UNIT 12 THE EXPERIENCE OF VULNERABILITY-I

Structure

12.0 LEARNING OUTCOME

After reading this Unit, you should be able to:

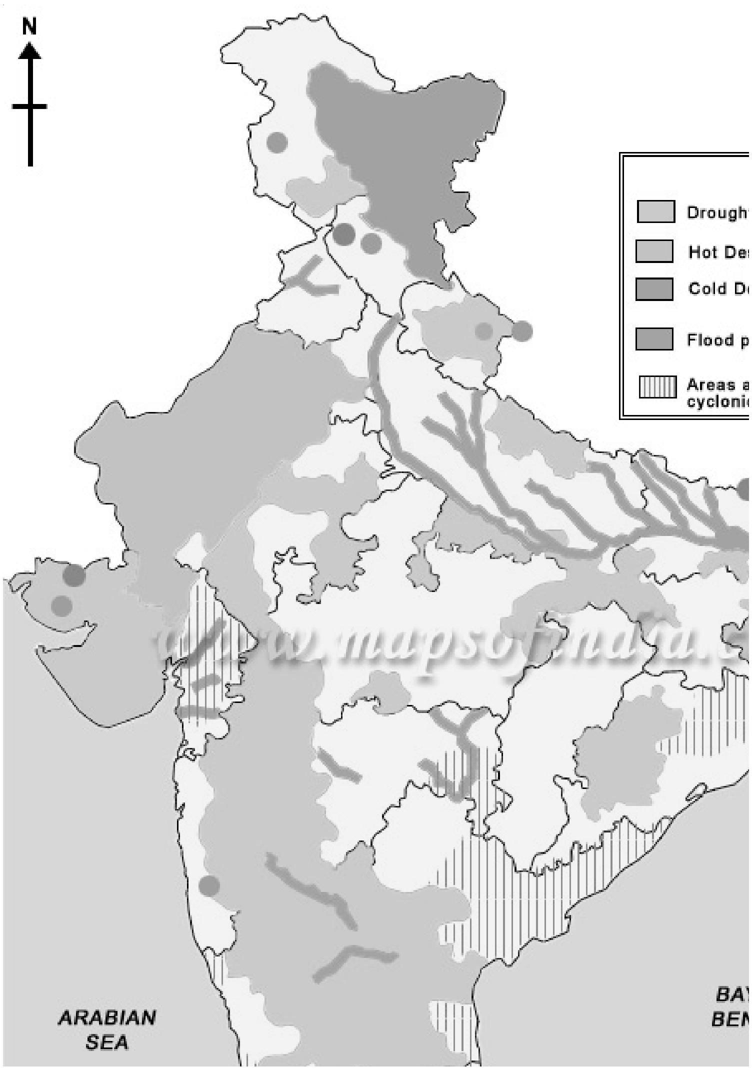
- Understand and depict on map, the geo-climactic vulnerabilities of India;
- Understand the likely causes of complex vulnerabilities; and
- Study major natural hazards affecting different parts of India.

12.1 INTRODUCTION

India is vulnerable to natural disasters of potentially serious magnitudes, and its disaster management requirements are likely to extend beyond the scope of “natural” to more “complex” (for example, man-made) emergencies in the future. Enormous population pressures and urbanisation have forced people to live on marginal lands where they are at greater risk to disasters. Whether a flood, a regional drought or a devastating earthquake, millions of Indians are affected each time a disaster occurs. In addition to large-scale displacement and loss of life, these events result in the loss of property and agricultural crops worth millions of dollars annually. For example, the Orissa Super Cyclone in 1999 killed thousands and destroyed more than one million hectares of crops;

the Gujarat earthquake in 2001 claimed thousands of lives, left millions of people homeless and ruined public infrastructure worth hundreds of millions of Indian rupees. These catastrophes typically result in the substantial loss of hard won development gains.

Natural hazards like floods, cyclones, droughts and earthquakes are not rare or unusual phenomenon in the country. While vulnerability varies from region to region, a large part of the country is exposed to such natural hazards that often turn to disasters causing significant disruption of socio-economic life of communities resulting in loss of life and property. As can be seen in the map given below, the Indian subcontinent is among the world's most disaster prone area. (The map is self-illustrative).



Source: *Compare Info base Pvt. Ltd., 2003*

12.2 INCREASING IMPACT OF NATURAL VULNERABILITY IN INDIA

Natural disasters are increasingly making headline news due to the impact of modern communications and connectivity, and the proliferation of television and news media. Awareness of Risk or Risk Perception has increased substantially among officials as also common people, of the various natural and man made disasters they are exposed to. A project entitled, “Global Change Impact Assessment for Himalayan Mountain Region for Environmental Management and Sustainable Development” has attempted to assess the vulnerability and the possible impacts of global change on food security and water resources including transfer of resources between uplands and lowlands. Also it assessed the vulnerability of the mountain people to global change and assesses the multiple environmental stresses.

In India, the concern relates to multi-hazard vulnerability as is seen in the map above. This is mainly on account of its geographical position, climate and geological setting, which make it one of the most disaster-prone areas of the world. For example, heavy concentration of rainfall within a span of three months in most areas of the country causes heavy runoff, leading to high floods, uprooting people, disrupting livelihoods and damaging infrastructure. On the other hand, non-availability of moisture during the major duration of the year, particularly in the arid and semi-arid regions makes almost sixty eight percent of the country’s landmass vulnerable to drought. The fragility of the Himalayan mountain ranges is a continuing source of concern for their high vulnerability to earthquakes, landslides and avalanches. Cyclones strike the coastal regions of the country nearly every year. Table-1 shows the human lives lost due to various disasters in India.

Table-1

Human Lives Lost Due to Various Disasters in India

Year	Floods	Cyclones/Floods	Hailstorm	E
1990-91	1320	979	-	-
1991-92	1185	304	-	7
1992-93	1193	497	-	-
1993-94	1690	318	-	7
1994-95	2038	247	59	-
1995-96	2072	361	31	-
1996-97	2069	1719	40	-
1997-98	1560	216	247	3
1998-99	2567	1292	-	1
TOTAL	15694	5933	377	8

Source: Ministry of Agriculture, Government of India

Data for subsequent period is given separately as studied in the World Disasters Report, 2004. Total number of people affected and killed for the period 1984- 2003 is as follows:

- Number of people killed (1984-1993)-42,171;
- Number of people affected (1984-1993)-551, 374,370;

- Number of people reported killed (1994-2003)- 68,671; Number of people reported affected (1994-2003) - 680,657,773;
- Total number of people reported affected (2003) – 3082; Total number of people reported killed (2003)-8,098,666;
- Corresponding figures for Asia; reported killed (1984-1993)-341,143; reported affected (1984-1993)-1,425,145,631;
- Total number of people reported killed (1994-2003)-480,001; Total number of people reported affected (1994-2003)-2,342,913,147;
- Total number of people reported killed (2003)-37,860; Total number of people reported affected (228,895,146).

India has been identified as one amongst twenty-seven countries, which are most vulnerable to the impacts of global warming and accelerated sea level rise. The high degree of vulnerability of Indian coasts can be mainly attributed to the extensive low-lying coastal areas, high population density, frequent occurrence of cyclones and storms, high rate of coastal environmental degradation on account of pollution and non-sustainable development. Most of the people residing in coastal zones are directly dependent on natural resource bases of coastal ecosystems. Any global warming-induced climate change such as increase in sea surface temperature, change in frequency, intensity or tracks of cyclones, sea level rise may aggravate the potential risks to coastal zones. The rise in sea level could result in the loss of cultivable land due to inundation, salt-water intrusion into coastal ecosystems and into groundwater systems and loss of terrestrial and marine biodiversity.

12.3 EXPERIENCE OF CYCLONES IN INDIA

India's 7,517 km coastline has been raked by cyclone for centuries. Given the state of knowledge and resources, damage on still larger scales is expected in the coming years. Tropical cyclones are intensifying swirls of cloud and rain which then progress into tropical storms.

The Indian subcontinent is the worst cyclone-affected part in the world, as a result of low-depth ocean bed topography and coastal configurations (areas can be seen in the map above). Stretches along the Bay of Bengal coastline have the world's shallowest waters. A cyclone causes large-scale destruction, particularly in the coastal areas because of storm surges (rise in the sea level inundating coastal areas), strong winds, and, heavy widespread rain causing floods. There are three elements associated with a cyclone, which cause destruction. (a) Cyclones are associated with high-pressure gradients and consequent strong winds, which in turn, generate *storm surges*. A storm surge is an abnormal rise of sea level near the coast caused by a severe tropical cyclone; as a result, sea water inundates low lying areas of coastal regions drowning human beings and livestock, eroding beaches and embankments, destroying vegetation and reducing soil fertility, (b) Cyclones rank along with earthquakes as the biggest geophysical causes of loss of life and property. Cyclones do most damage to structures; most fatalities come from the rain and flooding that follow, (c) In shallow water, tropical cyclones whip up low waves that translate into long and powerful shore currents.

Cyclone formation requires warm seas and still air. In the Bay of Bengal, these are the conditions that normally occur in the months of April-May and October-November. The frequency of tropical cyclones is the least in the Bay of Bengal and the Arabian Sea where they are mostly moderate in intensity. But the storm surges make them ferocious when they cross the shoreline. Very strong winds may damage installations, dwellings, communication systems, trees etc, resulting in loss of life and property. Heavy and prolonged rains due to cyclones may cause river floods and submergence of low-lying areas by rain causing loss of life and property. Floods and coastal inundation due to storm surges pollute drinking water sources causing outbreak of epidemics.

The Indian subcontinent is particularly hard hit because as pointed out earlier storm surges increase in intensity on crossing the coast, as a result of low-depth ocean bed topography and coastal configuration. Predictable latitude of origin and a predictable direction of advance characterise cyclones. However, their exact path and point of crossing the coast (the latter is where the most severe effects may be expected) remain unpredictable. The relatively dense population and poor economic condition compounds the vulnerability of the area. The population density in some of the coastal districts is as high as 670 persons per square km compared to the state average of 268 persons per sq km. Cyclones strike in May-June and October-November, with the monsoon's onset and retreat.

North Orissa and Bengal coasts are the most cyclones prone, followed by the Krishna delta in Andhra Pradesh. The most vulnerable districts are Nellore, Krishna, Srikakulam, and East Godavari. On November 6, 1996, a ferocious cyclonic storm pounded the East and West Godavari districts of Andhra Pradesh, killing over 4,000, rendering some 100,000 homeless and destroying standing crops, livestock and public property worth Rs. 35 billion. Hurricane winds, moving in from the Bay of Bengal at 120 km/h, uprooted rail and road bridges, power transmission towers and communication links, while two-meter high tidal waves inundated several islands and townships, turning the entire coastal belt into a vast sheet of water. Andhra Pradesh is particularly vulnerable to devastating cyclones and in the last two and half decades at least a dozen major cyclones have struck the area, each time killing thousands of people and causing extensive damage to property. The seafront of Orissa and Tamil Nadu and the Sundarban delta in West Bengal also have to bear the brunt of severe cyclonic onslaughts from the rough seas of the Bay. The victims are usually poor fisher-folk who are helpless in the face of government apathy. A rather more devastating cyclone was experienced in Orissa on October 29, 1999. Orissa has a low rate of urbanisation (13.43 percent), which is lower than the national average. The super cyclone that struck and ravaged 12 coastal districts of Orissa with a wind velocity of 260-300 km/h affected an urban population of 1.9 million. About 20 urban settlements were badly affected, among which pilgrim town of Puri, commercial centre of Cuttack, port town of Paradip and state capital of Bhubaneshwar merit attention. It may be mentioned that after a week of the catastrophe, power supply could be restored to only 28 percent of Bhubaneshwar and 13 percent to Cuttack.

Damage assessment as per the situation report 8.The official death toll of 23 November 1999, is 9083, with Jagat singhapur recording 8119.Damage Assessment caused due to the cyclone is represented in a tabular form (Table-2).

Table-2

Damage Assessment

S. No.	**District**	**No. of affected villages**	**No. of deaths**	**Affected Population**
1	Balsore	-	49	941000
2	Bhadrak	-	98	1550000
3	Jajpur	-	178	1300000
4	Kendrapara	-	418	1200000
5	Jagtasinghpur	-	8119	1200000
6	Khurda	-	91	100000
7	Puri	-	301	2052000
8	Cuttack	-	454	150000
9	Nayagarh	-	03	250000
10	Keonjhar	-	31	70000
11	Denkanal	-	51	
12	Mayurbhanj	-	10	
Total		**-**	**9803**	**12,021,000**

Source: Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation.

Anil Sinha, (2002) gives an account of the recent major cyclones hitting the Indian Coast. The figures are mentioned in Table-3

Table-3

Sl. No.	State	Time	Wind Speed	Sea Surge
1	Andhra Pradesh	May 1990	24-250	5-6
2	Andhra Pradesh	Nov. 1996	140-150	2-2
3	Gujarat	June 1998	200	2-3
4	Orissa	Oct. 1999	270-300	6-7

*Families

Global warming is believed to be the reason for the increasing incidence of cyclones on the East Coast. Global warming pulls up sea surface temperature that leads to boost in cyclone frequency, intensity, duration, and track modification. The global warming also raises the sea level due to the melting on the polar ice cap, eventually leading to inundation of coastal land in huge chunks. Storm surges, or tidal waves, occur when the level of the sea is raised by direct and wind-driven water combined with an uplift of the sea surface induced by the low pressure at the cyclone centre. The height (up to 7 m) and length (up to 50 km) of storm surges depends on the tides, the rate of water run-off from the land, onshore winds, and the coastal configuration. Storm surges cause the most havoc when receding. As they move inland, wind speed drop, but the accompanying floods constitute the greatest threat. On an average, storm surges kill seven times more people and damage three times more crops than severe cyclones that are storm surge-free. About 6.5% of about world's 80 tropical storms are formed annually in the Indian Ocean. Frequency of formation of cyclones is 5-6 times more in the Bay of Bengal as compared to the Arabian Sea (IMD, 1979). Therefore, the east coast of India (particularly the States of Andhra Pradesh, Orissa and West Bengal) is more vulnerable than the west coast to the fury of cyclones and massive damage of life and property occurs almost every year. The 1999 tropical super cyclone that hit the coast of Orissa on 29th October with wind speed of 260 km per hour resulted in a death toll of over 10, 000 and demonstrated the extreme significance of impacts related to climate variability and extremes. There have been a number of studies on the likelihood of changes in the tropical storms in the event of global warming. Recent studies on the potential impact of one-meter sea level rise along the Indian coasts give an idea about the land that could be inundated and the population that would be affected provided no protective measures are taken. It has been suggested that the total area of 5763 sq. km along the coastal states of India, that is, 0.41% could be inundated and almost 7.1 million, that is, 4.6 % of coastal population could be directly affected. The most vulnerable areas along the Indian coastline are the Kutch region of Gujarat, Mumbai and South Kerala, deltas of rivers Ganges (West Bengal), Cauvery (TamilNadu), Krishna and Godavari (Andhra Pradesh), Mahanadi (Orissa) and also the islands of Lakshadweep Archipelago which could be totally lost. Vulnerability of the region should not be assessed only in terms of physical exposure to sea level rise but also in terms of the level of socio-economic development of that region measured by variables like population density, land use, level of infrastructure and other investments. From a purely physical point of view, Gujarat and West Bengal would be most affected since they stand to lose the maximum land area to one-meter sea level rise. In terms of population, West Bengal, Maharashtra and Tamil Nadu would be the worst affected because of their high population density. In terms of the fractional area, Goa would be most affected, as it would lose almost 4.34 % of its total area.

In India, climate change could represent additional pressure on ecological and socio-economic systems that are already under stress due to rapid urbanisation, industrialisation, and economic development. With its huge and growing population, a 7500-km long densely populated and low-lying coastline, and an economy that is closely tied to its natural resource base, India is considerably vulnerable to the impacts of climate change. Most countries in temperate and tropical Asia have already felt the impact of extreme climate events through such as droughts and floods. The intensity of extreme rainfall events is projected to be higher in the warmer atmosphere, suggesting a decrease in the return periods for extreme precipitation events and the possibility of more frequent flash floods in parts of India, Nepal, and Bangladesh.

Severe storms, floods and droughts since the eighties have served as reminders that climate change is a global problem. The most dramatic change has been in temperature, with measurement records suggesting that warming by 0.3-0.6°C has already taken place since the 1860s. The last two decades of the 20th century were the warmest in the period. Over the next hundred years, the earth's surface temperature is projected to increase by 1.4 to 5.8°C which will be greater than that experienced over the last 10,000 years.

12.4 EXPERIENCE OF FLOODS IN INDIA

Flood is one of the most devastating natural calamities, which has been the cause of extensive damage to life and property in India. Since flood is a natural phenomenon, it is usually difficult to predict a definite trend, especially with regard to the time and place of its occurrence. The flood hazard strikes with varying degrees of intensity and severity. Any natural hazard becomes a disaster when it comes in contact with vulnerable social settings of human population. Human settlements, structures and centers of economic activity increase the damage caused by disasters. Land use occupants and anthropogenic activities cannot be moved away from disaster prone areas as the human population in India; particularly the poor are dependent on such regions.

Natural disasters in India have ranged from rampaging floods, when rivers have sought to extend their watery grip over large land areas, to scorching droughts, which have left in their wake festering sores upon once fertile lands. Floods, however, have visited the country more frequently. The twin calamities of flood and drought, both natural and man-made have been laying waste vast stretches of fertile land, turning free-flowing rivers into swamps, bringing misery to millions of people, killing livestock, and draining dry the exchequer year after year with unfailing regularity. Since the 1950s, when construction of large-scale dams and embankments was initiated, the severity and extent of floods has risen sharply. The most flood-affected country after Bangladesh, India accounted for 20 percent of the global flood fatalities from the 1960s to the 1990s. Over half a million people died in floods during 1953-87, averaging 1500 deaths annually. In the 50s, annual flood damages were estimated at rupees 600 million a year which affected 6.4 million-hectare (mha) land; in the eighties, the corresponding figures were rupees 231 billion and 9mha. Average flood affected population per year increased from about 16 million in the fifties to 43 million in the seventies and 53 million in the eighties, a growth faster than India's population increase. Floods and droughts are considered endemic and government endeavor in flood management and relief is mired in apathy and complacency.

While floods are a phenomenon older than the cities that exist on banks of rivers in the Indo-Gangetic plain and the art of flood control is an ancient one in India, large-scale measures to control floods were only taken after independence and that too, after the floods in Bihar in 1954.

Floods, which are often described as natural disasters, turn out to be social disasters as well, tending to choose their victims by class. It is usually the poor who are severely affected because they live on the periphery of human habitat. An event, which would not result in the loss of many lives in the affluent North, often results in a major disaster when it takes place in a country in the South. One disaster makes the poor more vulnerable to the next and, in this way, converts a disaster into a disaster process.

The most clinching evidence of floods having increased as a physical phenomenon comes from the increase in flood- affected area. The flood-affected area increased from an annual average of 6.48 mha in the 1950s to over nine mha in the 1970s and 1980s. This increase is definitely an indication of the country's growing flood-proneness.

To cite a recent report, As per *The Event India- Orissa Super Cyclone, Situation Report 8,* the Northern States of Assam and Bihar were affected by severe flooding which struck around mid June in 2004.Over 3 million people were affected in these two states with more than 900 killed in the disaster. At the height of the flooding, approximately

1.3 million people were forced to take refuge in relief camps while many others fled to temporary accommodations. Over half of Bihar's districts were inundated by floodwaters while all the 27 districts of Assam were affected. Communication was badly affected As per UNDP assessment about 60% of crops has been destroyed affecting nearly 1.2 million farming families and 1.15 million hectares. Nearly 600,000 families dwellings have been damaged or destroyed further flooding is expected.

The Rashtriya Barh Ayog (RBA) or National Commission of Floods set up by the government in 1976, because of the growing public concern over increasing floods first provided statistical evidence of the problem. The commission took the maximum area affected by floods in the state in any year as its flood-prone area and added up the flood prone areas of all the states to calculate the flood prone area of the country. This method underestimates the problem because there is no guarantee that floods in any year will affect only those areas, which were affected during the maximum flood year. Yet the commission found that the country's flood-prone area, which had been estimated at about 25 mha during the 1960, went up to 34 mha by 1978. Since 10 mha had been covered by flood protection measures by then, it is well known that these measures often fail during high floods. The commission put the country's flood prone area at about 40 mha. This report thus, revealed a rapid increase in flood proneness in just over a decade.

The most flood prone basins were identified as the Ganga and the Brahmaputra in Uttar Pradesh, Bihar, West Bengal and Assam, followed by Baitarni, Brahmani and Subarnarekha basins in Orissa. The commission, analysing flood damages in the late 1970s, pointed out that during the period 1976-78, floods were also experienced "in Andhra Pradesh. The share of damages went up in from around 20-25% to about 50 % of the total. Even in the chronically flood prone states of Uttar Pradesh and Bihar, the flood-affected area has been increasing.

The commission did not find any evidence to show that rainfall had increased during the 1970s. The commission, therefore, felt that floods had increased more because of human factors like deforestation; drainage congestion caused by badly planned construction of bridges, roads, railway tracks and other developmental activities; reduction industries and large-scale urbanisation and construction of embankments along rivers. Apart from inflation, damages increased because of the increased flood incidence and encroachment of flood plains.

12.5 EXPERIENCE OF VOLCANIC ERUPTIONS IN INDIA

Volcanoes are vents or fissures in the earth's crust through which gases, molten rock, or lava, and solid fragments are discharged. Their study is called Volcanology. Volcanism is the name given to the processes and phenomena associated with the surface discharge of such material from volcanoes, geysers, and fumaroles. The term volcano is commonly applied both to the vent and to the conical mountain (cone) built up around the vent by the erupted rock materials.

Volcanoes are described as *active, dormant, or extinct.* The soil resulting from decomposition of volcanic materials is extremely fertile, and the ash itself is a good polishing and cleansing agent.

Active volcanoes are not scattered over the Earth randomly; instead, most occur in belts, especially in the island arcs and mountain ranges bordering the Pacific Ocean. The concept of seafloor spreading and, more broadly, the theory of plate tectonics offer a logical explanation for the location of most volcanoes.

When a volcano erupts it throws out large volumes of sulphur dioxide (SO_2), water vapour, dust, and ash into the atmosphere. Although the volcanic activity may last only a few days, yet the large volumes of gases and ash can influence climatic patterns over years. Millions of tonnes of sulphur dioxide gas can reach the upper levels of the atmosphere (called the stratosphere) from a major eruption. The gases and dust particles partially block the incoming rays of the sun, leading to cooling. Sulphur dioxide combines with water to form tiny droplets of sulphuric acid. These droplets are so small that many of them can stay aloft for several years. They are efficient reflectors of sunlight, and screen the ground from some of the energy that it would ordinarily receive from the sun. Winds in the upper levels of the atmosphere, called the stratosphere, carry the aerosols rapidly around the globe in either an easterly or westerly direction. Movement of aerosols north and south is always much slower. This should give you some idea of the ways by which cooling can be brought about for a few years after a major volcanic eruption.

Volcanic eruptions are characterised by *pyroclastic surges*, which are a special type of pyroclastic flow, which are more dilute, turbulent and mobile but still contain gas and rock debris. Violent explosions, early in eruption or near the vent, generate them. Speeds over 360 km/h have been measured (Moore, 1967; Fisher, 1979; Wilson and Head, 1981). Due to their lower density and greater speed, surges are better able to overtop topographic barriers and cross bodies of water than pyroclastic flows. Surges are extremely destructive.

Lava flows are among the least hazardous processes associated with a volcanic eruption because they are usually slower and affect smaller areas than explosive eruptions. However, if they occur near populated areas they can be destructive. High-silica compositions (dacites, rhyolites) tend to form thick (50-500m) lobes or domes due to their high viscosity and eruption conditions (Stasiuk and Jaupart, 1997).

Catastrophic landslides may remove portions of volcanoes. If the collapse is associated with a volcanic eruption, it can cause a larger magnitude eruption than would otherwise be expected, due to sudden depressurisation. This was the case in the May 18, 1980 eruption of Mount St. Helens, where the landslide triggered a violent laterally directed blast (Voight et al, 1981). Steepened slope due to ground deformation heightened steam venting and sustained shaking due to shallow seismicity favour landslides associated with eruption.

A *lahar* is an Indonesian word for mudflow, which is a slurry of water and dominantly volcanic rock particles generated on volcanoes during or associated with volcanic eruptions (Cas and Wright, 1988). The suspended particles, if dominantly fine material such as volcanic ash, lead to viscous mudflows that behave like wet concrete. *Lahars* commonly suspend a broad range of particle sizes, from ash up to blocks as large as houses, and are more generally described as volcanic debris flows. If the source material for the debris flow is young, still hot material, the flow may be dangerously hot. Volcanic debris flows are extremely destructive, but are confined to valleys. They are most common and most voluminous as a result of eruption on snow or ice-clad volcanoes.

Debris flows pose a significant secondary volcanic hazard as they can occur days, weeks or years following an eruption. Vast areas may be covered by unconsolidated tephra, which is easily remobilised by rainfall or rapid snow/ice melting. Debris flows of comparable volumes generated in volcanic materials appear to have much longer run-off distances than those generated in non-volcanic materials, apparently because of a greater percentage of fine particles (Jordan, 1990). Jordan recorded many large postglacial debris flows unrelated to eruptions at Mt. Meager that nevertheless originated from the volcano's deposits. Those debris flows can be considered secondary volcanic hazards. Debris flows move large amounts of sediment into drainages and hence lead to secondary flooding and river aggradations.

Volcanoes produce large quantities of gases, mostly H_2O, but also significant amounts of CO_2, CO, SO_2, HF, and Cl and N compounds (Thorarinsson, 1979; Baxter, et al., 1982 and Baxter, 1992). Loss of life and damage has been attributed to each of these gases, such as SO_2 from Laki.

Mount Pinatoba, in the Philippine islands erupted in April 1991 emitting thousands of tonnes of gases into the atmosphere. Volcanic eruptions of this magnitude can reduce the amount of solar radiation reaching the Earth's surface, lowering temperatures in the lower levels of the atmosphere (called the troposphere), and changing atmospheric circulation patterns. The extent to which this occurs is an ongoing debate.

Another striking example was in the year 1816, often referred to as "the year without a summer" with significant weather-related disruptions occurred in New England and in Western Europe with killing summer frosts in the United States and Canada. These strange phenomena were attributed to a major eruption of the Tambora volcano in Indonesia, in 1815.

Volcano in Iceland in 1783 damaged crops and killed livestock and people. Many more died of starvation (Thorarinsson, 1979). SO_2 has produced a number of problems including increasing incidents of acute asthma and bronchitis (Baxteret al., 1982). Fluorine killed and disfigured livestock after the 1845 Hekla eruption and again in 1970 (Thorarinsson, 1979). Acid rain from volcanic clouds can damage crops. In Hawaii, the increasing acidity of water collected in cisterns released heavy metals into drinking water, the long-term health effect of which has not yet been assessed.

When water percolates into rocks heated by nearby magma, or into still hot volcanic deposits, it may be rapidly heated and flash to steam. The accompanying volumetric increase within a confined space can cause violent steam venting, hydrothermal fracturing or sudden, brief pheratic explosions (Sheridan and Wohletz, 1981). These eruptions behave similarly to pyroclastic eruptions but are not associated with the eruption of magma; in fact, the deposits are made up completely of bedrock fragments rather than primary ash and pumice. Phreatic explosions do not produce sustained eruption columns, but they can generate widely dispersed tephra blankets and pyroclastic surges.

A secondary hazard from volcanoes is contamination of ground and surface water. Highly fractured or porous volcanic deposits are more susceptible to weathering by percolating groundwater than most plutonic and metamorphic rocks. In addition, commonly associated acidic thermal spring can chemically leach toxic metals from the rocks, leading to natural pollution in streams (Bortleson, et al., 1977).

12.6 VULNERABILITY OF EARTHQUAKE AND OTHER NATURAL DISASTERS IN THE HIMALAYAN REGION

About 200 million years ago the Himalaya arose from the continental collision of the Eurasian and Indian (Gondwana) tectonic plates floating on the Tethys Sea. While on the Eurasian side, earth's crust thickened and moved up to form the Tibetan plateau, the sub-continental plate sheared off along two major thrust faults, one of which, 2400 km long and 96-192 km wide, is still active.

Plate tectonic studies reveal that the Himalayan mountain ranges were formed when the Indo-Australian plate collided with the Eurasian plate. The Indian subcontinent, once part of a super continent called Gondwanaland, which consisted also of present-day Africa. Australia, Antarctica, broke away about 100 million years ago and crawled northwards across the Tethys Sea before ramming into Asia.

The Indian plate then slid under the Asian landmass. Its upper layers peeled and thrust upward, forming the Himalayan ranges. The Indian plate is still barging into the Asian plate at about 5 cm every year. Seismic studies show that great earthquakes tend to recur in cycles of 200-300 years along the length of the Himalayas. In the past century, Assam (1897-1950), Bihar, Nepal (1934), and Kangra (1905) have witnessed high intensity earthquakes. Kashmir, Uttarakhand, and Nagaland have not had major earthquakes for over 170 years; the fear is that these 'seismic gaps' the building up tremendous stresses.

The series of major earthquakes in the Lesser Himalaya in the last 100 years, all above 8 on the Richter scale, indicate continuous subterranean activity causing severe stress and eventual rupture at several points. One section of this fault, 480-800 km long between the Kangra valley in Himachal Pradesh and the Nepal-Bihar border has not witnessed any major tremor in over three centuries. Tehri dam is located in this Central Himalayan Seismic Gap where the Indian plate is crashing into the Asian mainland at a speed of 2 cm per year.

The stress that is building up here is reaching criticality and scientists predict that when the rupture occurs it is likely to cause an earthquake, or a series of tremors of calamitous proportions. The geological disturbances being created by the construction of the dam may hasten and intensify the catastrophe.

Being brittle and cracked, the rocks lining the walls of Bhagirathi gorge are prone to seepage and the accumulating water may exert immense pressure on the hill slopes. This along with the constantly eroding shale of the riverbed will weaken the dam's foundation, which is said to be lying on a fault. The stress may reach such magnitude that Tehri dam may not be able to with stand the weight of the immense volume of water in its reservoir and collapse, fracturing the ground and triggering a quake. In that event over 3 billion cubic meter water will burst over, obliterating the pilgrim towns of Haridwar and Rishikesh and their 200,000 inhabitants. Towns and villages on the banks of Ganga will be inundated, affecting 100-200 million people in the hills and plains.

On October 20, 1991, an earthquake of Richter magnitude 6.1 struck Garhwal, killing hundreds and causing irreparable damage to land and property. The natural ecosystems the Himalaya are extremely fragile. Soils are susceptible to erosion; rainfall is highly inconsistent, with considerable seasonal and annual fluctuations. Recent environmental stresses, such as deforestation, erosion, landslides, all increase the risks for the poor and vulnerable.

12.7 EXPERIENCE OF EARTHQUAKES AND LANDSLIDES IN INDIA

12.7.1 Gujarat Earthquake: Vulnerability Experience

21 of the total 25 districts of Gujarat were affected in the devastating earthquake of 6.9 magnitudes on the Richter scale on January 26, 2001. Around 18 towns and 182 talukas in the affected districts saw large-scale destruction. The effect was particularly severe in the Kutch district, where its four major urban centres of Bhuj, Anjar, Bachau and Ropar suffered near-total destruction. Urban areas of Gandhidham, Morvi, Rajkot, Jamnagar and the state capital of Ahmedabad suffered extensive damage. While earlier moderate earthquakes, which have struck the country since 1988 consistently demonstrated the vulnerability of rural constructions, this event is significant in that it illustrated the failure of engineered structures to withstand the quake. The collapse of modern RCC frame buildings and damage to dams, bridges and industrial facilities serve to portray the need for strict adherence of building codes and vulnerability studies before construction.

12.7.2 South Asia Earthquake: Vulnerability Experience

On the eighth day of October 2005, an earthquake with a magnitude of 7.4 on the Richter scale, with epic center in Muzaffarabad, about 95 kilometers of Islamabad, rocked many parts of Pakistan, India and Afghanistan. It has killed a lot many people and flattened several areas. It was stated that the new mega-fractures developing across the Himalayan region were responsible for the earthquake. As per the Director, Geological Survey of India, " The quake was caused due to adjustments in the earth's crust resulting from the fractures. Seismicity in the Himalayas was shifting from the north to the south and areas south of the ranges were now more vulnerable. As a result, the foothills of the Himalayas and Indo-Gangetic areas were developing into quake-prone zones"(The Times of India, October 9, 2005).

As observed by the USGS Earthquake Hazard Programme (2005), "Earthquakes and active faults in northern Pakistan and adjacent parts of India and Afghanistan are the direct result of the Indian subcontinent moving northward at a rate of about 40 mm/yr (1.6 inches/yr) and colliding with the Eurasian continent. This collision is causing uplift that produces the highest mountain peaks in the world including the Himalayan, the Karakoram, the Pamir and the Hindu Kush ranges. As the Indian plate moves northward, it is being sub ducted or pushed beneath the Eurasian plate. Much of the compressional motion between these two colliding plates has been and continues to be accommodated by slip on a suite of major thrust faults that are at the Earth's surface in the foothills of the mountains and dip northward beneath the ranges. These include the Main Frontal thrust, the Main Central thrust, the Main boundary thrust, and the Main Mantle thrust. These thrust faults have a sinuous trace as they arc across the foothills in northern India and into northern Pakistan. In detail, the modern active faults are actually a system of faults comprised of a number of individual fault traces. In the rugged mountainous terrain, it is difficult to identify and map all of the individual thrust faults, but the overall tectonic style of the modern deformation is clear in the area of the earthquake; north- and northeast-directed compression is producing thrust faulting. Near the town of Muzaffarabad, about

10 km southwest of the earthquake epicenter, active thrust faults that strike northwest-southeast have deformed and warped Pleistocene alluvial-fan surfaces into anticline ridges. The strike and dip direction of these thrust faults is compatible with the style of faulting indicated by the focal mechanism from the nearby M 7.6 earthquake".

It calls for more proactive structural and non-structural measures to be initiated for identification of more vulnerable areas, people and infrastructures.

12.7.3 Landslides

The frequent occurrence of landslides both in space and time undoubtedly makes it most widely occurring environmental hazard. The complex geologic set up with contemporary crystal adjustments of Indian plates, the mountain and hill ranges of Northeast India is seismically very unstable and highly vulnerable to landslide. With the growing development activities in the rugged topography of north- east (N.E) India characterised by steep slope with highly weathered, fractured and folded rocks, low strength of soil materials, heavy rainfall and frequent occurrence of earthquake ranging between 2-6 in Richter scale are the basic factors of landslide.

Being the youngest mountain range in the world, the Himalaya is made up of glacial rocks and loose soils. Its slopes, therefore, easily give way whenever the hills are lashed with heavy snow and rain. Avalanches and landslides bring down hundreds of tonnes of moraine and boulders blocking roads and cutting off supplies, choking streams and rivers and inducing flashfloods, strike the middle and lower reaches of the mountains time and again. Their frequency and intensity have gone up with increasing deforestation, quarrying and dam construction. The poor and simple hill-dwellers have to bear the major burden of such 'human-made' natural disasters.

Due to strategic as well as commercial reasons, human venturing in snow bound regions of the western Himalayas has multiplied manifold in recent times. Many new routes have been opened and habitation areas have spread out deep into mountains. With this exodus has also increased the vulnerability of mankind to avalanche threat.

12.7.4 Increasing Vulnerability to Earthquakes

Massive tremor rocked Uttarkashi and the surrounding Himalayan Hills on October 20, 1991. The 6.6- Richter quake, which left behind a trail of death and destruction, was a highly localised burst of energy, indicating the potential of geological instability of the region. The quake was likely to have been prompted by three days of torrential rain and the accompanying landslides and flashfloods in several areas. The morning after quake, the river Bhagirathi had run dry because one of its tributaries was blocked by a rockslide, but timely natural clearance averted a major catastrophe. Deforestation, hydel power projects and terrace agriculture have considerably increased the vulnerability of the fragile Himalayan geology.

As mega-projects continue to interface with geology, earthquakes have increased in frequency and more areas are turning quake-prone. Political expediency and the contractor lobby usually dictate relief and rehabilitation in the aftermath of a quake. The scheme to rebuild houses for the victims of the earthquake that devastated Latur in the Marathwada region of Maharashtra in 1993 has turned out to be a farce. The state government's white paper on rehabilitation emphasised the restoration of property with active involvement of the local people and in line with their functional needs.

During the last three decades newly developed settlement are widely scattered on the hill slope of Guwahati city. Rapid growth of settlement on the hill slope plays manifold adverse effect on the slope. Although the actual cause of instability may vary in different parts of the city, basic causes of instability of slope are toe cutting, constructions of heavy structures on steep slope, deforestation etc. The study revealed that areas situated above 25° slope are badly affected due to human interference.

12.8 EXPERIENCES OF DROUGHT AND DESERTIFICATION IN INDIA

In India, the purely meteorological phenomenon of dry spell has been converted into a permanent and pervasive process of desertification in areas around hot tropical arid lands. The trend is not restricted to the fringes of Thar Desert but is also penetrating into the vast hinterland between the Ganga and the Indus river basins as well as across the central Deccan Plateau. Developmental activities, risky and faulty agricultural practices, ground water mining have only added to population and livestock pressures in ruining the biological productivity of land and making it vulnerable to drought and desertification. Water logging, salinity and industrial effluents have hastened the process. Nearly 33 percent of western Rajasthan has been turned into an arid landscape and more are being encroached by the expanding sand dunes of Thar.

12.8.1 Vulnerability due to Desert Landscape in Rajasthan

The dream of transforming the desolate landscape of Thar Desert in western Rajasthan into a verdant expanse has turned out to be a nightmare. The Indira Gandhi Canal, the world’s longest reached the tail end of its 649 km run in 1987 after a 35-year long engineering feat. Today, indiscriminate use of the canal’s waters for irrigation has turned vast stretches of Ganganagar and Bikaner districts into waterlogged, saline wastelands, besides being vulnerable to annual floods over the past few years. Equally tragic is the silent threat to the 300 species of endemic desert birds, including the great Indian bustard, and a healthy population of gazelles and reptiles. Also at stake are the grasslands providing arid sustenance to the nomadic Bishnoi tribes.

12.9 OTHER NATURAL VULNERABILITIES

In the coastal regions of Tamil Nadu, salinity of groundwater due to the intrusion of seawater into the subsurface aquifer is a major problem. Due to excess withdrawal of ground water, the water table has fallen too far below thereby allowing seawater to percolate. Similarly, in Gujarat, due to uncontrolled withdrawal of groundwater, it is becoming highly saline, apart from the depth of the water table, reaching at places, beyond 200 meters. Coastal aquifer system will be more contaminated with salinity bringing greater complicacy to the problem of tapping usable groundwater (Mohanty, 1990). In coastal regions of West Bengal and Orissa, the problem of fresh water is fairly acute because of the depth of water table and high cost of lifting the same from the depth of 700-1000 meters. The shallow salt water table often renders stored water in ditches and ponds brackish and surface soil saline. In view of this, only one kharif crop is possible. Tidal ingress and pushing up of saline waters inland may extend by 35-50 kms beyond the present limit and during storm conditions, the spread of salinity in the low-lying agricultural lands may ruin the prospect of good crops.

The people living in the coastal regions of India are highly vulnerable to natural hazards such as cyclones and man-made hazards like water pollution. The natural hazard takes million of lives, damage properties and natural resources in coastal areas. In spite of cyclone warning systems, a recent cyclone and studied above, killed over 10,000 people in Orissa states and millions of people became vulnerable. About half of the Indian boundary is surrounded by ocean and approximately 40% of total population lives within the100 km ocean coast.

Bounded by the highest mountain range in the world and tropical seas, and sitting on an active continental plate, India is particularly vulnerable to climatic fluctuation and tectonic movements. People on the Bay of Bengal coast, mainly in Andhra Pradesh and Orissa, live with the fear of devastating cyclones that have been taking an immense toll on life and crop year after year; those inhabiting the geologically volatile Himalayan slopes in the north and northeast are in constant danger of avalanches, landslides, flashfloods and violent earthquakes; and millions in the vast Ganga-Brahmaputra plains have to cope with the perennial problems of extensive floods and river erosion, even as the Thar desert in the west moves eastwards to encroach on the mainland. Large-scale deforestation, construction of mega-dams, poor river constructions and planning and destruction of coastal ecology have magnified the extent of disasters and intensified their destructive potential. There are only stopgap measures that are always inadequate, in the event of a calamity, and there is little in the way of either long-term solutions or a disaster-management policy. Inevitably, the poor are the worst victims of natural catastrophes.

The river Ganga originates in the Himalaya, and is fed by several glaciers. The Gangotri is the longest of these, at 26 km, but there are hundreds of smaller ones, too. One of these is the Dokriani Bamak, which is 5 km long and has a permanent research station at its base. Scientists studying this glacier have found that it has been retreating at a rate of 20 mt. a year compared to about 16 m per year in the past.

If the present trend continues, over the next twenty years, the Ganga could initially swell in volume because of increased melting but then dry out as the water supply in the mountains runs low. This will endanger the lives of about 400 million people who live in the river's plains and depend upon it for their supply of water.

12.10 INTER-CONTINENTAL ASSESSMENT OF VULNERABILITY

Highest incidence of hydro-meteorological disasters is seen almost across all continents. Floods are the most commonly reported natural disasters in Africa, Asia, Europe, while windstorms are most common in the Americas and Oceania. Transport accidents are even more common accounting for 49% of all technical disasters in Africa, 31% in Asia, and 26 % in Europe. Earthquakes, floods, windstorms, show high incidence as compared to other continents. Even figures for Asia show high incidence of disasters and impact of such events on human life. A corresponding classification between (HHD), (MHD) and LHD) has been attempted in the World Disasters Report (2004). While fatalities from transport accidents and technical disasters have gone up, low-income countries reported less disasters. Among recorded disasters, drought and famines remained the major killers in low-income developed nations. Both hydro-meteorological disasters and geological disasters besides transport accident have become more common, becoming respectively 68% and 62% more frequent over the last decade. Among natural disasters floods are more common in Africa, Asia and Europe, while windstorms are the most common event in Africa, Asia and Europe, while windstorms are the most reported disasters in the Americas and Oceania. However because of the better forecasting and warning systems less people have died from hydro-meteorological disasters. Rapid increase in population and climate change are causing more exposure to hazards in low-income developed countries. It would be pertinent to cite the World Disaster Report (2004), which illustrates continent wide susceptibilities to hazards.

Total number of reported disasters by type of continent and by the type of phenomenon (1994-2003) is given below as referenced from the World Disasters Report, 2004.

	Africa	**Americas**	**Asia**	**Europe**	**Oc**
Avalanches And Landslides	12	42	105	19	8
Droughts and Famines	118	46	86	13	10
Earthquakes	11	47	145	45	9
Extreme Temperatures	7	32	45	61	4
Floods	269	256	411	195	29
Forest/scrub fires	13	66	22	46	11
Volcanic Eruptions	4	25	12	2	6
Windstorms	70	277	307	87	61
OTHER NATURAL DISASTERS	3	5	10	1	2
Total Natural Disasters	507	769	1,143	469	140
Industrial Accidents	39	50	262	73	2
Miscellaneous accidents	75	55	203	61	4
Total Technical Disasters	702	376	1,185	341	18
Total	1,209	1,712	2,328	810	158

HHD-high Human Development

MHD- medium human development countries

LHD- Low Human development

Source: *World Disasters Report, 2004*

12.11 CONCLUSION

Disasters are upsetting events that require adjustment measures to control the impact of a disaster and resume normal life after the initial set back. Science and technology has a major role to play in instituting forecasting and early warning systems and facilitating disaster response. The onus is on the policy makers to integrate disaster planning in policy planning to minimise the impact of disaster. Policy intervention for instance could control global warming. Particularly cyclone threat could be minimised a great deal by effective impetus to scientific research in the country, particularly, placing the specialist in his due position in the decision hierarchy. Flood management is contingent on good district administration. The question is timely response, administrative and political will and effective coordination between agencies involved. Earthquake proofing of structures and site assessment for project location could help in disaster mitigation.

12.12 KEY CONCEPTS

Desertification : Desertification is a process of regions going arid because of deforestation, ground water depletion, and absence of water harvesting techniques.

Global Warming : Rising surface temperature due to green house gas emissions. Chief sources of green houses emissions are coal. Green house gases trap energy from the sun raising sub surface temperature.

Landslides : Soil liquefaction causes surface layers to slide and fall off leading to massive mudflows that sweep whatever comes in the way. Soil Type on mountainous areas vulnerable to earthquakes is soft, grainy and not hard and concrete like as is found otherwise.

Volcanoes : Bursts of lava from beneath the surface of the atmosphere leading to molten lava outflow and massive mud flows. The temperature of these emissions is very high. There are three kinds of volcanoes, active (erupt frequently), dormant (hard to predict since they burst after along time or may nor erupt at all), and extinct (inactive) Soil is fertile around volcano regions, it is also an attractive tourist destination.

12.13 REFEFRENCES AND FURTHER READING

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12.14 ACTIVITIES

1) India is vulnerable to natural disasters of potentially serious magnitude. In the light of this statement, write notes on the following:

   a) Experiences of Cyclones;

   b) Experience of Floods;

   c) Experience of Landslides; and

   d) Experience of Earthquakes.