CHAPTER-2

Theoretical Orientation

The starting of 21st century has already seen several harbingers of a troubled future due to climate change and its disastrous effects on global food security and livelihood, where ecological catastrophe brought about by climate change will be inevitable. India is now confronted with the challenge of sustaining rapid economic growth, burgeoning population demand, nutritional security and the most important the increasing threat of climate change. In India more than 56% of work force engaged in agriculture and allied sectors related with agriculture, while many others earn their living in coastal areas tourism and fishing, indeed most of the poor and marginalized sectors living in rural areas reliant on natural resources for their food and shelter (UN Human Development Report 2007/8) will be affected most.

2.1 Climate change:

Climate change' means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC 1994).

For this research purpose definition given by Intergovernmental Panel for Climate Change (IPCC) has been used, which defines climate change as a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.

2.1.2 Perception:

As Ban and Hawkins (2000) define perception‘, it is the process by which we receive information or stimuli from our environment and transform it into psychological awareness. It is interesting to see that people infer about a certain situation or phenomenon differently using the same or different sets of information. Knowledge, interest, culture and many other social processes that shape the behavior of an actor who uses the information and tries to influence that particular situation or phenomenon (RECOFTC 2001, Cited by Banjade, 2003).

Saarinen (1976) talks about perception as an extremely complex concept and confines social perception ‘which is concerned with the effects of social and cultural factors on cognitive structuring of our physical and structural environment. This varies with the individual‘s past experiences and present sets or attitudes acting through values, needs, memories, moods, social circumstances, and expectations (Saarinen, 1976, Cited by Banjade, 2003).

2.1.3 Food Security:

Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices (World Food Conference of 1974).

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO 1996).

2.1.4 Livelihood:

A person's livelihood refers to their "means of securing the basic necessities -food, water, shelter and clothing- of life". Livelihood is defined as a set of activities, involving securing water, food, fodder, medicine, shelter, clothing and the capacity to acquire above necessities working either individually or as a group by using endowments (both human and material) for meeting the requirements of the self and his/her household on a sustainable basis with dignity (Wikipedia).

2.1.5 Impact:

The effects of climate change on natural and human systems (IPCC, 2007). Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts:

- **Potential impacts**:
  - All impacts that may occur given a projected change in climate, without considering adaptation.
- **Residual impacts**:

The impacts of climate change which would occur after adaptation.

2.1.6 Hazard:

A hazard is a potentially damaging physical event, phenomenon, or human activity that may cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation (ISDR 2004).

2.1.7 Risk:

Risk is the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted, environmental damage) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Conventionally risk is expressed by the notation Risk = Hazards x Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability (ISDR2004).

2.1.8 Vulnerability:

In the context of climate change, vulnerability is the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change, and the variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2007).

2.1.9 Adaptation:

Adaptation to climate change is the adjustment of a system to moderate the impacts of climate change to take advantages of new opportunities or to cope with the consequences (Adger et al. 2003, p 192).

2.1.10 Adaptive capacity:

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (IPCC 2007). Adaptive capacity is shaped among others by available resources, institutions, and skills and knowledge.

2.1.11 Coping strategies:

Coping strategies are short-term actions to ward off immediate risk, rather than to adjust to continuous or permanent threats or changes. Coping strategies usually rely on selling or using up assets and reserves and are often the same set of measures that have been used before. When using coping strategies as a response to stress, it is possible that vulnerability will increase in the long term (ICIMOD 2009).

2.1.12 Maladaptation:

Maladaptation is an action or process that increases vulnerability to climate change-related hazards. Maladaptive actions and processes often include planned development policies and measures that deliver short-term gains or economic benefit but lead to exacerbated vulnerability in the medium to long-term (UNDP 2011).

2.1.13 Mitigation:

In the context of climate change, mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (UNFCCC 2011).

2.1.14 Resilience:

Resilience is the ability of a social-ecological system to absorb disturbances without losing its fundamental structure and function (combination of definitions).

2.2 The Climate System:

Earth’s climate is determined by complex interactions between the Sun, oceans, atmosphere, cry sphere, land surface and biosphere. The Sun is the principal driving force for weather and climate. The uneven heating of Earth’s surface (being greater nearer the equator) causes great convection flows in both the atmosphere and oceans, and is thus a major cause of winds and ocean currents.

Five concentric layers of atmosphere surround this planet. The lowest layer (troposphere) extends from ground level to around 10-12 altitude on average. The weather that affects Earth’s surface develops within the troposphere. The next major layer (stratosphere) extends to about 50 km above the surface. The ozone within the stratosphere absorbs most of the sun’s higher energy ultraviolet rays. Above the stratosphere are three more layers: mesosphere, thermosphere and exosphere.

Overall, these five layers of the atmosphere approximately halve the amount of incoming solar radiation that reaches Earth’s surface. In particular, certain "greenhouse “gases, present at trace concentrations in the

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troposphere(and including water vapor, carbon dioxide, nitrous oxide, methane, halocarbons, and ozone), absorb about 17% of the solar energy passing through it. Of the solar energy that reaches Earth's surface, much is absorbed and reradiated as long-wave (infrared) radiation. Some of this outgoing infrared radiation is absorbed by greenhouse gases in the lower atmosphere, which causes further warming of Earth's surface. This raises Earth's temperature by33ºC to its present surface average of 15ºC. This supplementary warming process is called "the greenhouse effect".

2.3 Greenhouse Gases:

Human-induced increases in the atmospheric concentration of GHGs are amplifying the greenhouse effect. In recent times, the great increase in fossil fuel burning, agricultural activity and several other economic activities has greatly augmented greenhouse gas emissions. The atmosphere concentration of carbon dioxide has increased by one-third since the inception of the industrial revolution. Gases that trap heat in the atmosphere are called greenhouse gases. Water vapour is the most abundant greenhouse gas, followed by Carbon- dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons (HCFCs), ozone (O_3), per fluorinated carbons (PFCs), and hydro fluorocarbons (HFCs).

2.3.1 Carbon dioxide (CO2):

Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.

2.3.2 Methane (CH4):

Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.

2.3.3 Nitrous oxide (N2O):

Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.

2.3.4 Fluorinated gases:

Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases")

Fig. 1: Source: Web

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Table 1: Ozone Depleting Substances And Their Ozone-Depletion Potential. Taken directly from the Clean Air Act, as of June 2010.

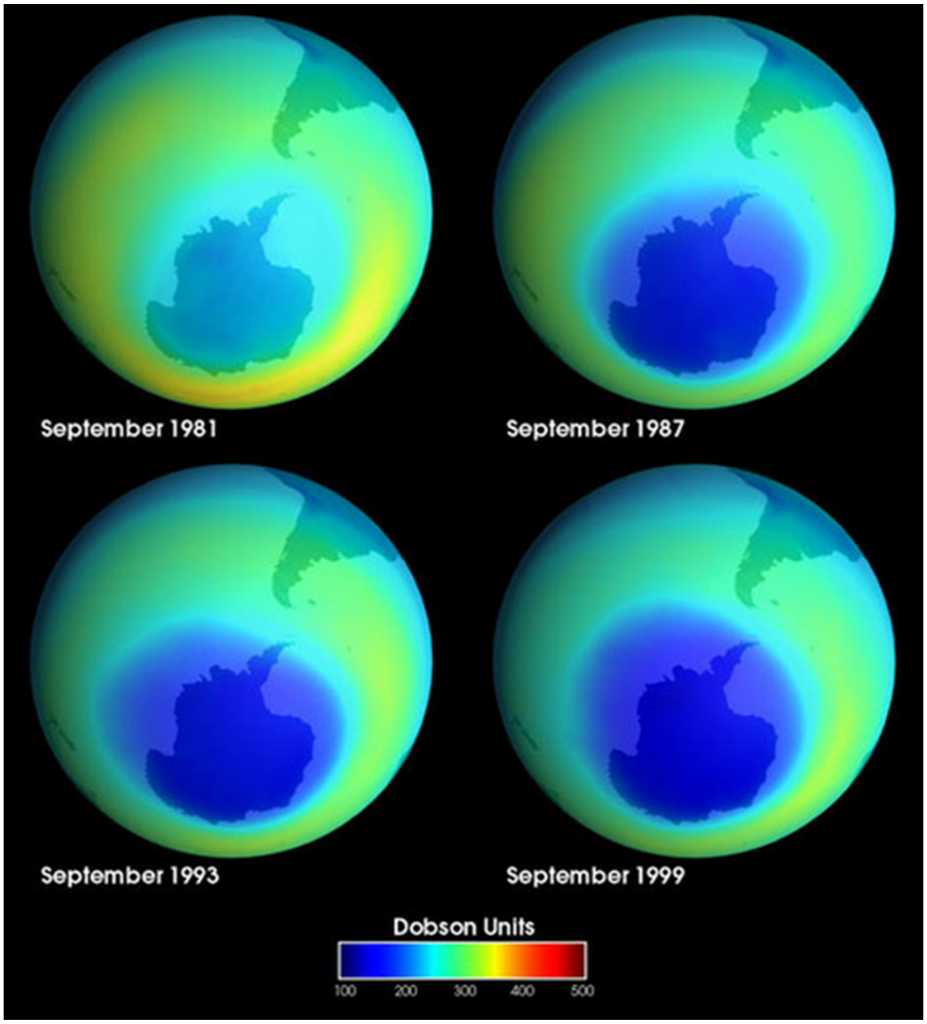
Substance	Ozone- depletion potential
chlorofluorocarbon-11 (CFC–11)	1.0
chlorofluorocarbon-12 (CFC–12)	1.0
chlorofluorocarbon-13 (CFC–13)	1.0
chlorofluorocarbon-111 (CFC–111)	1.0
chlorofluorocarbon-112 (CFC–112)	1.0
chlorofluorocarbon-113 (CFC–113)	0.8
chlorofluorocarbon-114 (CFC–114)	1.0
chlorofluorocarbon-115 (CFC–115)	0.6
chlorofluorocarbon-211 (CFC–211)	1.0
chlorofluorocarbon-212 (CFC–212)	1.0
chlorofluorocarbon-213 (CFC–213)	1.0
chlorofluorocarbon-214 (CFC–214)	1.0
chlorofluorocarbon-215 (CFC–215)	1.0
chlorofluorocarbon-216 (CFC–216)	1.0
chlorofluorocarbon-217 (CFC–217)	1.0
halon-1211	3.0
halon-1301	10.0
halon-2402	6.0
carbon tetrachloride	1.1
methyl chloroform	0.1
hydrochlorofluorocarbon-22 (HCFC–22)	0.05
hydrochlorofluorocarbon-123 (HCFC–123)	0.02
hydrochlorofluorocarbon-124 (HCFC–124)	0.02

Source: The following substances are listed as ozone depleting substances under Title VI of the United State Clean Air Act:

2.4 Depletion of ozone hole:

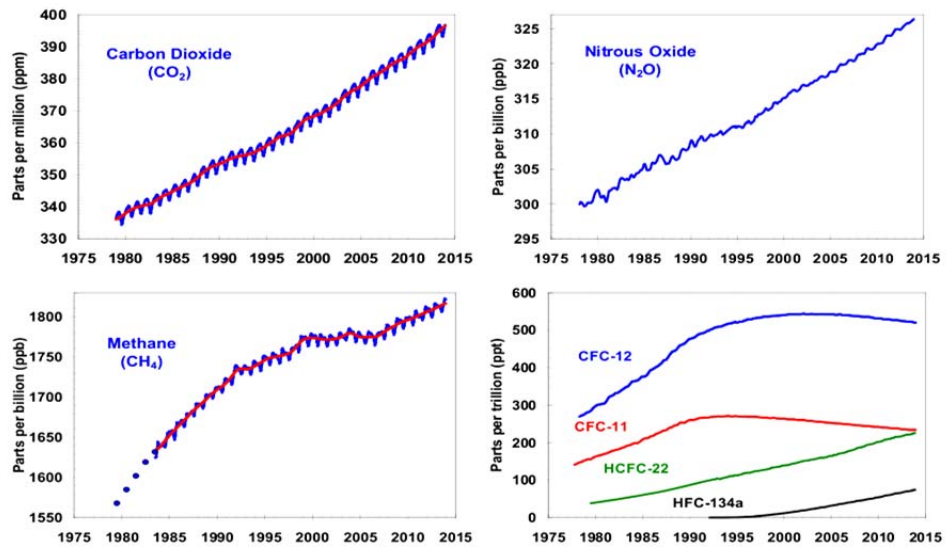
The earth's stratospheric ozone layer plays a critical role in absorbing ultraviolet radiation emitted by the sun. The atmosphere of the Earth is divided into five layers. In order of closest and thickest to farthest and thinnest the layers are listed as follows: troposphere, stratosphere, mesosphere, thermosphere and exosphere. The majority of the ozone in the atmosphere resides in the stratosphere, which extends from six miles above the Earth's surface to 31 miles. Humans rely heavily on the absorption of ultraviolet B rays by the ozone layer because UV-B radiation causes skin cancer and can lead to genetic damage. The ozone layer has historically protected the Earth from the harmful UV rays, although in recent decades this protection has diminished due to stratospheric ozone depletion.

From 1985 to 1988, researchers studying atmospheric properties over the South Pole continually noticed significantly reduced concentrations of ozone directly over the continent of Antarctica. In 1988, researchers finally realized their error and concluded that an enormous hole in the ozone layer had indeed developed over Antarctica. Examination of NASA satellite data later showed that the hole had begun to develop in the mid 1970's Fig. 2: These images from the Total Ozone Mapping Spectrometer (TOMS) show the progressive depletion of ozone over Antarctica from 1979 to 1999. This "ozone hole" has extended to cover an area as large as 10.5 million square miles in September 1998. The previous record of 10.0 million square miles was set in 1996.



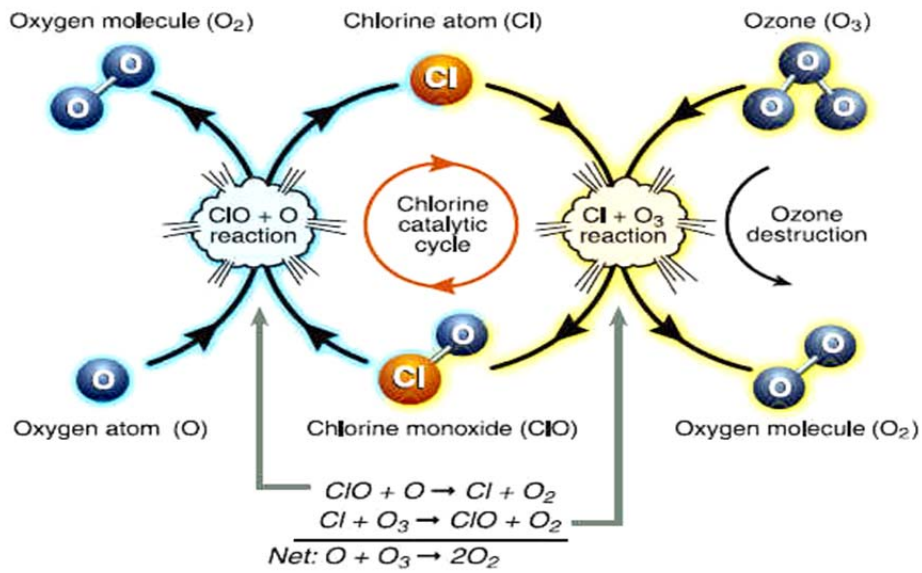
Source: *Fig. courtesy of NASA.*

Graph 1: Major greenhouse gases trend from 1975 to 2015.



Source: *National Oceanic and Atmospheric Administration*

2.4.1 Chemistry of ozone depletion:



(**Source**: Web)

Fig. 3: Ozone destruction cycle (Cycle 1);

Ozone is destroyed by reactions with chlorine, bromine, nitrogen, hydrogen, and oxygen gases. Reactions with these gases typically occur through catalytic processes. A catalytic reaction cycle is a set of chemical reactions which result in the destruction of many ozone molecules while the molecule that started the reaction is reformed to continue the process.

The destruction of ozone in Cycle 1 involves two separate chemical reactions. The net or overall reaction is that of atomic oxygen with ozone, forming two oxygen molecules. The cycle can be considered to begin with either ClO or Cl. When starting with ClO, the first reaction is ClO with O to form Cl. Cl then reacts with (and thereby destroys) ozone and reforms ClO. The cycle then begins again with another reaction of ClO with O. Because Cl or ClO is reformed each time an ozone molecule is destroyed, chlorine is considered a catalyst for ozone destruction. Atomic oxygen (O) is formed when ultraviolet sunlight reacts with ozone and oxygen molecules. Cycle 1 is most important in the stratosphere at tropical and middle latitudes, where ultraviolet sunlight is most intense.

Cycle 2

$$ClO + ClO \rightarrow (ClO)_2$$

$$(ClO)_2 + \text{sunlight} \rightarrow ClOO + Cl$$

$$ClOO \rightarrow Cl + Cl_2$$

$$2(Cl + O_3) \rightarrow ClO + O_2$$

$$\text{Net: } 2O_3 \rightarrow 3O_2$$

Cycle 3

$$ClO + BrO \rightarrow Cl + Br + O_2$$

$$ClO + BrO \rightarrow BrCl + O_2$$

Or

$$BrCl + \text{sunlight} \rightarrow Br + Cl$$

$$Cl + O_3 \rightarrow ClO + O_2$$

$$Br + O_3 \rightarrow BrO + O_2$$

$$\text{Net: } 2O_3 \rightarrow 3O_2$$

Significant destruction of ozone occurs in polar regions because ClO abundances reach large values. In this case, the cycles initiated by the reaction of ClO with another ClO (Cycle 2) efficiently destroy ozone. The net reaction is two ozone molecules forming three oxygen molecules. The reaction of ClO with BrO has two pathways to form the Cl and Br product gases. Ozone destruction Cycles 2 and 3 are catalytic, as illustrated for Cycle 1, because chlorine and bromine gases react and are reformed in each cycle. Sunlight is required to complete each cycle and to help form and maintain ClO abundances.

Chemical equation

$$CFCl_3 + UV \rightarrow CFCl_3 + Cl$$

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O \rightarrow Cl + O_2$$

The free chlorine atom is then free to attack another ozone molecule

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O \rightarrow Cl + O_2$$

and again…

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O \rightarrow Cl + O_2$$

and again…for thousands of time. Because of catalytic reactions, an individual chlorine atom can on average destroy nearly a thousand ozone molecules before it is converted into a form harmless to ozone.

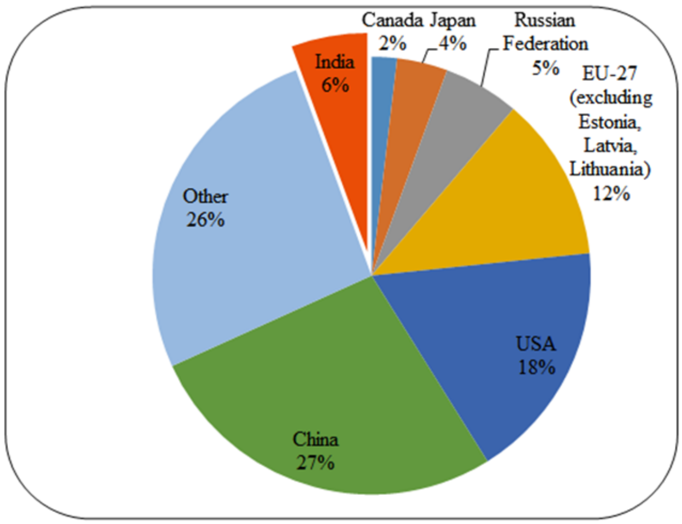


Chart 1: In 2008, the top carbon dioxide (CO_2) emitters were China, the United States, the European Union, India, the Russian Federation, Japan, and Canada. These data include CO_2 emissions from fossil fuel combustion, as well as cement manufacturing and gas flaring.

Source: *IPCC (2007), Climate Change 2007: Mitigation of Climate Change*

Source: *IPCC (2007), Climate Change 2007: Mitigation of Climate Change*

2.4.2 Atmospheric Greenhouse Gas Emissions:

From 10,000 years ago until 250 years ago, atmospheric concentrations of CO_2, CH_4, and N_2O were relatively stable. During the last 250 years, concentrations of CH_4 and N_2O increased 150 percent (%) and 20 percent (%), respectively. Pre-Industrial Revolution, the concentration of CO_2

remained around 280 parts per million (ppm) by volume. By 2013 the concentration had increased to 396 ppm, which is about 2 ppm higher than in 2012. In 2004, total global anthropogenic GHG emissions were 49 Gt(Giga tons = 2.2 billion pounds) CO_2e (IPCC 2007). There is high agreement among international scientists and much evidence that global GHG emissions increased 70percent (%) from 1970 to 2004 (IPCC 2007). Emissions from fossil fuel combustion account for a majority of anthropogenic CO_2 emissions.7 In 2011, global emissions of CO2 from energy use total 32 $GtCO_2$ (U.S. Department of Energy). From 2000 to 2011, global CO_2 emissions from energy use increased 35percent (U.S. Department of Energy). In 2006, China became the world's largest contributor of CO_2 emissions, surpassing the U.S.

Table 2:

Compound	Pre-industrial concentration (ppmv*)	Concentration in 2005 (ppmv)	Atmospheric lifetime (years)	Main human activity source	GWP**
Carbon dioxide (CO_2)	280	379	variable	Fossil fuels, cement production, land use change	1
Methane (CH_4)	0.715	1.774	12	Fossil fuels, rice paddies, waste dumps, livestock	25
Nitrous oxide (N_2O)	0.27	0.319	114	Fertilizers, combustion industrial processes	298
HFC 23 (CHF_3)	0	0.000018	270	Electronics, refrigerants	14,800
HFC 134a (CF_3CH_2F)	0	0.000035	14	Refrigerants	1,430
HFC 152a (CH_3CHF_2)	0	0.0000039	1.4	Industrial processes	124
Perfluoromethane (CF_4)	0.00004	0.00008***	50,000	Aluminum production	7,390
Perfluoroethane (C_2F_6)	0	0.000003***	10,000	Aluminum production	12,200
Sulphur hexafluoride (SF_6)	0	0.0000042***	3,200	Dielectric fluid	22,800

*ppmv = parts per million by volume, **GWP = 100-year global warming potential, ***Concentration in 1998
Water vapor not included in table, see bullet.

Source: *Intergovernmental Panel on Climate Change (IPCC) (2007) Climate Change 2007: The Physical Science Basis. Eds. S. Solomon, et al.; Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*

Sources of Greenhouse Gas Emissions: Anthropogenic CO_2 is emitted primarily from fossil fuel combustion. Cement production and changes in land use, e.g., deforestation, are other significant sources of CO_2 emissions.

- CH_4 and N_2O are emitted from both natural and anthropogenic sources.
- Domestic livestock, landfills, and natural gas systems are the primary anthropogenic sources of CH_4. Agricultural soil management (fertilizer) contributes 75% of anthropogenic N_2O. Other significant sources include mobile and stationary combustion, and livestock.
- Hydrofluorocarbons (HFCs) are now used in refrigeration, cooling, and as solvents in place of ozone depleting chlorofluorocarbons (CFCs).
- Perfluorocarbons (PFCs) are used primarily for aluminum production, and SF_6 is used as an insulator in electricity distribution equipment.

2.5 Causes of climate change

2.5.1 Natural causes

The Earth's climate can be affected by natural factors that are external to the climate system, such as changes in volcanic activity, solar output, and the Earth's orbit around the Sun. Of these, the two factors relevant on timescales of contemporary climate change are changes in volcanic activity and changes in solar radiation. In terms of the Earth's energy balance, these factors primarily influence the amount of incoming energy. Volcanic eruptions are episodic and have relatively short-term effects on climate.

Changes in solar irradiance have contributed to climate trends over the past century but since the Industrial Revolution, the effect of additions of greenhouse gases to the atmosphere has been over 50 times that of changes in the Sun's output.

- Milankovitchtheory predicts ice ages peak every 100,000 and 41,000 years, with additional “blips” every 19,000 –23,000 years. This is based on the amount of sunlight each latitude receives in every phase of the Earth’s orbital variations.
- Changes occurring within the sun can affect the intensity of the sunlight that reaches the Earth's surface. Energy output of the sun varies slightly (0.1%) in an 11 year cycle.
- Volcanoes affect the climate because they can emit aerosols and carbon dioxide into the atmosphere. The eruption of the TamboraVolcano in Indonesia in 1815 lowered global temperatures by as much as 5 ºF and historical accounts in New England describe 1816 as “the year without a summer.”

2.5.2 Human causes

Climate change can also be caused by human activities, such as the burning of fossil fuels and the conversion of land for forestry and agriculture. Since the beginning of the Industrial Revolution, these human influences on the climate system have increased substantially. In addition to other environmental impacts, these activities change the land surface and emit various substances to the atmosphere. These in turn can influence both the amount of incoming energy and the amount of outgoing energy and can have both warming and cooling effects on the climate. The dominant product of fossil fuel combustion is carbon dioxide, a greenhouse gas. The overall effect of human activities since the Industrial Revolution has been a warming effect, driven primarily by emissions of carbon dioxide and enhanced by emissions of other greenhouse gases.

The build-up of greenhouse gases in the atmosphere has led to an enhancement of the natural greenhouse effect. It is this human-induced enhancement of the greenhouse effect that is of concern because ongoing emissions of greenhouse gases have the potential to warm the planet to levels that have never been experienced in the history of human civilization. Such climate change could have far-reaching and/or unpredictable environmental, social, and economic consequences.

2.5.3 Short-lived and long-lived climate forcers

Carbon dioxide is the main cause of human-induced climate change. It has been emitted in vast quantities from the burning of fossil fuels and it is a very long-lived gas, which means it continues to affect the climate system during its long residence time in the atmosphere. However, fossil fuel combustion, industrial processes, agriculture, and forestry-related activities emit other substances that also act as climate forcers. Some, such as nitrous oxide, are long-lived greenhouse gases like carbon dioxide, and so contribute to long-term climate change. Other substances have shorter atmospheric lifetimes because they are removed fairly quickly from the atmosphere. Therefore, their effect on the climate system is similarly short-lived. Together, these short-lived climate forcers are responsible for a

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significant amount of current climate forcing from anthropogenic substances. Some short-lived climate forcers have a climate warming effect (‘positive climate forcers') while others have a cooling effect (‘negative climate forcers').

If atmospheric levels of short-lived climate forcers are continually replenished by ongoing emissions, these continue to exert a climate forcing. However, reducing emissions will quite quickly lead to reduced atmospheric levels of such substances. A number of short-lived climate forcers have climate warming effects and together are the most important contributors to the human enhancement of the greenhouse effect after carbon dioxide. This includes methane and tropospheric ozone – both greenhouse gases – and black carbon, a small solid particle formed from the incomplete combustion of carbon-based fuels (coal, oil and wood for example).

2.6 IPCC Projection:

The IPCC has made the following projections for the next century:

- ❖ Global mean surface temperature will rise by 1.1–6.4°C, depending partly on future trends in energy use. Warming will be greatest over land areas and at high latitudes.
- ❖ Heat waves, heavy precipitation events and other extreme events will become more frequent and intense.
- ❖ Sea level rise is expected to continue at an accelerating rate.
- ❖ Changes in snow, ice and frozen ground have with high confidence increased the number and size of glacial lakes, increased ground

instability in mountain and other permafrost regions and led to changes in some Arctic and Antarctic ecosystems.

- ❖ There is high confidence that some hydrological systems have also been affected through increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers and through effects on thermal structure and water quality of warming rivers and lakes.
- ❖ Climatic changes triggered by global warming can bring in their wake, extreme conditions like abnormal storms, drought and floods, and can cause threat to life. Recent outbreaks of malaria, dengue fever, Hanta virus and similar diseases in the west due to climate change are the consequences of global warming. The incidence of kidney stones is likely to go up and so are many other conditions. The long-term serious consequence to human health is likely to threaten our very existence on this planet. Warm temperatures will aggravate air and water pollution and pose health hazards. Some researchers predict algal blooms to occur, especially in polluted sea waters and cause infectious diseases like cholera.

2.7 The future impacts of climate change identified by the Government of India’s National Communications (NATCOMs) in 2004 include:

- ❖ Decreased snow cover, affecting snow-fed and glacial systems such as the Ganges and Brahmaputra. Erratic monsoon with serious effects on rain-fed agriculture, peninsular rivers, water and power supply.
- ❖ Drop in wheat production by 4–5 million tonnes, with even a 1ºC rise in temperature.

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- ❖ Rising sea levels causing displacement along the most densely populated coastlines in the world, threatening fresh water sources and mangrove ecosystems.
- ❖ Increased frequency and intensity of floods, increased vulnerability of people in coastal, arid and semi-arid zones of the country.
- ❖ Studies indicate that over 50% of India's forests are likely to experience shift in forest types, adversely impacting associated biodiversity, regional climate dynamics as well as livelihoods based on forest products.

Some of the key predictions, according to the Stern report, of changes over the next 100 years are:

- ❖ Regional climate models suggest 2.5–5°C rises in mean surface temperature. In India, northern India will be warmer.
- ❖ Twenty percent rise in summer monsoon rainfall. Extreme temperatures and precipitations are expected to increase.
- ❖ All states will have increased rainfall except Punjab, Rajasthan, and Tamil Nadu, where it will decrease. Extreme precipitation will increase, particularly along the western coast and west central India.
- ❖ Hydrological cycle is likely to be altered. Drought and flood intensity will increase. Krishna, Narmada, Cauvery and Tapti river basins will experience severe water stress and drought. Mahanadi, Godavari and Brahmaputra will experience floods.
- ❖ Crop yield decreases with temperature and rises with optimal rainfall. Wheat production will be reduced. Rabi crops will be worst hit, which will threaten food security.

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- Economic loss due to temperature rise is estimated between 9% and 25%. Gross domestic product loss may be to the tune of 0.67%.
- 100 cm sea level rise can lead to welfare loss of $1,259 million in India equivalent to 0.36% of gross national product (GNP).
- Frequencies and intensities of tropical cyclones in the Bay of Bengal will increase particularly in the post-monsoon period and flooding will increase in low-lying coastal areas.
- Malaria will continue to be endemic in current malaria-prone states (Orissa, West Bengal and southern parts of Assam). It may shift from the Central Indian region to the south-western coastal states of Maharashtra, Karnataka and Kerala. New regions (Himachal Pradesh, Arunachal Pradesh, Nagaland, Manipur and Mizoram) will become malaria prone and transmission duration will widen in northern and western states and shorten in southern states.
- Other vector-borne diseases such as schistosomiasis, Chaga's disease, sleeping sickness, river blindness and various strains of encephalitis may all change their ranges and patterns of infection in the course of climate change.
- The increase of chloro-fluoro-carbons in the atmosphere, leading to global warming will increase ultraviolet (UV) radiation in the atmosphere, affecting the immune systems and leading to infectious diseases. Susceptibility to important skin infections such as leishmaniasis or leprosy might be increased by greater exposure to UV light. The UV radiation affects the immune system of the skin and hence, there might be an increased number of cases of skin cancer.

Other minor effects are increased incidence of skin disorders, such as prickly heat, ringworm and athlete's foot.

- ❖ In the case of acid rain, water vapours reach the atmosphere, condense and react with atmospheric gases like SO2 and NO2. When it rains, these atmospheric pollutants are deposited on the soil, vegetation, surface water or reservoirs. The deposition ultimately results in damage because of the acidity of the pollutants. Acidic rainwater liberates mercury from the soil, which can hinder brain development during the fetal stage. Fish-eating birds and humans acquire mercury by eating fish with high levels of the metal in them. The fish also ingest microorganisms, which consume mercury released by acid rain in the water. Acid rain also releases aluminum and cadmium. Cadmium can cause kidney disorders while aluminum, on the other hand, causes problems in patients with chronic kidney disease or patients receiving renal replacement therapy. This may cause skeletal and brain damage. It may also cause Alzheimer's and Parkinson's diseases.

Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures

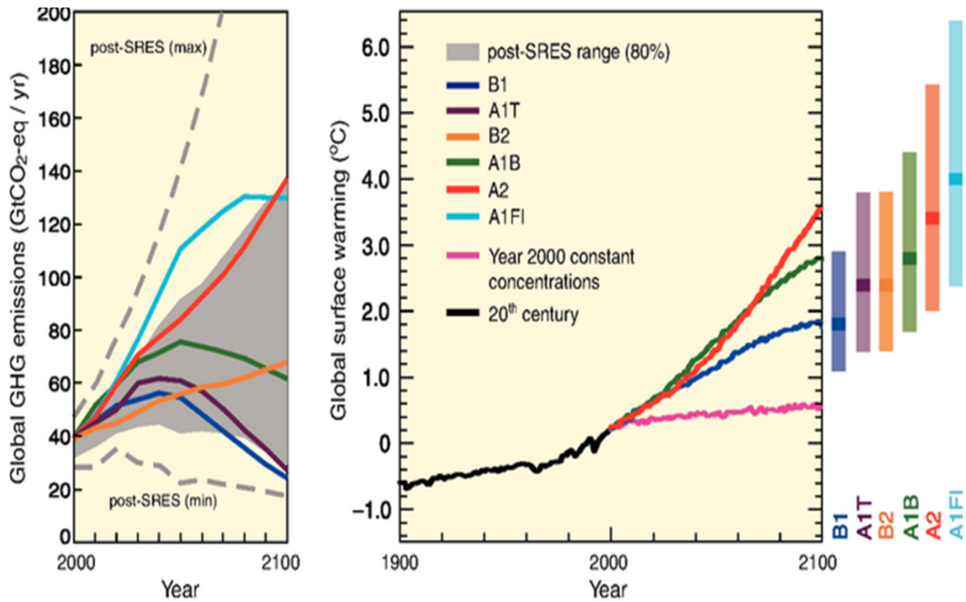

Fig. 4 (Left Panel): Global GHG emissions (in $GtCO_2$-eq) in the absence of climate policies: six illustrative SRES marker scenarios (colored lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. Right Panel: Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the Fig. indicate the best estimate (solid line within

each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999**.**

2.8 Community perceptions on climate change

Farmers are concerned more with the impacts and adaptation to climate change rather than the nature and degree of climate change. Reconstruction of the past by farmers will always be limited to variables which are traditionally quantified, and to a time scale within the range of human memory (Showers, 1996). Farmers can hide or providing inaccurate information (Omiti et al., 1999) and careful cross-checking of responses is required. One can ask farmer to identify climate change or to list changes in their surroundings first and then to identify the causal factors. Majority of Himalayan farmers accept climate change but are unable to measure its rate. They conclude warming based on a trend of a decline:

(i) In area and duration of snow around snow peaks and

(ii) In time and energy put in to clear pathways during snowfall period.

By ‘good climate year’ farmers mean sporadic low rainfall events during March-May, peak monsoon rainfall during July-August, moderate rainfall/heavy snowfall during December-January and absence of cloud burst events, with highest degree of uncertainty attached to the onset of monsoon and time of abnormally high rainfall events. Thus, farmers attach more importance to precipitation than temperature. Farmers feel a trend of decrease in frequency of occurrence of good climate years, with increasing frequency and intensity of abnormally high precipitation events in at elevations more than 1500 m, low precipitation events in 500-1500 m zone and both kinds of abnormalities in the foot hill zone. People believe drought, excessive rainfall/flood, hail storm and cloud burst events as unpredictable and unavoidable events in the hands of supernatural powers.

Prayers and rituals devoted for favorable climates, though undoubtedly superstitious, seem to have fostered evolution of ecosystem management practices and institutions enabling minimal possible damage due to and fast recovery following catastrophic events. Farmers consider climate change a factor not as crucial as other factors in determining spatio-temporal dynamics of ecosystems and livelihoods, suggesting the need of integrating climate change issues with the livelihood issues.

2.9 Impact of Climate Change on Agriculture:

There is no doubt that the 21st century is the age of technology, when we are researching on terrafarming, C_4ness of rice, development of multiple resistant cultivars through MAGIC (multi-parent advanced generation intercross), development of super hybrids, application of GIS/Remote sensing technologies, nanotechnology, crop modeling etc., but still we are neither able to stop the climate change nor even acclimatized with that. Climate which is the main driving force of agriculture is now itself in danger. Climate change effects on agriculture are not a new phenomenon. As early as 1896, the Swedish chemist and Nobel Prize winner Svante Arrhenius published a paper discussing the role of carbon dioxide in the regulation of the global temperature and calculated that a doubling of CO_2 in the atmosphere would trigger a rise of about 5-6^{o}C. According to the complex climate model of 'Intergovernmental Panel on Climate Change' in

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their third assessment report has forecast that global mean surface temperature will rise by $1.4^{o}C$ to $5.8^{o}C$ by the end of 2100.The atmospheric concentration of carbon dioxide (CO_2) has also risen from a preindustrial 280 parts per million to approximately 400 parts per million, and was rising by about 2 parts per million per year during the last decade.

Table 3: Increase in atmospheric concentration of greenhouse gases since pre industrial times

Greenhouse gas	Conc. in 2010	Increase since pre Industrial time
Carbon dioxide	389 ppm	39%
Methane	1808 ppb	158%
Nitrous oxide	323.2 ppb	20%

Source: *WMO, 2013*

There is a combined increase in temperature and CO_2 concentration which has lead to complex behavioral changes in plants physiology and genetic behavior. Due to high temperature, the rate of evaporation from the plant and soil surface become higher, leads to moisture deficit in soil as well as plant bodies. In order to keep cool, plant transpires more and loss more water from its body. For more 'evapotranspiration' plants have to burn more calories, would also suffer from food deficit and sometime may got die. Studies indicate, higher concentration of CO_2 has beneficial effects on certain crops like rice, wheat those are utilizing C_3 pathway, cause more photosynthesis. But CO_2 fertilization effect is by no means save us from the catastrophic effects of climate change. First, the effects is only observed in C_3 plants, not necessarily to the C_4 plants like sugarcane, maize which accounts for one fourth of total crops value. Second, there will be accumulation of non-structural carbohydrate in leaves and other plants organ in the form of starch, soluble carbohydrates or polyfructosans, depending on species which may be the feedback inhibition of photosynthesis. Third, weeds and other undesirable plants will also enjoy this fertilization effects of CO_2, become more vigorous and shift to northward following their 'climatic envelop' as a result of warming temperature. Fourth, this will increase plants WUE (*Water-use-efficiency*), means more dry matter production per unit of water. But, if temperatures rise, however, the increased WUE caused by the CO_2 fertilization effect could be diminished or negated, unless planting dates can be changed to more favorable seasons. The Indian Council of Agricultural Research made a forecast using crop simulation models incorporating future projections. Climate change is projected to reduce timely sown irrigated wheat production by about 6% by 2020. In the case of late sown wheat, the projected levels are alarmingly high, to the extent of 18%. Similarly, a 4% fall in the yield of irrigated rice crop and a 6% fall in rain-fed rice are foreseen by 2020 due to climate changes.

In the Indo-Gangetic plains of South Asia, heat stress is projected to reduce wheat yields by almost 50 per cent (*IPCC 2014, ch24*). Rice production is expected to be affected by the inundation of low-lying areas because of a rise in sea levels. For India, however, there was no change in the mean rice yield projections. The reportquotes the study by Srivastava, Kumar, and Aggarwal (*2010*) for India, which uses the InfoCrop-SORGHUM simulation model to analyze the impact of climate change on sorghum production. The yields of monsoon sorghum are estimated to reduce by 2-14per cent by 2020, worsening further by 2050 and 2080.

Table 4: Impact of climate change in scenarios of temperature increase of 1-3°C on crop

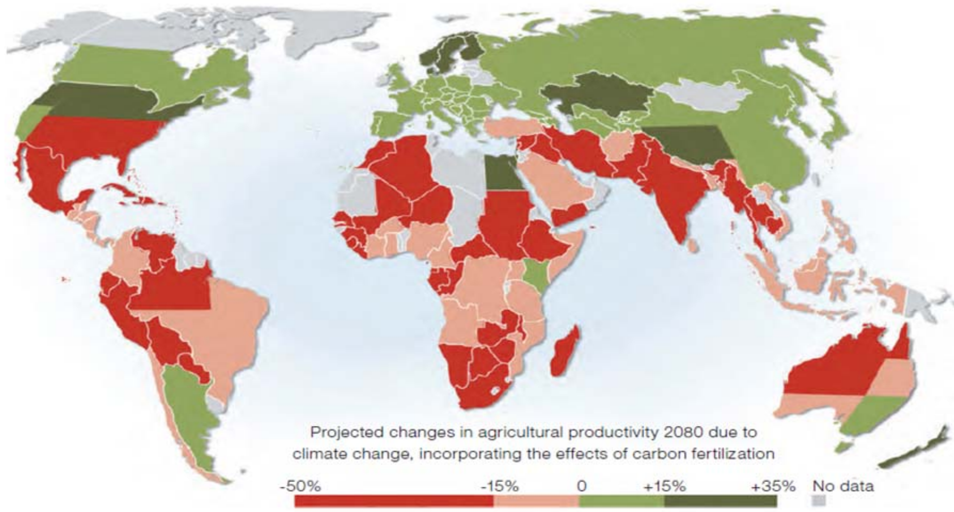
Yields for major crops across regions in per cent

Crop	**Change in crop yields (%)**	**Reference**
Wheat	–10 to –13	(Nelson *et al*. 2010)
Maize	– 4 to – 12	(Nelson *et al*. 2010)
Rice	– 9.5 to –12	(Nelson *et al*. 2010)
Sorghum	–11 to –15	(Knox *et al*. 2012)
Barley	–1 to –8	(Lobell*et al*. 2008)
Millets	–10 to –20	(Knox *et al*. 2012; Ben Mohamed 2011)
Beans	–1.5 to +45	(Thornton *et al*. 2009)
Soybean	–14 to –25	(Travasso*et al*. 2008)
Potato	0 to –5	(Lobell*et al*. 2008)
Oilseeds	–50 to +25	(Kulshreshtha 2011)

Source**:** *Table adapted from IPCC WG-II, AR5*

The Intergovernmental Panel on Climate Change (*IPCC*) has produced several reports that have assessed the scientific literature on climate change. The IPCC Third Assessment Report, published in 2001, concluded that the poorest countries would be hardest hit, with reductions in crop yields in most tropical and sub-tropical regions due to decreased water availability, and new or changed insect pest incidence.

Map 1: Global Worming effects on Agriculture



Source**:** Based on Cline, W. R. 2007. Global Warming and Agriculture: Impact Estimates by Country. Washington D.C.: Peterson Institute

In Africa and Latin America many rainfed crops are near their maximum temperature tolerance, so that yields are likely to fall sharply for even small climate changes; falls in agricultural productivity of up to 30% over the 21st century are projected. Marine life and the fishing industry will also be severely affected in some places.

2.10 Climate change effects on food security:

Many definitions of food security exist and these have been the subject of much debate. As early as 1992, Maxwell and Smith (1992) reviewed over 180 items discussing concepts and definitions, and more definitions have been formulated since (Defra, 2006). While many earlier definitions centered on food production, more recent definitions highlight access to food, in keeping with the 1996 World Food Summit definition (FAO, 1996) that food security is met when ‘all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life’. World-wide attention on food access was given impetus by the food ‘price spike’ in 2007-08, triggered by a complex set of long- and short-term factors (von Braun and Torero, 2009). FAO’s provisional estimates show that, in 2007, 75 million more people were added to the total number of undernourished relative to 2003–2005 (FAO, 2008); other studies report a lower number (Headey and Fan, 2010). More than enough food is currently produced *per capita* to feed the global population, yet about 870million people remained hungry in 2012 (FAO *et al.*, 2012).

2.11 The Current State of Food Security

Most people on the planet currently have enough food to eat. The vast majority of undernourished people live in developing countries *(medium evidence, medium agreement)*, when estimated based on aggregate national calorie availability and assumptions about food distribution and nutritional requirements. More precise estimates are possible with detailed household surveys, which often show higher incidence of food insecurity than estimated by FAO. Using food energy deficit as the measure of food insecurity, Smith et al. (2006) estimated average rates of food insecurity of 59% for 12 African countries, compared to a 39% estimate from FAO for the same period (Smith et al., 2006). While there is *medium evidence, medium agreement* on absolute numbers, there is *robust evidence, high agreement* that Sub-Saharan Africa has the highest proportion of food

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insecure people, with an estimated regional average of 26.8% of the population undernourished in 2010-2012, and where rates over 50% can be found (FAO et al., 2012). The largest numbers of food insecure are found in South Asia, which has roughly 300 million undernourished (FAO *et al.*, 2012. In addition to common measures of calorie availability, food security can be broadened to include nutritional aspects based on the diversity of diet including not only staple foods but also vegetables, fruits, meat, milk, eggs, and fortified foods (FAO, 2011). There is *robust evidence* and *high agreement* that lack of essential micronutrients such as zinc and vitamin A affect hundreds of millions of additional (Lopez *et al.*, 2006; Pinstrup-Andersen, 2009).

Food insecurity is closely tied to poverty; globally about 25 to 30 percent of poor people measured using a $1 to $2 per day standard, live in urban areas (Ravallion *et al.*, 2007; IFAD, 2010). Most poor countries have a larger fraction of people living in rural areas and poverty rates tend to be higher in rural settings (by slight margins in South Asia and Africa, and by large margins in China). In Latin America, poverty is more skewed to urban areas, with roughly two-thirds of the poor in urban areas, a proportion that has been growing in the past decade *(medium evidence, medium agreement).* Rural areas will continue to have the majority of poor people for at least the next few decades, even as population growth is higher in urban areas *(medium evidence, medium agreement)* (Ravallion *et al.*, 2007; IFAD, 2010).

The effects of price volatility are distinct from the effects of gradual price rises, for two main reasons. First, rapid shifts make it difficult for the poor to adjust their activities to favour producing higher value items. Second, increased volatility leads to greater uncertainty about the future, and can dampen willingness to invest scarce resources into productivity enhancing assets, such as fertilizer purchases in the case of farmers or rural infrastructure in the case of governments. Several factors have been found to contribute to increased price volatility: poorly articulated local markets, increased incidence of adverse weather events and greater reliance on production areas with high exposure to such risks, biofuel mandates, and increased links between energy and agricultural markets (World Bank, 2012). Vulnerability to food price volatility depends on the degree to which households and countries are net food purchasers, the level of integration into global, regional and local markets and their relative degree of volatility, which in turn is conditional upon their respective governance (HLPE, 2011; World Bank, 2012) with robust evidence and medium agreement.

2.12 The Climate change effects on livelihood

When people have to move, they need shelter, access to land, water, food and new sources of income. Often, they have lost all their belongings. Loss compensation is thus the cornerstone of starting a new life somewhere else. In this context, the most important measure is to reduce people's risk by providing new sources of income if previous sources have been lost due or partly due to phenomena related to climate change. Development cooperation can help tackle these challenges by assisting local governments and authorities. Therefore, supporting mechanisms in receiving communities – taking into account their own needs – have to be developed.

Girot (2002) quotes Folke *et al*. (2002) to identify three defining features of resilience in integrated human-ecological systems:

1. The amount of disturbance a system can absorb and still remain within the state of domain of attraction;

2. The degree to which the system is capable ofself-organization versus the lack of organization, or organization forces by external factors; and

3. The degree to which the system can build and increase the capacity for learning and adaptation. This reflects a further characteristic of discussions on resilience. It can be risk-specific: for example, the existence of cyclone shelters or the ability of a farming system to withstand drought. Strategies to enhance such specific resilience have been the focus of much attention in adaptation, and tend to take place where the severity of the risk can clearly be identified and the investments in specific adaptations shown to be worthwhile. Resilience can also be general: the ability to withstand the impacts of shocks and trends that disrupt lives and livelihoods. Examples of this are the overall health or economic status of households, the diversity of livelihood sources, access to savings or credit or the existence of strong social networks that are supportive whatever the problem. Targeting improvements to general resilience is likely to be most effective where either demonstrating investments in reducing the threat of specific but unpredictable risks (such as possible changes to future climate in specific places) is difficult or where households and communities face multiple vulnerabilities, including ones not connected with climate or natural resources. In these cases, it may well be more effective to improve overall resilience rather than trying to reduce specific vulnerabilities.

Taken together, the reduction of vulnerabilities and the improvement of resilience of poor people to withstand the impacts of climate change will improve their *securit*y: that is, the extent to which they can live their lives and conduct their livelihoods free from threats. These threats have many forms. They can be to the very lives of people, with the incidence of more climate-related disasters likely to increase in many parts of the world and particularly an issue in tropical regions where most of the world's poor live. Changing climate conditions and rising sea levels are also likely to make many places uninhabitable unless concerted and effective adaptation measures are taken, which could displace many vulnerable people with devastating consequences for their livelihoods and social relations. Climate change and associated ecological changes also pose threats to the viability of many economic and social structures, even where people are not displaced or in serious physical risk. This is particularly true where they will lead to decline in the availability or quality of natural resources such as water or land on which the livelihoods of many poor people are based. This is the ultimate goal of adaptation processes: to provide security to people who face greater threats because of changes to the climate conditions in which they live.

2.31 Climate Change Effects on Biodiversity:

The term 'bio-diversity' was first used by Dasmann in 1968. According to WWF, "Biological diversity or biodiversity the term given to the variety of life on earth. It is the variety within and between all species of plant, animal and microorganism and the ecosystem within which they live and interact".

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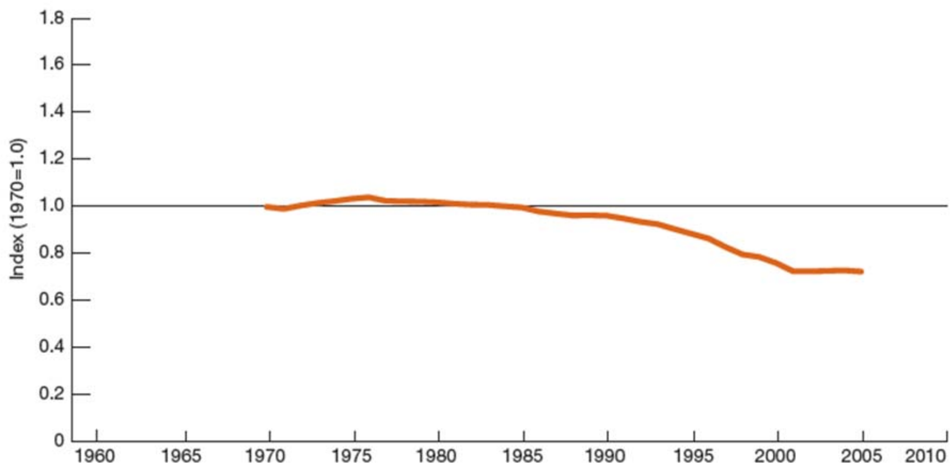
Still now only 1435662 species are identified out of approx. 3 million to 100 million species existed in earth and in India 130000 species documented so far. According to the International Union for Conservation of Nature (IUCN), globally about one third of all known species are threatened with extinction due to climate change which include 21% of all mammals, 29% of all amphibians and 12% of all birds. In India, endemism is estimated at 33% of plant species with about 140 endemic species (*Botanical Survey of India 1983*).

Though the species extinction is a natural phenomenon in the history of earth ecosystem, but with human intervention this rate have increased at least 100 times more than the natural rate. It is estimated approximately about 27000 species become extinct every year and if this situation goes on about 33% of global biodiversity may be extinct within 2050.The Global Living Planet Index, compiled by WWF isdeclined by 27 per cent from 1970 to 2005.

Global Living Planet Index, 1970 to2005



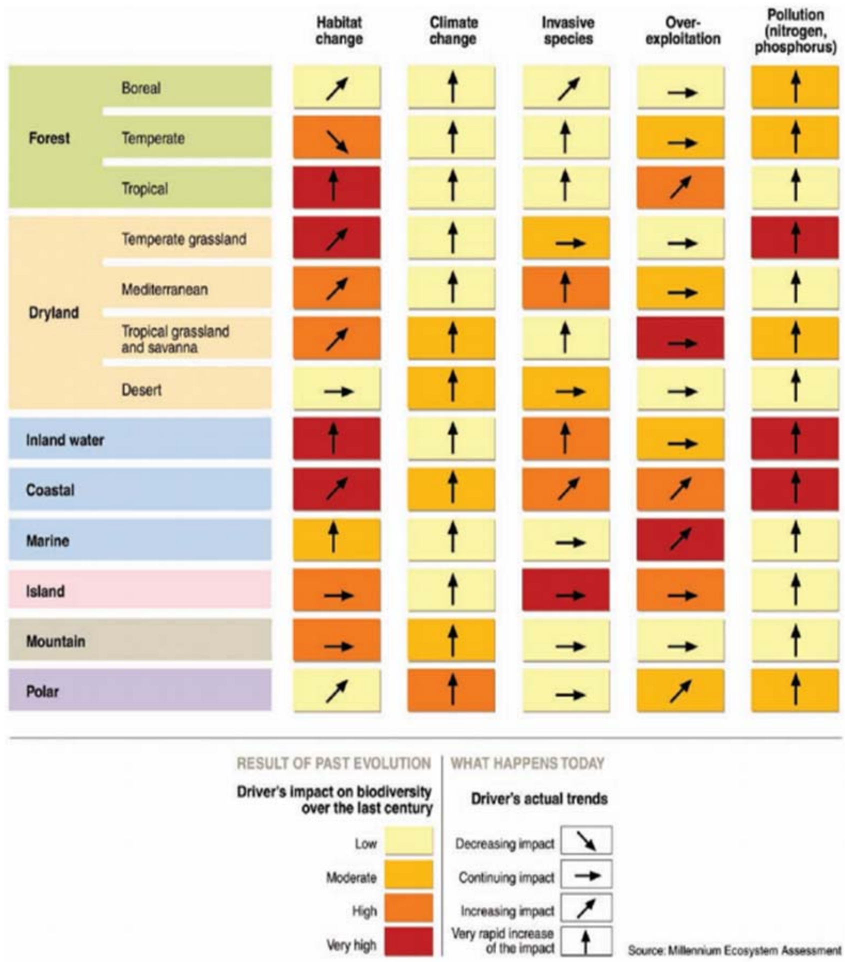
Global Living Planet Index: The average of three indices which measure overall trends in populations of terrestrial, marine and freshwater vertebrate species. The index declined by 27 per cent from 1970 to 2005

The Living Planet Report 2008 (*WWF International, 2008*) shows if current trends don't change, humanity will be demanding two planets worth of resources by the mid-2030s, while a 2009 assessment of the Global Footprint Network (*Global Footprint Network Standards Committee, 2009*) reveals if all people lived and consumed like Europeans we would need 2,6 planets.

According to the global assessments, more than one third of species assessed are facing extinction and an estimated60% of the Earth's ecosystems have been degraded in the last 50 years, with negative consequences for the ecosystems services that flow out of them (*Millennium*

Ecosystem Assessment, 2005). Besides, in the 10 years from 1995 to 2005 atmospheric CO_2 increased by about 19 ppm; the highest average growth rate recorded for any decade since direct atmospheric CO_2 measurements began in the 1950s (IPCC,2007).

It is increasingly evident that global climate change and bio-diversity is intricately interrelated. Millennium Ecosystem Assessment (MEA) predicts climate change to be the principle threat to the biodiversity. According to India's National Action Plan on Climate Change (IPCC), multi-model averages show that the temperature increases during 2090-2099 relative to 1980-1999 may range from 1.1 to 6.4^{o}C and sea level rise from 0.18 to 0.59 meters. At the national level, increase of –0.4^{o}C has been observed in surface air temperatures over the past century. This will lead to not only extreme weather condition but at the same time giant destruction of bio-diversity.The environment is polluted both by nature itself and of course human induced factors which are the direct and indirect drivers of biodiversity declination. Climate change, introduction of invasive species, over exploitation and pollution comes under direct driver and increasing human population, changing income & life-style pattern which are operate in a more diffusive manner by changing or altering the direct drivers, comes under in the category of indirect drivers. Higher income or technological improvement of the community would also indirectly amplify the climate change by combining with direct drivers.

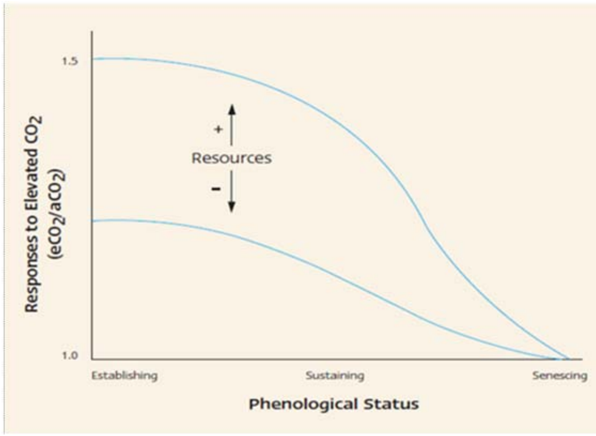


Source: Millennium Ecosystem Assessment (MA, 2005).

Fig. 5: Drivers of change in ecosystem services. IPCC, Perspectives on climate change and sustainability,

2.13.1 Effects of Climate Change on Bio-diversity:

Scientist are generally use a term called '**climatic envelop'** (*also sometimes referred asbioclimatic envelop)* to estimate the effects of climate change. Climatic envelops is the range of temperature, rainfall and other climatic parameters within which species exist.As the climate warms, the geographic location of climatic envelopes will shift significantly, possibly even to the extent that species can no longer survive in their current locations.Such species will need to follow their climatic envelopes by migrating to cooler and moister environments, usually uphill or northwards in the northern hemisphere. There is some evidence that plants and animals are already responding to warmer temperatures. According to climatologists and palynologists, temperature change of 3°C may lead to forest movement of250 km at a rate of 2.5 km/year which is ten times the rate of natural forest movement. For Example, in Nainital, species such as *Berberisasiatica, Taraxacumofficinale, Jasminumofficinale*etc have shifted from 1000 to 2000m height .Teak dominated forests are predicted to replace the Sal trees in central India and also the conifers may be replaced by the deciduous types.Alaska's boreal forest has moved about 100 km for every 1°C rise in temperature.



Schematic diagram showing the plant level relationships between response to the elevated (eCO_2) and phonological status as modulated by resource supply (cf. ambient CO_2, i.e. aCO_2). At the early 'establishing' stage of plant development, the plant is primed for growth and is thus responsive to an increased supply of CO_2. Modulation by the environmental constrains, for example, by nutrient inputs and increasing temperature, is also strong at this stage. The effect is still present, but at the reduced magnitude, during the 'sustaining' phase in the plant's life, and much diminishing in the 'senescing' phase

Source: (Australian Greenhouse Office, in the Department of the Environment and Heritage)

Fig. 8:

2.13.2 Effects on flora:

Currently we are releasing 70 million tons of CO_2per day into the atmosphere (Kannan and james, 2009). Carbon dioxide which were under 300ppm for the past 600,000 years are approaching 385ppm and expected to reach 550ppm by the year 2100 (Cicerone, 2006; Gore, 2006).Plant cannot synthesize its food without carbon dioxide and water. So, one may can think that its good news to the farmers because as there is more CO_2 in the atmosphere, the plants will synthesize more and the agricultural productivity will also be more due to carbon dioxide '*fertilization*' effects. But in this situation plant will also respire more, very high due to higher CO_2 concentration along with high temperature and the plants will simply die due to water stress in their body.C_4 and CAM plant may be benefited but increased level of carbon dioxide could diminish the nutritional value of their foliage. So, the leaf eating animals will also be affected due to less nutrition in their food. Changes are also coming in the phenological behavior of the plant. Plants starts early flowering, early fruiting and early maturity which has shorten their grain filling period lead to less yield.Climate change affect the bud, flower and leaf structure, changing fertilization patterns, fruiting behavior, grains are becoming chaffy and plants are becoming sterile.Due to climate change, pests (Pine wood nematode-*Bursaphelenchusxylophilus*, Pitch canker-*Gibberellacircinata*, Red palm weevil-*Rhynchophorusferrugineus,* virus, aphids, and fungi) have increased in number. In the new climatic condition some insect species are gaining resurgence and becoming more virulent.

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2.13.3 Effects on marine ecosystem:

Seventy percent (70%) of the Earth's surface is covered by oceans comprising some of the world's most diverse and unique ecosystems (mangroves, coral reefs, sea grass beds). Climate change is leading to sea level rise, increased coastal erosion, flooding, higher storm surges, sea salinity ingress, increased sea-surface temperatures, ocean acidification, coral bleaching, mangroves and millions of climate change refugees. Tropical rainforests of the ocean are estimated to provide about US$ 30 billion worth of benefits in goods and services. Although reefs cover only 0.2% of the world's sea floor, they contain about 25% of marine species. Warmer sea surface temperatures are blamed for an increase in a phenomenon called coral bleaching, which a whitening of coral is caused when the coral expels a single-celled, symbiotic alga called zooxanthellae. This alga usually lives within the tissues of the corals and, among other things, gives them its spectacular range of colors. Zooxanthellae are expelled when the coral is under stress from environmental factors such as abnormally high water temperatures or pollution. Since the zooxanthellae help coral in nutrient production, their loss can affect coral growth and make coral more vulnerable to disease. Major bleaching events took place on the Great Barrier Reef in 1998 and 2002, causing significant die-off of corals in some locations. Rising levels of atmospheric carbon dioxide could also decrease the calcification rates of corals, meaning that reefs damaged by bleaching or other agents would recover more slowly. Species composition and distribution will surely be affected by such changes. Indian coastal areas vulnerable to climate change are Sundarban, Maharashtra, Goa and Gujarat (Rann of Kutch). The distribution and composition of the species is bound to be effected.

2.13.4 Effects on faunal ecosystem:

Sensitivity of the species to even a slight change in the climate leads to their extinction as in case of the golden toad. Polar bears are in danger due to reduction in Arctic ice cover. North Atlantic right whale may become extinct, as planktons, its main food have shown decline due to climate change. The sex of sea turtle depends on temperature and more female turtles are produced as a result of high temperature. Some threatened species (frogs, toads, amphibians, tigers and elephants) are vulnerable to the impacts of climate change like sea level changes and longer drier spells. Changes in ocean temperature and acidification may lead to loss of 95% of the living corals of Australia’s Great Barrier Reef.

2.13.5 Polar ice/Glaciers:

They are diverse ecosystem facing extremes of the cold temperature with the flora (planktons) and fauna (migratory birds, whales) and Arctic people modified to such conditions. Climate change has resulted in an increase in the temperature to about 5°C to the normal and has resulted in the melting of the ice, increase in sea level which is threatening the endemic species (polar bears, walruses, seals, emperor penguins, krill, ringed seal). Studies show a decline in the weight of the polar bears from 325 kg in 1980 to 253 kg in 2004. Biodiversity loss has impacted the fishing and hunting practices by indigenous people (Saamiand Inuit of Canada) posing an implication on their only source of food. (ref. table-3)

The following list describes the list of endangered species in India including all animals and birds which occur in India and are rated as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) in the 2004 International Union for Conservation of Nature and Natural Resources (IUCN) and Wildlife Institute of India(WII).

a. Critically Endangered

- Red Panda (Lesser Panda) (Ailurus fulgens).
- Royal Bengal Tiger (Panthera tigris tigris).
- Ganges Shark (Glyphis gangeticus)(Endemic to India.)
- Himalayan Wolf (Canis himalayensis) (Endemic to India and Nepal.)
- Indian Vulture (Gyps indicus)
- Namdapha Flying Squirrel (Biswamayopterus biswasi). (Endemic to India.)
- Pygmy Frog (Sus salvanius).
- Salim Ali’s Fruit Bat (Latidens salimalii). (Endemic to India.)
- Nilgiri Tahr (Hemitragus hylocrius). (Endemic toIndia).
- Olive Ridley Turtle. (Endemic to Orissa, AndhraPradesh, India)

b. Endangered

- Hoolock Gibbon (Bunipithecus hoolock)(Previously Hylobates hoolock).
- Indian Elephant or Asian Elephant (Elephasmaximus)
- Indus River Dolphin (Platanista minor).
- Kashmir Stag/ Hangul (Cervus elaphus hanglu)

- Kondana Soft-furred Rat (Millardia kondana).(Endemic to India).
- Lion-tailed Macaque (Macaca silenus). (Endemicto India).
- Loggerhead Sea Turtle (Caretta caretta).

c. Vulnerable

"Endangered Mammal List". Wildlife Institute of India (WII).

- Andaman Horseshoe Bat (Rhinolophus cognatus). (Endemic to India.)
- Andaman Rat (Rattus stoicus). (Endemic to India.)
- Himalayan W-toothed Shrew (Crocidura attenuate)
- Sri Lankan Highland Shrew (Suncus montanus).
- Asiatic Black Bear (Ursus thibetanus).
- Himalayan Tahr (Hemitragus jemlahicus).

d. Threatened

- Indian Wild Ass (Equus hemionus khur)
- Leopard (Panthera pardus)
- Red Fox (Vulpes vulpes montana)
- Kashmir Stag (Praygnaa)

2.14 Effects on Human:

Climate change leads toan increase in temperature, melting of the ice and increased extreme events. All the extreme events like floods, droughts, cyclones displace the humans from their home and lead to outbreak of water borne diseases like cholera, typhoid etc.;spread of tropical and vector borne diseases like malaria, dengue etc. and rodent borne diseases like plague. These diseases have shown a persistent increase in the past 50 years. The incident of heat waves has registered an increase throughout the world taking away a heavy toll of the people life every year. The increasing sea level rise has already submerged many islands and will soon leave millions of refugees for the world to provide shelter. The sea salinity ingress in the fresh water sources has made land barren and will soon be a threat to the food security.

2.14.1 Climate Change Effects on Human Health

World Health Day celebrated on 7th April every year provides a unique opportunity to draw worldwide attention to a subject of importance to global health. It is vital that everyone is aware of the health issues and the urgency of goals to be achieved. Unstable and changing climate affects health through heat waves, storms, floods and droughts which kill tens and thousands each year. It has become clearer as the science of climate change has consolidated that societal adaptation to climate change will be necessary because a significant amount of climate change is inevitable (*IPCC 2007, Parry et al. 2009*).

Scientists believe that climate change could increase the spreading of disease. Dissemination of diseases could lead to heat-related illnesses and even death. Extreme weather such as storms, could increase the risk of high winds, dangerous flooding, and direct threats to human being and property (*United State Environmental Protection Agency, 2012*). Projections of future climate change come from past observation, observed interventions and modeling. The NIWA models, outlined by Reisinger et al. (*2010*) detail the potential effects of two climate change scenarios. The first is the 2°C scenario, the “rapidly decarbonising world” scenario, in which there are local effects of heat and air pollution and an extended range of vector-borne infectious diseases. The second is the 4°C scenario, the “high carbon world” scenario, in which there will be a substantial increase in all these effects. The 4°C scenario is now starting to look increasingly likely (*Ramanathan & Feng 2008, Rogelj et al. 2009, WBGU 2009*). There are already major direct and indirect impacts globally, including in the Pacific, which are beginning to involve considerable social disruption and, potentially, migration (*Oxfam 2009).* Some of the major impacts of climate change are likely to be on population health (*Hales & Woodward 2006).* A recent review concluded that climate change is potentially the biggest global health threat of the 21st century (*Costello et al. 2009*).

2.15 Global Health Scenario

Health includes physical, social and psychological well-being. Population health is a primary goal of sustainable development. Human beings are exposed to climate change through changing weather patterns (*for example more intense and frequent extreme events*) and indirectly though changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods and infrastructure (*IPCC 2007*). These direct and indirect exposures can cause death, disability and suffering. Ill-health increases vulnerability and reduces the capacity of individuals and groups to adapt to climate change. Populations with high rates of disease and debility cope less successfully with stresses of all kinds, including those related to climate change.

In many respects, population health has improved remarkably over the last 50 years. For instance, average life expectancy at birth has increased worldwide since the 1950s (*WHO, 2003b, 2004b*). However, improvement is not apparent everywhere, and substantial inequalities in health persist within and between countries (*Casas-Zamora and Ibrahim, 2004;*

McMichael et al., 2004; Marmot, 2005; People's Health Movement et al., 2005). In parts of Africa, life expectancy has fallen in the last 20 years, largely as a consequence of HIV/AIDS; in some countries more than 20% of the adult population is infected (*UNDP*, *2005*). Globally, child mortality decreased from 147 to 80 deaths per 1,000 live births from 1970 to 2002 (*WHO, 2002b*). Reductions were largest in countries in the World Health Organization (*WHO*) regions of the Eastern Mediterranean, South-East Asia and Latin America. In sixteen countries (*fourteen of which are in Africa*), current levels of under-five mortality are higher than those observed in 1990 (*Anand and Barnighausen, 2004*). The Millennium Development Goal (*MDG*) of reducing under-five mortality rates by two-thirds by 2015 is unlikely to be reached in these countries.

While climate change is a global process, it has very local impacts that can profoundly affect communities. It can affect people's health and well-being in many ways, some of which are already occurring, by:

- Increasing the frequency and severity of heat waves, leading to more **heat-related illnesses and deaths**.
- Changing the range of disease-carrying insects, such as mosquitoes, ticks, and fleas that transmit **West Nile Virus, dengue fever, Lyme disease, and malaria** to humans.
- Increasing exposure to pollen, due to increased plant growing seasons; molds, due to severe storms; and air pollution, due to increased temperature and humidity, all of which can worsen **allergies and other lung diseases, such as asthma**.

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- Increasing temperatures and causing poor air quality that can affect the heart and worsen **cardiovascular disease**.
- Increasing flooding events and sea level rise that can contaminate water with harmful bacteria, viruses, and chemicals, causing **food borne and waterborne.**

2.15.1 Vulnerable population

- **Infants and children, pregnant women, the elderly, people with chronic medical conditions, outdoor workers, and people living in poverty** are especially at risk from a variety of climate related health effects. Examples of these effects include increasing heat stress, air pollution, extreme weather events, and diseases carried by food, water, and insects.
- Children's small ratio of body mass to surface area and other factors make them vulnerable to **heat-related illness and death**. Their increased breathing rate relative to body size, additional time spent outdoors, and developing respiratory tracts, heighten their sensitivity to air pollution. In addition, children's **immature immune systems** increase their risk of serious consequences from **waterborne and food-borne diseases**, while developmental factors make them more vulnerable to complications from severe infections such as **E. coli or Salmonella.**
- The greatest health burdens related to climate change are likely to fall on the poor, especially those lacking adequate shelter and access to other resources such as air conditioning.

- Elderly people are more likely to have **debilitating chronic diseases or limited mobility**. The elderly are also generally more sensitive to extreme heat for several reasons. They have a reduced ability to regulate their own body temperature or sense when they are too hot. They are at greater risk of **heart failure**, which is further exacerbated when cardiac demand increases in order to cool the body during a heat wave. Also, people taking medications, such as diuretics for high **blood pressure, have a higher risk of dehydration.**
- The multiple health risks associated with diabetes will increase the vulnerability of the U.S. population to increasing temperatures. The number of Americans with diabetes has grown to about 24 million people, or roughly 8 percent of the U.S. population. **Almost 25 percent of the population 60 years and older had diabetes in 2007**.Fluid imbalance and dehydration create higher risks for diabetics during heat waves. People with diabetes-related heart disease are at especially increased risk of dying in heat waves.
- High **obesity rates** in the United States are a contributing factor in currently high levels of diabetes. Similarly, a factor in rising obesity rates is a sedentary lifestyle and automobile dependence; 60 percent of Americans do not meet minimum daily exercise requirements. Making cities more walkable and bikeable would thus have multiple benefits: improved personal fitness and weight loss; reduced local air pollution and associated respiratory illness; and reduced greenhouse gas emissions.

2.15.2 Diseases spread by floods

- A number of important disease-causing agents (pathogens) commonly transmitted by food, water, or animals are susceptible to changes in replication, survival, persistence, habitat range, and transmission as a result of changing climatic conditions such as increasing temperature, precipitation, and extreme weather events.
- Cases of food poisoning due to Salmonella and other bacteria peak within one to six weeks of the highest reported ambient temperatures.
- Cases of waterborne **Cryptosporidium** and **Giardia** increase following heavy downpours. These parasites can be transmitted in drinking water and through recreational water use.
- Climate change affects the life cycle and distribution of the mosquitoes, ticks, and rodents that carry **West Nile virus, equine encephalitis, Lyme disease, and Hantavirus**. However, moderating factors such as housing quality, land use patterns, pest control programs, and a robust public health infrastructure are likely to prevent the large-scale spread of these diseases in the United States.
- Heavy rain and flooding can contaminate certain food crops with feces from nearby livestock or wild animals, increasing the likelihood of food-borne disease associated with fresh produce.
- **Vibrio sp. (shellfish poisoning)** accounts for 20 percent of the illnesses and 95 percent of the deaths associated with eating infected shellfish, although the overall incidence of illness from Vibrio infection remains low. There is a close association between temperature, **Vibrio sp.**

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abundance, and clinical illness. The U.S. infection rate increased 41 percent from 1996 to 2006, concurrent with rising temperatures.

- As temperatures rise, tick populations that carry Rocky Mountain spotted fever are projected to shift from south to north
- The introduction of disease-causing agents from other regions of the world is an additional threat.

2.15.4 Allergens

Rising carbon dioxide levels have been observed to increase the growth and toxicity of some plants that cause health problems. Climate change has caused an earlier onset of the spring pollen season in the United States. It is reasonable to conclude that allergies caused by pollen have also experienced associated changes in seasonality. Several laboratory studies suggest that increasing carbon dioxide concentrations and temperatures increase ragweed pollen production and prolong the ragweed pollen season. Poison ivy growth and toxicity is also greatly increased by carbon dioxide, with plants growing larger and more allergenic.

2.15.5 Change related disorders

While the physical health impacts of climate change are well known, the impact on mental health has only begun to be recognized in the last decade. According to 2011 in American Psychologist Clayton & Doherty, concluded that global climate change is bound to have substantial negative impacts on mental health and well-being, effects which will primarily be felt by vulnerable populations and those with pre-existing serious mental illness.

They identified three classes of psychological impacts from global climate change:

- Direct - "Acute or traumatic effects of extreme weather events and a changed environment"
- Indirect - "Threats to emotional well-being based on observation of impacts and concern or uncertainty about future risks"
- Psychosocial - "Chronic social and community effects of heat, drought, migrations, and climate-related conflicts and post disaster adjustment"

Direct impacts on mental health, such as landscape changes, impaired place attachment, and **psychological trauma** are all immediate and localized problems resulting from extreme weather events and environmental changes. Research has shown that extreme weather events lead to a variety of mental health disorders from the impacts of loss, social disruption, and displacement. Further reinforced by Clayton & Doherty (*2011*), “acute and direct impacts include mental health injuries associated with more frequent and powerful weather events, natural disasters, and adjustment to degraded or disrupted physical environments”. For example, events such as wildfires and hurricanes can lead to anxiety and emotional stress, further exacerbated in already vulnerable populations with current mental health issues.

According to the United States Environmental Protection Agency, particle matter is defined as “a complex mixture of extremely small particles and liquid droplets.” These small particles and liquid droplets consist of acids (such as nitrates and sulfates), organic chemicals, metals (such as cadmium, mercury, and lead compounds), and soil or dust particles. According to the

WHO assessment, taking into account only a subset of the possible health impacts, and assuming continued economic growth and health progress, concluded that climate change is expected to cause approximately 250 000 additional deaths per year between 2030 and 2050; 38 000 due to heat exposure in elderly people, 48 000 due to diarrhea, 60 000 due to malaria, and 95 000 due to childhood under nutrition.

Table 6

Short-term Effects	**Long-term Effects**
Irritation to eyes, nose, and throat	Chronic respiratory disease
Upper respiratory infections	Lung cancer
Bronchitis	Asbestosis
Pneumonia	Heart disease
Headaches	Reproductive defects
Inflammation	Decreased birth rate
Nausea	Malformed infants
Allergic reactions	Damage to:
Aggravate asthma	Brain
Liver	Nerves
Kidneys	

2.16 Climate Change Effects on Migration

In the coming decades climate change will increasingly threaten humanity's shared interests and collective security in many parts of the world, disproportionately affecting the globe's least developed countries. It is difficult to fully understand the detailed causes of migration and economic and political instability, but the growing evidence of links between climate change, migration, and conflict raise plenty of reasons for concern. Climate change is a new driver of human migration worldwide. Though, almost in all the cases of migration generated by climate change, are considered as the results of complex mix factor, a combination of exposure to natural hazards. In the 21st century the world could see substantial numbers of climate migrants—people displaced by either the slow or sudden onset of the effects of climate change. The United Nations' recent Human Development Report stated that, worldwide, there are already an estimated 700 million internal migrants—those leaving their homes within their own countries—a number that includes people whose migration is related to climate change and environmental factors. Overall migration across national borders is already at approximately 214 million people worldwide, with estimates of up to 20 million displaced in 2008 alone because of a rising sea level, desertification, and flooding.

2.16.2 Causes of displacement

Climate change will cause population movements by making certain parts of the world much less viable places to live; by causing food and water supplies to become more unreliable and increasing the frequency and severity of floods and storms. Recent reports from the *IPCC* and elsewhere set out the parameters for what we can expect: By 2099 the world is expected to be on average *between 1.8ºC and 4ºC hotter* than it is now.21 Large areas are expected to become drier—the proportion of land in constant drought expected to increase from 2 per cent to 10 per cent by 2050.

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Meanwhile, the proportion of land suffering extreme drought is predicted to increase from 1 per cent at present to 30 per cent by the end of the 21st century. Rainfall patterns will change as the hydrological cycle becomes more intense. In some places this means that rain will be more likely to fall in deluges *(washing away top-soil and causing flooding*).

Changed rainfall patterns and a more intense hydrological cycle mean that extreme weather events such as droughts, storms and floods are expected to become increasingly frequent and severe. Less rain would have particularly serious impacts for sub-Saharan African agriculture which is largely rain-fed: the 2007 IPCC report of the Second Working Group estimates that yields from rain-fed agriculture could fall by up to 50 per cent by 2020. *"Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change"* the report notes.

2.16.3 Environmental Refugees and Climate Refugees…

There are broad-ranging estimates on how many people will be forced to move due to environmental phenomena. Numbers largely depend on how the group of affected people is being defined. Experts speak of 15 million in 2009 and 38 million in 20103. According to recent estimates, between 250 million and one billion people might be affected by 2050. But there are clear limitations to such predictions, which should therefore be handled with caution.

There is considerable debate about the terminology – which is to be welcomed, as experts thereby frame the discussion and possible solutions.

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In this context, terms like *"environmental refugee"* or *"climate refugee"* have been questioned. Especially UNHCR sees the use of *"refugee"* critically, underlining that it has a specific meaning in international law as defined by the Geneva Convention. UNHCR therefore fears that using "refugee" may undermine systems currently in place to provide protection to refugees. On the other hand one immediately contentious issue is whether people displaced by climate change should be defined as *"climate refugees"* or as *"climate migrants"*. This is not just semantics—which definition becomes generally accepted will have very real implications for the obligations of the international community under international law.

Campaigners have long used the phrase "environmental refugee" or "climate refugee" to convey added urgency to the issue. They argue that, in the most literal sense of the words, such people need to "seek refuge" from the impacts of climate change. Any other terminology, they maintain, would downplay the seriousness of these people's situation. Moreover, the word "refugee" resonates with the general public who can sympathize with the implied sense of duress. It also carries fewer negative connotations than "migrant" which tends to imply a voluntary move towards a more attractive lifestyle.

If the term *"climate refugee"* is problematic it is still used, in part, for lack of a good alternative. "*Climate evacuee*" implies temporary movement within national borders *(as was the case with Hurricane Katrina*). *"Climate migrant"* implies the *"pull"* of the destination more than the "push" of the source country and carries negative connotations which reduce the implied responsibility of the international community for their welfare. .

2.16.4 Worldwide problems of migration

The costs and consequences of climate change on our world will define the 21st century. Even if nations across our planet were to take immediate steps to rein in carbon emissions—an unlikely prospect—a warmer climate is inevitable. As the U.N. Intergovernmental Panel on Climate Change, or IPCC, noted in 2007, human-created *"warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.* "As these ill effects progress they will have serious implications for national security interests as well as global stability—extending from the sustainability of coastal military installations to the stability of nations that lack the resources, good governance, and resiliency needed to respond to the many adverse consequences of climate change. And as these effects accelerate, the stress will impact human migration and conflict around the world. *According to Nicholls and Lowe (2004),* using a mid-range climate sensitivity projection, the number of people flooded per year is expected to increase by between 10 and 25 million per year by the 2050s and between 40 and 140 million per year by 2100s, depending on the future emissions scenario. India's urban population which was 17 percent in 1951 is expected to jump to over 42 per cent in 2025. The increase will be on account of migration of people from rural areas, who will shift location of greener pastures. In the last 50 years the rural population has decreased from 82.0 to 68.9 per cent.

In the coming decades climate change will increasingly threaten humanity's shared interests and collective security in many parts of the world, disproportionately affecting the globe's least developed countries. Climate change will pose challenging social, political, and strategic questions for the many different multinational, regional, national, and nonprofit organizations dedicated to improving the human condition worldwide. Organizations as different as Amnesty International, the U.S. Agency for International Development, the World Bank, the International Rescue Committee, and the World Health Organization will all have to tackle directly the myriad effects of climate change.

A growing scientific consensus suggests that human-induced climate change is already occurring, and a number of factors suggest the importance of climate change impacts on migration in the region. These are:

- Population *(4.1 billion people)* and environmental management pressures are already enormous;
- Climate change impacts are projected to be large, particularly because monsoonal rainfall patterns could become less reliable and cyclonic activity more intense; and
- •A large part of the population in the region lives in poverty *(Asian Development Bank estimates 903 million struggle on $1.25 per day)* and their well-being is highly vulnerable to environmental hazards and degradation of natural resources.

Despite the importance of climate change impacts on migration, relatively little empirical research has been done on the topic for Asia and the Pacific because, as already stated, it remains very difficult to determine their likely origins or destinations or to estimate how many people may move.

There have been a number of speculative predictions of displacements at the global level:

- Environmentally displaced people by 2010: 50 million (UNFCCC 2007)
- Refugees due to climate change by 2050: 250 million (Christian Aid cited in Bierman and Boas 2007)
- People estimated to become permanently displaced "climate refugees" by 2050: 200 million (Stern 2006)

But in fact, there are so many gaps in current knowledge on climate change, migration, and the relationships among these in Asia and the Pacific that it would be irresponsible to speculate on future numbers of people likely to migrate.

2.17 Adaptation

Climate-resilient pathways are defined as development trajectories that combine adaptation and mitigation with effective institutions to realize the goal of sustainable development. They are seen as iterative, continually evolving processes for managing change within complex socio-ecological systems; taking necessary steps to reduce vulnerabilities to climate change impacts in the context of development needs and resources, building capacity to increase the options available for vulnerability reduction and coping with unexpected threats; monitoring the effectiveness of vulnerability reduction efforts; and revising risk reduction responses on the basis of continuous learning. As such, climate-resilient pathways include two main categories of responses:

- Actions to reduce human induced climate change and its impacts, including both mitigation and adaptation towards achieving sustainable development
- Actions to assure that effective institutions, strategies, and choices for risk management will be identified, implemented, and sustained as an integrated part of achieving sustainable development (IPCC WGII AR5).

2.17.1 Selected Elements of Climate-Resilient Pathways

a. Awareness and capacity

- A high level of social awareness of climate change risks
- A demonstrated commitment to contribute appropriately to reducing net GHG emissions, integrated with national development strategies
- Institutional change for more effective resource management through collective action
- Human capital development to improve risk management and adaptive capacities
- Leadership for sustainability that effectively responds to complex challenges.

b. Resources

- Access to scientific and technological expertise and options for problem-solving, including effective mechanisms for providing climate information, services and standards
- Access to financing for appropriate climate change response strategies and actions
- Information linkages in order to learn from experiences of others with mitigation and adaptation

c. Practices

- Continuing development and evaluation of institutionalized vulnerability assessments and risk management strategy development, and refinement based on emerging information and experience
- Monitoring of emerging climate change impacts and contingency planning for responding to them, including possible needs for transformational responses
- Policy, regulatory, and legal frameworks that encourage and support distributed voluntary actions for climate change risk management
- Effective programs to assist the most vulnerable populations and systems in coping with impacts of climate change.

Disaster preparedness on a local community level could include a combination of indigenous coping strategies, early-warning systems, and adaptive measures (Paul and Routray, 2010). Heat warning systems have been successful in preventing deaths among risk groups in Shanghai (Tan et al., 2007). New work practices to avoid heat stress among outdoor workers, in Japan and the UAE have also been successful (Morioka et al., 2006; Joubert et al., 2011). Early warning models have been developed for haze exposure from wildfires, in for example Thailand (Kim Oanh and Leelasakultum, 2011), and are being tested in infectious disease prevention and vector control programs, as for malaria in Bhutan (Wangdi et al., 2010) and Iran (Haghdoost et al., 2008), or are being developed, as for dengue fever region-wide (Wilder-Smith et al., 2012).

Some adaptation practices provide unexpected livelihood benefits, as with the introduction of traditional flood mitigation measures in China which could positively impact local livelihoods, leading to reductions in both the physical and economic vulnerabilities of communities (Xu et al., 2009). A greater role of local communities in decision making is also proposed (Alauddin and Quiggin, 2008) and in prioritization and adoption of adaptation options (Prabhakar et al., 2010; Prabhakar and Srinivasan, 2011). Defining adequate community property rights, reducing income disparity, exploring market-based and off-farm livelihood options, moving from production-based approaches to productivity and efficiency decision-making based approaches, and promoting integrated decision-making approaches, have also been suggested (Merrey et al., 2005; Brouwer et al., 2007; Paul et al., 2009; Niino, 2011; Stucki and Smith, 2011).

2.18 Mitigation

Climate change mitigation are actions to limit the magnitude and/or rate of long-term climate change. Climate change mitigation generally involves reductions in human (anthropogenic) emissions of greenhouse gases

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(GHGs). Mitigation may also be achieved by increasing the capacity of carbon sinks, e.g., through reforestation. By contrast, adaptation to global warming are actions taken to manage the eventual (or unavoidable) impacts of global warming, e.g., by building dikes in response to sea level rise. Examples of mitigation include switching to low-carbon energy sources, such as renewable and nuclear energy, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere. Energy efficiency can also play a major role, for example, through improving the insulation of buildings. Another approach to climate change mitigation is geo-engineering.

The framework for statistics related to climate change included the following variables/ indicators.

a. Solar Energy

- Solar Energy,
- Solar Cells,
- Solar Lanterns,
- Solar Water Heater,
- Solar Electricity Generation Plants and Capacity

b. Energy Use

- Use of fuel like Condensed Natural Gas (CNG), Liquid Petroleum Gas (LPG)
- Industries adopted fuel efficient technologies
- Use of Compact Fluorescent Light (CFL)

c. Dry-land Agriculture

- Crop Varieties for drought prone areas

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- ❖ Varieties of pest-resistant crop

d. Renewable Energy

- ❖ State-wise cumulative installations of Solar Photovoltaic Systems
- ❖ State wise details of Small hydro power projects (upto 25 MW) set up & under implementation (as on 31.03.2012)
- ❖ Distribution of family- type biogas plants (number of installations)
- ❖ State- wise break-up of the energy parks and energy clubs as on 31.03.2012
- ❖ Source wise and State wise estimated potential of renewable power in India (In Mega Watts as on 31.03.2012)

2.18.1 Energy use

a. Solar Energy:

The radiant light and heat from the sun that is harnessed by human made technologies, which generates electricity.

In many parts of rural India, solar energy is being used widely to meet the needs of the poor. For example the Ministry of New and Renewable Energy has introduced the Remote Village Electrification Programme in over 4000 villages and hamlets. This solar technology enables children to study after dark due to solar powered lighting and it can illuminate street lights. Furthermore, solar powered cookers emit no harmful gases during cooking and so women who traditionally cook everyday in the home are not exposed to the excessive carbon emissions expelled during cooking (UNDP 2007/8).

b. Hydro Energy:

The production of power through the use of gravitational force of falling or flowing water; it is the most widely used form of renewable energy.

Hydro energy produces no direct waste and has a considerably lower output level of the greenhouse gas carbon dioxide than fossil fuel powered energy plants. Hydroelectricity currently supplies about 715,000 MW or 19% of the world's electricity, accounting for 63% of the total electricity from the renewable energy sector. Hydro Power has a prominent role to play in responding to the energy challenges. The electricity generated from small hydro power projects iscost-effective. Such projects are simple to operate, have a relatively short gestation period and are environmentally friendly. In addition, these hydro energy projects can be located in remote areas for generating power. The global estimated potential of SHP is about 180,000 MW (Gonsalves 2006).

c. Biomass/Biofuels:

Material derived from recently living organisms. This includes plants, animals and their by-products. For example, manure, garden waste and crop residues are all sources of biomass. It is a renewable energy source based on the carbon cycle, unlike other natural resources such as petroleum, coal and nuclear fuels.

In addition to providing energy security and a decreased dependence on oil imports, biofuels offer several significant benefits such as reduced emission of pollutants and greenhouse gases and increased employment in the agricultural sector. In India, the National Biodiesel Mission promotes the use of *Jatropha*, which research shows to have the following advantages: it requires low water and fertilizer for cultivation, is not grazed by cattle or sheep, is pest resistant, is easy propagated, has a low gestation period, has a high seed yield and oil content and produces high protein manure.

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The main problem in getting the biodiesel programme up and running in India has been the difficulty in initiating the large-scale cultivation of Jatropha as farmers do not consider Jatropha cultivation rewarding enough. The Government needs to sponsor confidence-building measures such as establishing a minimum support price for Jatropha oilseeds and assuring farmers of timely payments. It is also important to note that bio fuel production should be based non-agriculturalland, or at least on land that is not substituting agriculture, so as not to jeopardise food security (Gonsalve,2006)

d. Wind Energy:

The conversion of wind energy into a useful form, such as electricity, using wind turbines. Wind power is produced in large scale wind farms connected to electrical grids, as well as individual turbines for providing electricity to isolated locations.

Wind power accounts for 6% of India's total installed power capacity, and it generates 1.6% of the country's power– currently India has the 5th largest installed wind power capacity in the world. Short gestation periods for installing wind turbines and the increasing reliability and performance of wind energy machines has made wind power a favored choice for capacity addition in India. Wind power is also cost competitive to other fuel sources as it is the least expensive of all renewable energy resources. Because wind is free, it can provide a stable long term price for power production.

2.18.3 The Renewable Energy Park:

The Renewable Energy Park Scheme was started in 1994-95 under the Special Area Demonstration Programme. The main objective of the

Renewable Energy Park Scheme is to create awareness, publicity and provide an opportunity to the students / teachers and rural and urban masses about the use and benefits of the renewable energy by demonstrating new and renewable energy systems and devices by demonstrating working systems, cut models, LED models, blow ups etc.

Two types of Renewable Energy Parks are being supported under this scheme namely District Level Renewable Energy Parks (DLEP) and State Level Renewable Energy Parks (SLEP). DLEPs are set up at Educational Institutions, Krishi Vigyan Kendras, Registered Consumer Forums, and registered NGOs with facilities for Science and Environment Education and public places where there is large inflow of public. SLEP is set up in a State at a location where large flow of people and tourists takes place every day.

(i) State Level Energy Park

Two State levels Energy Park would be considered for setting up in each State. The State level Energy Park would be established by the State Nodal Agency or departments either by the Agency themselves or through a Memorandum of Understanding with any reputed Government institution/organization.

(ii) District Level Energy Parks

The Ministry has so far sanctioned 484 District Level Energy Parks. The component of DLEPs from the existing scheme has been discontinued. The sanctioned parks are being completed.

Whatever happens to future greenhouse gas emissions, we are now locked into inevitable changes to climate patterns. Adaptation to climate change is therefore no longer a secondary and long-term response option only to be used as a last resort. It is now prevalent and imperative, and for those communities already vulnerable to the impacts of present day climate hazards, an urgent imperative.

Successful adaptation must be accomplished through actions that target and reduce the vulnerabilities poor people now face, as they are likely to become more prevalent as the climate changes. This approach calls for a convergence of four distinct communities who have long been tackling the issue of vulnerability reduction through their respective activities—disaster risk reduction, climate and climate change, environmental management, and poverty reduction. Bringing these communities together and offering a common platform— and a shared vocabulary—from which to develop an integrated approach to climate change adaptation can provide an opportunity to revisit some of the intractable problems of environment and development.

The starting point for this convergence is a common understanding of the concepts of adaptation, vulnerability, resilience, security, poverty and livelihoods, as well as an understanding of the gaps in current adaptation approaches. Taken together, they indicate a need—and an opening—for adaptation measures based on the livelihood activities of poor and vulnerable communities. This places the goal of poverty reductionat the centre of adaptation, as the capabilities and assets that comprise people's livelihoods often shape poverty as well as the ability to move out of poverty.

This "bottom-up" approach therefore requires an understanding of how livelihoods are conducted and sustained— that is, how resources are mobilized to earn an income and meet basic needs. Central to both the definition of livelihoods and household resilience are livelihood assets, i.e., the means of production available to a given individual or group that can be used to generate material resources sufficient enough to reduce poverty. The greater and more varied the asset base, the more sustainable and secure the livelihood. There are generally five forms of livelihood assets: natural capital, social-political capital, human capital, physical capital and financial capital. Taken together, these assets largely determine how people will respond to the impacts of climate change, and should therefore form the basis of adaptation strategies.

While all of these assets are important, natural resources are particularly important for the poorest and most vulnerable communities in the world. The poor are more heavily dependent on ecosystem services and therefore most severely affected by deteriorating environmental conditions and factors limiting resource access. While climate change is not the only threat to natural resources and livelihoods, climate-induced changes to resource flows will affect the viability of livelihoods unless effective measures are taken to protect and diversify them through adaptation and other strategies. For the poorest and most vulnerable, these strategies should include ecosystem management and restoration activities such as watershed restoration, agro-ecology, reef protection and rangeland rehabilitation. In fact, these activities can represent "win-win" approaches to climate change adaptation, as they serve immediate needs and bring immediate benefits to local communities while also contributing to longer-term capacity development that will create a basis for reducing future vulnerabilities.