground checking. Details of proposed research activities are as follows.

- Changes in the composition of species of different biomes and individual species responses to the climate change need to be studied
- The identification of migration corridors between the biomes, and of physical barriers between migration of species and biomes like rivers, cultivated areas, infrastructures and urban areas is another important research activity
- Changes in the phenology of trees i.e. pattern of bud-breaking, flowering and seed maturity in coincidence with the activity of pollinating insects, birds and time of natural regeneration are also areas that need to be looked at, as are phyto-sociological changes in the forest communities in different biomes.

Biomass and Carbon Stored

Investigations also need to be carried out to determine the impacts of climate change on the total forest biomass and the changes in the quantity of carbon stored in the forest ecosystems. Studies should be conducted on

- The net nutrient contents of forest soils as a result of nutrient depletion and rebuilding processes
- The nutrient loss due to repeated harvesting of fast growing crops raised at short rotations and

- The changes of and the net soil carbon balance as an outcome of soil carbon building and recycling processes.

Forest Protection

Issues concerning forest protection also need to be considered. These include the following research studies.

- Quantitative assessments of the spread of forest pests and diseases, their impacts on forest health and the economic and ecological implications of their control
- The use of environmentally friendly and cost effective methods of pest control. Studies on the development and spread of forest weeds, types of weeds and the economic and ecological impacts of weed control are also crucial as are studies on the incidence and extent of forest fires with their economic and ecological consequences.
- Net primary productivity of forests along with other vegetation based scenarios and the demand and supply of forest goods such as timber, fuelwood, etc., are also areas where further data should be collected, particularly in view of the need for updated data for future inventories.

Research on the Impacts of Climatic Extremes

Research also needs to be conducted on extreme events or climatic variations due to the impact of climate change. Such studies can include

- The impacts of early and late frost on the health and survival of forest stands, as well as species responses to this phenomenon and its ecological and economic consequences
- Impacts of warm and humid conditions on the growth and health of forest stands and species responses
- Impacts of extremely dry conditions on the growth and health of forest stands and species responses and extent of forest dieback under moisture stress conditions also require further study
- Damages due to high winds and storms in the form of windfalls and breakage losses of forest trees.

Research on Species Selection

Research on species selection is particularly important from the point of view of developing adaptation strategies based on the plantation of the correct species in correct biomes. Such a research program would include studies on

- The identification of best seed sources through progeny trials for improving the health and growth of forest stands
- Trials on the vegetatively propagated tree species for the selection of best clones for forestation

- Introduction of fast growing exotics for the production of industrial timber, fuelwood and fodder with respect to their suitability for forestation in different biomes and
- Development of appropriate nursery techniques for raising of seedlings of indigenous and exotic tree species and of appropriate forestation techniques on new sites emerging as a result of climate change

Forest Production

Research on the use and production of forest products is seriously lacking, and is a key research area not only from the point of view of climate change, but also to assess the productivity of a key sector of the economy. Possible research areas include the following.

- Economic and financial feasibility studies for the establishment and/or shifting of forest based industries close to forest areas
- Testing of suitability and determination of technological parameters of manufacturing of composite wood products from low quality timbers and wood waste
- The introduction of energy efficient cooking technologies in areas where fuelwood use is high - economic and social implications
- Economic and technical feasibility studies on the introduction of improved housing in mountain areas
- Economic and technical aspects of introducing wood preservation in the mountain areas to enhance timber service and thus, reducing burden on the wood resources of the area

9.4 Coastal Zones

Global research on sea level rise and the oceanographic effects of temperature increase is still in the nascent stages. Nevertheless, it is becoming increasingly clear that developing countries with large populations in or near deltas and other low-lying areas are especially vulnerable to future sea level rise. United Nations Environment Program (UNEP) through its regional seas program has grouped Pakistan in the countries, which are most vulnerable to the impacts of a rising sea level.

9.4.1 Research Programs

Existing research on sea level rise in Pakistan is fairly rudimentary and at this stage, the main focus of research efforts will be in the collection and analysis of suitable data and background material which would enable researchers to draw up a more long term research and development program for the country. The National Institute of Oceanography (NIO) in Karachi is the premier research institution in the country dealing with research on oceanographic processes, and is equipped to carry out major research studies in the area.

Geological Characteristics of the Coastal Zone

One of the first needs for any kind of analysis for coastal areas management with respect to climate change and sea level rise is a sound description of the geomorphology and geological characteristics of the coastline. This would enable researchers to get an insight into the physical dynamics of the coastline and may lead to important observations, which determine research requirements. Generally speaking the coast, in broad terms, comprises of shorelines, beaches, estuaries, and partly the offshore shelf area. The coastal zone is a highly dynamic domain where a number of physical processes interact to produce, alter or destabilize structure landforms and their associated resources. Fluxes to and from rivers and estuaries, the atmosphere and the seabed have vital bearing on the coastal and shelf areas. The physical processes and water mass dynamics of these areas profoundly affect biological, chemical, geological (sedimentary) physical oceanographic and meteorological conditions and as such have a direct bearing on the development and management of the coastal region. As such, detailed geomorphological studies of the coastal zone would constitute a key input into research on possible sea level rise along the Pakistan coast.

Analysis of Existing Geological Data

Geological evidence has shown that some degree of sea level rise has previously taken place in periods such as the Holocene age. Paleoclimatological research may reveal how the coastline in the study area reacted to that phenomenon. Although such a research effort would require considerable resources and technical expertise, it would significantly contribute towards understanding the possible effects of a rise in sea levels.

Carbon Sinks in the Arabian Sea

The north Arabian Sea, particularly the western region, is potentially an important carbon sink as it experiences extremes in atmospheric forcing that lead to the greatest seasonal variability observed in any ocean basin. Research in the area could serve to highlight the response of marine biogeochemical processes to climate change and could lead to a better understanding of ocean fluxes in the Arabian Sea.

9.5 Livestock

Like agriculture, livestock farming is a sector where information dissemination is difficult and has to be planned carefully. Research and mass awareness programs for the sector are discussed in this section.

9.5.1 Research Programs

Livestock research in Pakistan is almost entirely carried out by the public sector both at the federal and at the provincial levels. At the federal level, the Pakistan Agricultural Research Council (PARC) is the apex body concerned with planning, funding, coordinating and even conducting research in agricultural sciences including livestock. PARC prepared a five-year national agriculture research plan for the period 1997-2000 under a World Bank assisted project. Provincial governments established agricultural research boards with the help of the World Bank, which also include the livestock sector. The working and effectiveness of these boards is varied.

Currently, the private sector is not significantly involved in the research aspect of the livestock sector. There are a few instances in which the private sector has participated in research e.g. the cattle crossbreeding trials carried out mainly by commercial dairy farms. With the increase in the need for research and development in the near future, this type of private sector involvement is likely to increase. Possible research programs for the livestock sector include the following.

Rangeland Management

A significant proportion of the country's livestock is raised on rangelands. This is also the most vulnerable livestock group as rangelands in the country are largely degraded, very vulnerable to extreme events such as droughts. There is evidence that livestock herders in rangelands practice shifts in species composition, timing and duration of feed, and migration patterns in response to climatic events. However, more research in the different rangeland systems is needed to observe existing adaptation systems and recommend new ones in the light of expected climate change.

Fodder and Feed Systems

Improved feed for livestock can have a number of beneficial effects including reduction in methane emissions and improved milk production in buffaloes and cattle. Improved feed systems may also reduce dependence on fodder crops, thus rendering livestock less vulnerable to fluctuations in production of fodder crops. Research on multinutrient feed blocks or MNBs is continuing at the Animal Nutrition Institute associated with NARC, but more research is needed to bring down the costs of the feed substitute, so that its production and marketing can be facilitated. Research on drought and heat resistant varieties of fodder crops is also essential in view of the long term implications of climate change.

Economic and technical feasibility studies on the adoption of stall-feeding of livestock as opposed to open grazing and the social response to this change may also provide interesting results.

9.6 Biodiversity

The impacts of climate change on biodiversity are likely to be extensive, as detailed in **Section 4**, but it is also one of the areas where the most uncertainty prevails, due to the sheer scope of the subject.

9.6.1 Research Programs

Research on biodiversity in Pakistan has recently gained currency with the increased international interest in protecting the biodiversity in Pakistan having global significance. Nevertheless, much work is needed on understanding the impacts of climate change on biodiversity. Suggested research programs for the area are detailed below.

Monitoring Programs and Long-term Ecological Research

The political and scientific importance of understanding ecological responses to climate change underlines the need for radical improvement and expansion of biological monitoring activities. To give a few key examples, a greater emphasis will need to be placed on baseline studies, long-term ecological monitoring (particularly along climate gradients), large-scale field-based experimental manipulations, multiple-stress interactions, response to climate variability, landscape ecology, evolutionary adaptation and population genetics. Several recent reviews have proposed improved climate change research programs with strong monitoring components (e.g. Bernabo and Eglinton, 1992; Chapin et al., 1992; Kingsolver et al., 1993), but action to implements such recommendations is slow in coming.

National, regional and global monitoring programs could better meet the needs of climate change research and policy development if existing climate research programs, long-term ecological research site networks and global monitoring systems could be linked more effectively. Identification of priority biomes for global monitoring could be based upon a combination of criteria that might include:

- Global representation
- Biological importance
- Existing research network, and
- Sensitivity to climate change.

The choice of biomes should include terrestrial and marine, and provide the opportunity to integrate with monitoring of indicator species or taxonomic groups.

In order to fulfill these criteria, several biomes could be proposed for the development of multi-disciplinary climate and biodiversity monitoring programs, e.g. mangroves, montane ecosystems, and coastal wetlands. These biomes are found in most of the countries of the world, they are fully representative of latitudinal and altitudinal scales and they cover biological diversity and biological productivity.

Protected area management plans should be reviewed from a climate change perspective to understand possible effects of climate change on biodiversity, and to structure management systems with a long term perspective of protecting species from the impacts of climate change.

9.7 Energy and Industry

Research in the sector should focus on techniques to reduce fuel consumption, or to promote energy efficiency in key sectors such as manufacturing and transportation. Possible research programs for the sector are discussed below.

9.7.1 Research Programs

Agencies such as the National Energy Conservation Centre (ENERCON) in Pakistan have been active in promoting energy conservation programs in industry and transportation for some time, but have met with limited success. Energy use in the country remains sub-optimal, primarily due to the nature of the equipment used. The import of used equipment such as industrial boilers is frequent—imported secondhand boilers are estimated to constitute 50% of the total number of boilers in use—as this serves to reduce capital cost (ENERCON, 1993). According to the same study, out of approximately 4,500 boilers currently in use in industry, 3,342 are operating at less than 70% efficiency, and 1,247 boilers currently in use are more than 45 years old. Maintenance services are generally inadequate, and very few operators are properly trained in handling machinery to maximize efficiency.

Similar problems can be identified in transportation where engine and vehicle maintenance services are generally carried out by poorly trained technicians using sub-standard equipment. There is also a significant number of old vehicles (being used for over ten years) on the road, and the use of such vehicles on roads that are generally badly maintained adds to inefficient fuel consumption in the transport sector. Financing the acquisition of energy efficient equipment is another issue, given that most financial institutions in the country dealing with the manufacturing sector in particular tend to deal in equity finance.

Suggested research programs for the sector include the following.

Technology and Credit Needs Assessment for Industrial Enterprises

ENERCON has, in the past, been active in conducting a series of surveys to test the energy consumption characteristics and efficiency of process equipment in industry, particularly boilers. However, most of that work was completed almost a decade ago, and results from those studies are no longer likely to be representative of conditions in the sector. The promotion of energy efficiency programs in the sector would require a thorough, updated assessment of the conditions of existing equipment and the demand for energy efficient technology, particularly in small and medium enterprises (SMEs). Technology options most suitable or commonly required for use in these enterprises can then be assessed, along with the credit needs to upgrade key industries to accepted international standards. It would also be necessary to identify the kinds of financing mechanisms industry would be most responsive to.

The studies could also identify ways to enhance project development skills within industry for the identification, evaluation and development of investment grade energy efficiency improvement opportunities and the preparation of viable investment proposals. The involvement of industries and manufacturer's associations and the chambers of commerce would be particularly useful in this regard.

Assessment of Financial Institutions and Loan Disbursal Practices

Finding suitable mechanisms for financing equipment upgrades or retrofitting is crucial in order to promote energy efficiency measures in industry as well as transport. Studies on the current disbursement practices of financial institutions would be very helpful in evaluating the professional capability of existing financial institutions in carrying out appraisals of energy efficiency projects with quantifiable climate change impacts. It may be necessary to develop special financial instruments to finance small scale credit needs to enhance the energy efficiency of small and medium enterprises in particular.

Impact of Fuel Prices on Fuel Efficiency

The prices of petroleum products have been deregulated in Pakistan since 1st July 2001. The Oil Companies Advisory Committee (OCAC), a committee of petroleum refineries and distribution companies in the country, reviews and fixes the prices every 2 weeks based on the international prices. The constituents of the consumer price of petroleum products include government taxes. Since diesel oil is mostly used in public transport and freight movement thus having a direct impact on prices of other commodities in the country, it has lower taxes as compared to gasoline; the current ratio between the price of diesel oil and gasoline is 2:3.

The environmental and climate change effects of this practice, however, remain to be evaluated. Emission factors for diesel are higher than for motor spirit, and owners of diesel vehicles have less of an incentive to economize on fuel use or invest in regular maintenance. A thorough evaluation of existing fiscal and commercial policies, with a view to determining the impacts of these policies on the pattern of fuel use and maintenance practices would be useful in determining the possible future emission trends associated with the transport sector, and could also lead to the formulation of a set of policy recommendations for reform of the tariff and pricing structures.

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