The main cause for rise in global temperatures is the increase in greenhouse gases, mainly carbon dioxide, brought about by human activities.

The Bhojpatra forest in Manang, Nepal in winter *(Bhaskar Singh Karky)*

Carbon Dioxide Rise and Climate Change

2

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Introduction

The world has warmed by about 0.6 °C during the past century and the average global temperature has increased more in the last 100 years than at any other time in the past 10,000 years. According to the Third Assessment Report (IPCC 2001a), by the year 2100, surface temperatures would rise in global average by 1.4-5.8°C relative to 1990 levels.

Most scientists agree upon a 3°C rise (Kerr 2004). Out of the 10 warmest years of the last 125 years, nine were recorded during the last decade. With a mean global temperature of 14.5°C, 2005 was the second warmest year of the last 125 years. While some still question global warming, most people now consider it real. In a survey carried out for the United Nations Environment Programme (UNEP) based on perceptions of environmentalists and research scientists of 50 countries, 51% of respondents consider climate change as the principal environmental crisis. The other problems cited include water scarcity, deforestation and desertification, freshwater pollution, and loss of biodiversity.

The global increase in temperatures will affect global climate, but what changes it will bring remains a topic rife for debate. For example, it may cause an area to be more wet and the other drier. The eastern Himalayan regions are predicted to become more humid, while the north-west regions are likely to turn more arid. Evidences suggest that in the eastern regions precipitation has increased even in some rain shadow areas. This Chapter looks at the science of climate change and its adverse impact on the global ecology.

The Greenhouse Effect

According to the Third Assessment Report (IPCC 2001a), anthropogenic carbon dioxide concentrations have increased by 29%, methane by 150%, and nitrous oxide by 15% since the Industrial Revolution. The greenhouse gases in the atmosphere trap energy from the sun and slow the escape of long wave radiation back to outer space. The phenomenon of trapping and radiating heat by CO_2 and other GHGs in the atmosphere is called 'greenhouse effect'. Since greenhouse gases absorb the radiant heat energy, they are known as radiatively active gases. On a molecule for molecule basis, methane is 21 times more effective, N_2O 310 times more effective, and chlorofluorocarbons

(CFCs) 12,000-15,000 more effective than CO_2 in trapping heat in the atmosphere. It is the heat trapping quality of GHGs that warms the planet and makes the earth habitable. The problem is the extra warming resulting from the rise in concentrations of GHGs during the last century. The extra GHGs come mostly from large-scale burning of fossil fuels from industries and motor vehicles, from intensified agricultural activity and deforestation, and from various other land use changes, mining, and other human activities.

The major sources of methane are enteric fermentation in ruminant livestock, and rice cultivation. Fertiliser application to agriculture is a major source of nitrous oxide. CFCs are entirely human created, used in refrigeration and other such processes. In the year 2000, carbon dioxide accounted for 63%, methane for 24%, nitrous oxide for 10%, and other gases for 3% of carbon equivalent emissions (IPCC, 2001a).

The rates of emission of GHGs vary widely across different parts of the world (Table 2.1). For example, USA, Canada, and European Union countries alone accounted for 44% of global GHG emissions in 1990, compared to 4% emissions from Africa for the same year.

Table 2.1: Greenhouse gas emissions from regions of the world (1990 and 2000)

Region	1990 (%)	2000 (%)
Canada & USA	21	23
Enlarged EU	23	14
Russia & CIS	17	8
Oceania	1	5
Japan	4	4
Latin America	7	7
Africa	4	7
Middle East	4	5
South Asia	3	7
East Asia & South Asia	16	20

Source: Sharma et al. (2006)

While Europe has shown a considerable decrease in GHG emissions between 1990 and 2000, emissions remained high in the USA (Table 2.1). The per capita emission of CO_2 equivalent of the USA is over 15 times that of India, and about 2.6 times the global average (Table 2.2). According to *Earth Trends* (2003), per capita emissions for Nepal in 1998 was 0.1 t yr^{-1}, and the value is likely to be similar in the Indian Himalaya.

Table 2.2: Per capita CO_2 equivalent emission of selected countries in 2000		
Country	**Per capita CO_2 equivalent emission in year 2000 (tonnes/capita)**	**Ratio of per capita emissions with regard to Indian emissions**
USA	23	15.3
Germany	12	8.0
United Kingdom	11	7.3
Japan	10	6.7
India	1.5	1.0
Brazil	1.9	1.3
China	3.3	2.2
Global	3.9	2.6

Source: Sharma et al. (2006)

Carbon Cycle and Carbon Sinks

Since carbon dioxide is the principal greenhouse gas and its emissions keep rising, it is essential to have a closer look at the carbon cycle. Carbon is taken from the atmosphere in two ways, but is released back into the atmosphere in many different ways. The uptake of carbon from the atmosphere occurs (i) as a result of photosynthesis, in which CO_2 is converted into carbohydrates and releases oxygen, and (ii) as CO_2 dissolves in water at the surface of oceans near poles, when water becomes cooler.

The release of carbon back into the atmosphere can occur through: (i) respiration of plants and animals, involving the breakdown of glucose or other organic molecules into CO_2 and water (an exothermic reaction); (ii) decomposition of plant and animal matter, releasing CO_2 if oxygen is present, or methane if oxygen is absent; (iii) combustion of organic material, producing CO_2 and other things like smoke (e.g., burning of fossil fuels such as coal and petrol stored in the geo-sphere for millions of years); (iv) erosion by water of calcium carbonate-rich rocks such as limestone, marble, and chalk (breakdown products include CO_2 and carbonic acid), and production of cement and lime by heating limestone; (v) the release of dissolved CO_2 from ocean surface water as a consequence of warming; and (vi) volcanic eruptions.

The carbon dioxide concentration was almost stable at 280 ppm over hundreds of years, but increased rapidly following the Industrial Revolution (after 1800 AD), reaching 380 ppm levels in 2005. Carbon emission from the burning of fossil fuels, cement production, and deforestation, on an average, is about 8 Gt yr^{-1} (Figure 2.1). This is more than the average rate at which CO_2 is increasing in the atmosphere, which is 3.2 Gt yr^{-1} (Schimel, 1995). The balance is being taken up from the atmosphere up by lands and oceans. It is agreed that the global carbon sink is equally divided between the ocean and terrestrial ecosystems (Press et al. 2000). Understanding the variations in strength of the carbon sinks and their locations are major challenges and important for managing the carbon cycle in the biosphere. The current average rate at which oceans of the world are absorbing CO_2 is about 2 Gt C yr^{-1}, with strong sinks in north Atlantic and the Pacific. The mid-Pacific, on the other hand, is a source of CO_2 release (Peng et al. 1998). The sink strength of the ocean varies from year to year as a result of variations in current, which affect sea surface temperatures, and thereby influence the amount of CO_2-rich water brought to the surface. For example, the CO_2 efflux from the equatorial region is high during El Niño years, when the surface temperature of the Pacific Ocean rises. The ocean's sink strength depends both on physical and biological processes. In the latter the photosynthesis of short-lived phytoplankton plays an important role. However, the long-term anthropogenic CO_2 uptake by oceans depends upon the mixing of surface waters with water from the deep ocean, not on air-sea gas exchange. Though the ocean can theoretically absorb 70-80% of projected induction of anthropogenic CO_2, the process will take a long time because the mixing of surface water with deep ocean water is a slow process.

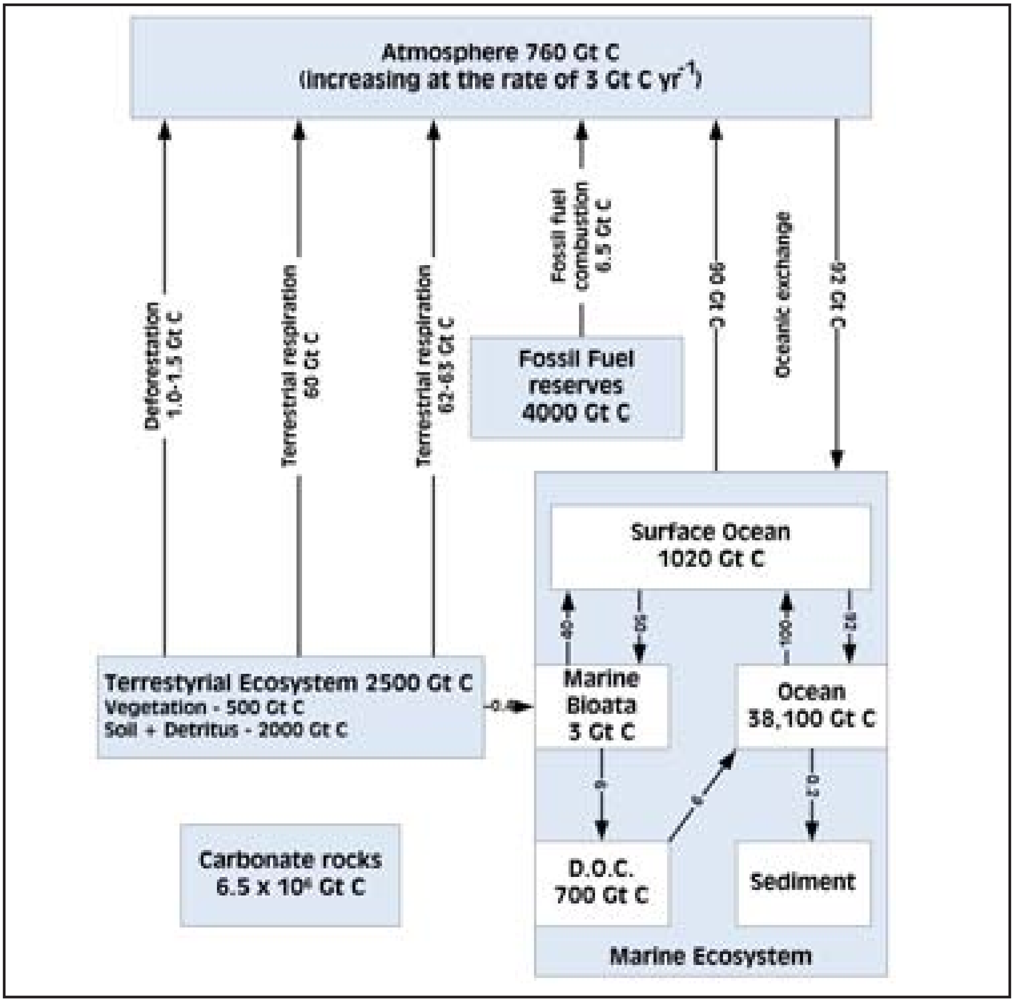

Figure 2.1: A representation of the global carbon cycle during the 1990s
Source: Grace et al. 2000
Note: The carbon stocks are in billion tonnes of C or Gt C. The carbon fluxes, shown with labeled arrows, are in Gt C yr^{-1}. Both terrestrial and marine ecosystems are net absorbers of CO_2, yet atmospheric stock is increasing approximately at the rate of 3.2 Gt yr^{-1} because of fossil fuels combustion (and also cement production) and deforestation (Grace et al. 2000).

Compared to oceans, many terrestrial systems have a much larger biomass and capacity to take up CO_2 per unit area. Many forest ecosystems, are known to have more than 200 t C ha^{-1} in biomass compared to generally less than 10 t C ha^{-1} in oceans (Table 2.3). Soils of forests located in cold climates, such as boreal forests, store unusually large amounts of carbon.

Table 2.3: Carbon stock and increments in the world's major forest types

	Area (10^6 km^2)	Carbon Stock (t ha^{-1})		Annual increment in stock of biomass (t ha^{-} yr^{-1})
		Biomass total	Soil organic matter	
Tropical forests	17.6	285	162	2.30
Temperate forests	10.4	125	56	4.19
Boreal forests	13.7	67	390	1.40
Indian Himalayan forests * (mean)	0.23	148	120	2.59

* Values for the Indian Himalaya are only gross approximations.

Source: Malhi et al. (1998)

Some of the conclusions of the measurements of net uptake of carbon, using sensors mounted above vegetation on towers distributed in different parts of world, are as follows:

- Most boreal and temperate forests are reasonably good C-sinks, sequestering between 0.5 - 8 t C ha^{-1} yr^{-1} (Press et al. 2000).
- Old growth Amazonian forests are also strong carbon sinks, with carbon store values in the range of 0.5 - 6 t C ha^{-1} yr^{-1} (Malhi et al 1998). This is contrary to the general perception that old growth forests are ineffective carbon sequesters.
- Of the respiratory fluxes of carbon, fluxes from the soil far exceed the fluxes from the aboveground parts of plants.
- Potential for soils to sequester carbon is considerable. For example, forests in Finland show that soil carbon content stabilises only after 2000 years (Liski et al. 1998). Even agricultural soil has considerable ability to store carbon.

The Impact of Climate Change

The warming of the earth is expected to affect other parameters of climate such as spatial distribution and amount of precipitation and its seasonal pattern. For example, in much of the Indian subcontinent global warming is likely to enhance the hydrological cycle and intensify severity of floods.

The possible impact of climatic change are listed in Table 2.4. Attempts have been made to include examples from the Indian subcontinent and the Himalayan region. The majority of the people in India and Nepal, for example, depend heavily on climate-sensitive sectors such as agriculture and forests, and on other natural resources such as water and biodiversity. Sizeable portions of the population in these countries are dryland farmers, nomadic shepherds, and forest dwellers, or forest dependents with limited adaptive capacity to deal with the problems likely to arise as a consequence of global climate change.

According to a projection, depending upon the rise of CO_2 concentrations in the atmosphere India's average temperature during 2071-2100 will rise by 2.9-4.2°C, and annual precipitation by 220-300m (Ravindranath et al. 2006).

Table 2.4: A broad outline of possible impacts of global warming

Temperature rise	Wider fluctuations in weather	Ecosystem disruption	Human health
Ice melting in polar and high mountain areas	More incidents of heavy rainfall	Stress and death of vegetation	Heat stress
Sea land rise and flooding of coastal cities	More incidents of severe drought	Species migration	Migration of disease vectors
Increased methane release from permafrost			Increase in incidents of diseases like malaria

Weather and climate

According to the IPCC (2001), average precipitation, particularly during winters, will increase in the Northern Hemisphere. There would be more incidents of floods and droughts. Warming is likely to cause severe floods in the Gangetic Plains adjacent to the Himalaya because of enhanced monsoon rainfall and glacial melting. In the Ganges, the peak time run-off at present is six times greater than the normal time. This is predicted to increase further by 27-116% (Beniston 2003). According to a report of UNEP and ICIMOD based on data from 49 monitoring stations, a number of melting glaciers are retreating by 30-100m in Nepal and Bhutan, leading to the formation of unstable lakes threatening to burst their banks.

Glaciers are found in every continent except Australia, and reports indicate that most of the glaciers are shrinking in size. The smaller they become, the faster they disappear. The Himalayan rivers would become seasonal once their glaciers are gone. The Arctic Greenland ice sheet is said to have shrunk by 6% between 1978 and 1996. The loss of ice cover is likely to increase warming because of reduced reflectance of solar energy.

Changes in distribution of species and ecosystems

With increasing global warming, species and ecosystems are likely to shift from lower to higher latitudes and altitudes. Temperatures decrease by altitude at the rate of 5-10°C/km across various mountains of the world. Species would need to migrate upward in order to survive. However, the upward movement of alpine species occurring near mountain peaks is likely to be restricted by the lack of space and soil. Since mountain tops are smaller than their bases, the species near the tops would occupy smaller and smaller areas with global warming. They may be severely affected by the smallness of the populations. Some of the important alpine species of the Himalaya that may face immediate extinction include the oak *Quercus semecarpifolia* (Singh et al. 1997), birch *(Betula utilis)*, some rhododendrons, several herbs of medicinal value, and mammals like pikas, brown bears, and snow leopards. Many highly preferred fodder species, like *Grewia optiva* (bheemal), *Celtis australis* (Kharhak), and Ficus spp, which local communities in Western and Central Himalayan regions cultivate around crop fields below 1600m altitude, would shift to higher ranges. Oaks which are the foundation tree species of much of the agricultural zone in these Himalayan regions would also shift to higher ranges provided they get favourable soil and moisture conditions. One of the major consequences of this would be the occupation of new areas in higher mountains above 2000m altitude by humans. The upward movement of local communities may lead to new people-protected area conflicts; as many of the large protected areas in the Himalaya are located in higher ranges above 2500m altitude, and more people are likely to occupy those areas with the rise in temperature.

Local communities would be forced to select new species and varieties of crops and fodder trees. They may also need to change the species they use for leaf litter and the practices they employ to prepare manure for crop fields. For example, the conversion of pine forests into Sal forests in the subtropical belt of the Himalaya is likely to improve manure quality but deprive local people of grasses that they collect from pine forests and store for the winters.

These altitudinal shifts may bring about major changes in the fire regime of an area. Enhancement in the hydrological cycle may restrict fire intensity, but severe droughts are likely to desiccate dry habitats like south-facing slopes and ridge tops more, and thus lead to more forest fires.

According to a projection for the year 2085, depending upon the rise in CO_2 in the atmosphere, 68-77% of forested grids in India are likely to experience a change in forest types. The shift generally would be towards wetter types of vegetation in the north-eastern parts and drier types in the north-western parts (Ravindranath et al. 2006). The tropical evergreen forest type is predicted to expand extraordinarily, from 3% of the grids at present, to 21.5% and 35%, respectively, under low and high increases in the atmospheric CO_2 concentration. The impact on tropical dry deciduous forests is likely to be negligible, in contrast.

The changes in mountains are expected to be much sharper. It is estimated that snowline will rise by about 150m for each degree Celsius increase in temperature. The warming would also affect vegetation by reducing snow pack duration, its amount, and water availability from snowmelt. Plant growth in alpine meadows, where many medicinal plants occur, can be severely affected by early snowmelt. Many species may be exposed to severe frosts with the thinning of the snow cover. Species requiring winter cooling for regeneration are likely to be most vulnerable to warming. In the Himalaya, junipers for which winter chilling is not necessary may survive warming.

At the species level there are three likely adaptational responses (Huntley 1991): (i) replacement of dominant species by more heat-loving species, (ii) replacement of climax species by pioneer species having adaptation capacity for wider ranges of environments, and (iii) better expression of the less important species of the same community. During the transitional stage many exotic weeds may invade new areas and expand their ranges.

Changes in phenology

A number of studies carried out in different parts of world indicates that global warming during the last three decades has advanced by a few days several springtime activities such as leaf production and flowering in plants, breeding in birds, and arrival time of migrant birds. There are also indications of delayed colouration of leaves during autumn. In the Himalaya, there are many dominant forest tree species (e.g., *Shorea robusta*, *Quercus floribunda*, and *Q. semecarpifolia*) in which seed maturation is synchronised with commencement of the monsoon and their seed viability is unusually short, one to two weeks. Early maturation of seeds due to warming or drought stress may break this synchronisation, and thereby impair regeneration of such species.

Failure of oak regeneration will adversely affect subsistence living of local communities, as people depend on these trees for nutrient replenishment of their crop fields, for hydrological services, and for firewood and fodder. Communities in the Himalaya will need to prepare themselves for these situations long before they begin to affect them. The growth in the national economy may help people to go beyond a biodiversity-dependent lifestyle.

Melting of ice sheet and rise in sea levels

Sea level rise can occur both because of ice melting and volume expansion of water at warmer temperatures. World over sea level rise of 1-2 mm yr^{-1} during the last century has been reported. Estimates of mean sea level rise at selected stations along the Indian coast indicate a rise of fairly close to 1mm yr^{-1}. Furthermore, intensity of tropical cyclones in Bengal is predicted to increase. Many coastal cities of the world would have problems.

Mention may be made of the melt of the ice sheets of Antarctica, the fifth largest continent. Its ice sheet is vast (covering 99.7% of the continent) and about 2 km thick, with a total volume of about 25 Mkm^3. If this were to melt completely, global sea levels would be about 57m higher. Fortunately, the net contribution of the Antarctic ice sheet to the global sea level change would be small during the 21st century. There is a need to investigate the matter more deeply (Repley 2006).

Oceanic pH and the marine ecosystem

Oceans, by absorbing atmospheric CO_2, have played a great role in slowing the process of global warming. But they tend to decrease the pH levels of seawater, and the consequent acidification has the potential to affect several marine geobiological and ecological processes (Turley et al. 2006). By 2100, atmospheric CO_2 concentrations is likely to be 700 ppm the pH of the ocean's surface water and is predicted to decline by 0.3-0.5 units from the levels in 1800 AD. Reduced pH levels is predicted to inhibit calcifying organisms such as cocolithophores, pteropods, gastropods, aminifers, and corals. This may lead to increase in non-calcifying organisms, affecting structure and process in marine ecosystems. Decrease in pH can also disrupt metal ions uptake, causing symptoms of toxicity and intra-cellular enzymatic reactions in marine life.

Malarial infection

The occurrence of many vector-borne diseases until now has not been seen in cold latitudes and altitudes. At elevations above 1500m in the Himalaya and other subtropical and tropical mountains, the Anopheles mosquito can neither breed nor survive (Craig et al. 1999). The warming is likely to lead to new distributions of vector-borne diseases. Malarial transmission is predicted to increase in warmer and wetter climates. Predictions are that even Himalayan states like Himachal Pradesh, Arunachal Pradesh, Nagaland, Manipur, and Mizoram are likely to be prone to malaria (Battacharya et al. 2006). Conditions in Nepal are not going to be any different.

Tourism

The skiing industry may be adversely affected, as it requires a continuous snow cover of over 30 cm depth for at least 100 days. However, tourist activity in general may expand because of longer summers in the mountains and more heat stress in the plains, particularly in the Indian subcontinent. Tourist centres are likely to move upward into remote areas, threatening some of the last remaining forest-rich areas in the Himalaya.

Atlantic thermohaline circulation

The Atlantic thermohaline circulation (ATHC) is a phenomenon which transports a huge amount of heat (currently about 1 petawatt or 10^{15}w or a million billion watts) toward poles. This amount of energy in equal to 100 times the current human use of energy, i.e., 10^{13} w. This northward circulation is driven by temperature (thermo) and salt (saline), and makes Europe up to 8°C warmer than other longitudes at its latitude. There is a risk of collapse of the ATHC as a consequence of the addition of freshwater from snowmelt. There are evidences to suggest that ATHC was shut down or slowed in the past, resulting in the cooling of Europe. The fear is that ATHC may collapse again because of global warming (Schlesinger et al. 2006).

Coral reef bleaching

Coral reefs are complex systems involving anthozoan corals and their symbiotic endozoan dinoflagellate and coralline algae. Though occurring in nutrient-poor tropical oceans, they support a high diversity of colourful organisms. There are indications that coral bleaching (reduction in the density of dinoflagellate algae and their pigments) and warmest years coincide.

Ecosystem level responses

Biotic communities are not merely slaves of climatic factors. They have the capacity to respond to climatic changes and determine the course of changes in them. For example, in response to warm temperatures, forests may enhance evapotranspiration and thus, affect precipitation at a regional level. In response to warming, boreal ecosystems are likely to increase CO_2 emissions from the soil and thus, escalate global warming.

The above description only gives an outline of the possible impacts of global climatic change. Since ecosystems function in a complex way and have the capacity to modify the course of warming, many changes under the influence of global warming could be different from what are being predicted. Carbon dioxide enrichment is likely to have many direct influences on biota and soil component, and may thus modify the path of global climate change.

The Global Community's Response

Achieving reductions in the emission of GHGs without affecting global economic growth is a challenging task in a world sharply divided between industrialised and non-industrialised countries. There are two broad ways of reducing the rate of increase of the atmospheric pool of carbon dioxide: (i) reduce CO_2 emissions by using energy sources which do not add to atmospheric concentrations of CO_2 (e.g., solar energy, wind energy, hydroelectricity, and biofuels), and by increasing energy use efficiency (high GDP-energy use ratio); and (ii) sequester CO_2 in vegetation and soil pools of the biosphere. There is a strong need to have an understanding among countries of the world to make any progress in this direction.

Irrespective of the success the global community achieves in controlling GHGs emissions, global temperature is going to rise. Therefore, it is important to develop strategies to adapt to the climatic change. These may pertain to dealing with problems of the rise of sea levels in coastal areas, shift in cultivation zones of agricultural crops, early snowmelt, species extinction, and others in terrestrial ecosystems. Needless to say, considerable efforts would be required to develop cooperation among countries of the world to tackle the global crisis. The Kyoto Protocol, an amendment to the UNFCCC, is an international treaty to address the problems of global warming. The KP entering into force in February 2005 in the global community is a matter to celebrate, but it is only a small step at best (Najam et al. 2004). Even if completely implemented, the KP is expected to reduce the average global temperature only between 0.02 and 0.28 °C by year 2050. Unfortunately, the greatest emitter of GHGs, USA, is still out of the orbit, and much of the post-KP period was consumed to make Annex I countries commit to what they had agreed to at Kyoto (Najam et al. 2004).

The impacts of global climatic change are already being felt and are likely to intensify in the coming decades. The most vulnerable to the ravages of climate change are people of poor countries who have contributed the least to the atmospheric accumulation of GHGs, and have a low capacity for climate change adaptation. The post-Kyoto phase is going to witness a dramatic improvement in the economy of several developing countries, including two Asian giants, China and India, each with more than a billion population. As economic growth picks up, total emissions from developing countries is going to be equal that of developed countries, even if per capita emissions remain much lower. In fact, the country level emissions of China may match that of the USA in next couple of decades. New coalitions of nations (Figure 2.2) are likely to develop to avoid the risks of climate change. Factors like exposure to risk, and ability to pay, apart from levels of emission, may play significant roles in determining the country groupings in the near future (Morlet et al. 2005). Vulnerability to climate change would also vary across different parts within a country. In the Himalayan region, people depending on alpine range resources, such as nomadic races, are likely to be worst affected. Glacier melts and flash floods will affect people living in both mountains and the adjoining plains. The problem of seasonal water scarcity may worsen.

It is important to have a better understanding of the problems of different countries, their limitations and strengths, and to be considerate of the problems of those who are less capable to deal with the ravages of climate change, to effectively deal with the crisis of global change.

High exposure	**Countries likely to be affected**		
Coastal and high mountain zones	Most Andean countries, Bangladesh, Indonesia, Nepal, many small island countries	Brazil, China, India, Malaysia, Thailand, S. Africa, etc.	Germany, Switzerland, UK, etc.
Arctic nations		Russia	US, Canada, Norway, Finland, Sweden, Iceland
Mediterranean nations	Albania, Egypt, Morocco, others	Croatia, Turkey, Tunisia, etc.	France, Greece, Norway, Sweden, Iceland
Low exposure	Low GHGs emitters Low ability to pay	→	High emitters High ability to pay

Figure 2.2: Likely coalition of countries to develop in view of the risks of climate change, their GHGs emissions, and ability to pay

Climate Change and Other Ecosystem Services

Carbon sequestration is one of the principal ecosystem services, but several other services flow from the ecosystems that play major roles in supporting all forms of life. The Kyoto Protocol has led to the establishment of carbon trade, and thus given economic value to standing forests. However, to promote conservation, payment mechanisms are required to be developed for other ecosystem services such as regulation of watershed hydrology, soil formation and climatic regulation by forests, and nutrient storage and recreational value of wetlands. Many payment schemes for ecosystem services from forests are being experimented in Mexico, Costa Rica, and Brazil (see Pagiola et al. 2002). Efforts are required to learn from these experiences and put payment mechanisms in place in other parts of the world. That may require identification of providers and receivers of services.

Services like carbon sequestration and biodiversity conservation are global in nature; those flowing through river connections, such as deposition of fertile soil, are regional level, and many, such as water and air purification and pollination of crops, are local in nature. Evidently, any payment system involving ecosystem services needs to consider educating people and developing understanding and agreements among the concerned parties. Climate change will affect the flow of many ecosystem services, particularly as a result of mid-continent drying and increased frequency and intensity of climate extremes, including rainfall. Mass-scale species extinction is likely to adversely affect ecosystem functioning and the services that ecosystems generate.

Conclusion

At this stage, as we do not understand the full extent of the damage climate change is inflicting on the earth and its diverse ecology, we need to focus on identifying measures that should be taken up collectively to slow this process. Strategies will also be required to develop adaptive measures specific to regional conditions. Some of the efforts that may be useful from the adaptation standpoint are identification and prioritisation of climate risks, compilation of existing knowledge on climate risks and their dissemination, analysis of critical knowledge gaps that impede effective adaptation decisions, and generation of new relevant knowledge. Developing the science of ecosystem services will be important for achieving sustainable development in a world faced with the threats of climate change.