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Climate Change: Impact, Adaptation and Mitigation

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ABSTRACT

Earth is undergoing changes in climate at an unprecedented rate. Majority of the researchers across the globe are of the view that such changes are as a result of human-induced factors which lead to increase in emission of greenhouse gases. However a few believe that this is a natural phenomenon and opine that climate change is due to decreased sun's activity or change in earth's orbital characteristics / natural earth cycle. Greenhouse gases act as one-way-filters, allowing energy from sun to enter the lower atmosphere but stopping longer wavelength heat from escaping. This results in enhanced greenhouse effect. Although Greenhouse effect is a life sustaining phenomena otherwise earth would have been a frozen mass, but too much of greenhouse effect causes global warming. Climatologists and researchers are of the opinion that the global warming trend has already begun like rise in sea level, receding glaciers, thermal expansion of oceans, extremes and erratic weather behavior, outbreak of diseases and displacement of climate zones resulting in unusual migration of species. Keeping in view the consequences ofglobal warming, many strategies have been put forth to combat it as it's too serious to further ignore it. Hence, whatever the causes may be, global warming represents a fundamental threat to all life on earth, even though there is less scientific and political consensus concerning the severity of the threat it poses.

Key Words: Greenhouse Adaptation Climate Glacier Climate

INTRODUCTION

Water stress, food insecurity, economic recession and migration are some of the impacts associated with climate change. One of the greatest crises faced by mankind today is that of global warming. This problem is not only global in nature but potentially threatens the survival of life on earth. During 1980's and 1990's many scientists argued about the causes and consequences of global warming, however, in late 1990s scientists reached a consensus that global warming was indeed an issue of major concern.

The earth's atmosphere acts as a greenhouse, wherein the shorter wavelength solar radiations of higher energy are emitted by sun reach onto the earth. Some of these radiations are reflected back by the atmosphere (albedo) but about half of it reaches the earth surface thereby heating it and in response the longer wavelength infrared radiations or heat radiations are radiated. Most of these radiations instead of being radiated back completely are retained by the atmospheric greenhouse gases (GHGs). The GHGs absorb infrared radiations (IR), emitted by the earth's surface, atmosphere and clouds. These gases in turn emit IR radiations in all directions. Thus, they trap heat within the atmosphere phenomena termed as greenhouse effect. The term greenhouse effect was coined by Joseph Fourier (1824). The absorption and emission of radiations is responsible for maintaining the earth's temperature at an average of 14^0C. Without this effect the earth's temperature would have been -18 ^{0}C (Lashof, 1989).

This natural greenhouse effect forms a part of the energy balance of earth (Baede*et al*., 2001). The greenhouse gases include Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Ozone (O_3), Hydrochlorofluorocarbon (HCFCs) and Chlorofluorocarbon (CFCs). The measurement of the influence of particular factors (GHGs, aerosols, etc.) on the net change in energy balance is referred to as radiative forcing. Positive radiative forcing (e.g. GHGs and black carbon aerosols) tends to warm the earth while as the negative forcing (e.g. sulfate aerosols) tend to cool it. The GHGs in atmosphere act as insulating elements, the richer the GHGs the better is the insulation. However, to counteract the excessive heating of life sustaining atmosphere, clouds play a role in slight cooling of it, however, their effect is highly variable and

depends on the cloud height, type and optical properties. Also during occasional volcanic eruption huge amount of aerosols are thrown into the atmosphere. For instance the eruption of Mount Pinatubo (Philippines) in 1991 sprayed a fine mist of sulphate aerosols which reflected the sunlight back into the space. According to Whyte (1995) the volcanic fallout was rich in iron which acted as a fertilizer for oceanic phytoplankton thereby increasing the uptake of CO_2 from atmosphere. Both these factors led to drop in average global temperature from 15.42 ^{0}C to 15.13 ^{0}C. Similar influence was observed during Mt. Tambora (1815), Mt. El Chichon (1982) eruptions.

The major area of concern is the increasing anthropogenic interferences that has disturbed energy budget of earth. The problem is not only of the gradual warming of atmosphere via enhanced greenhouse effect but also of the fact that GHGs have long residence time in atmosphere which envisages that despite the possibility that their emissions can be controlled , they would remain suspended in the atmosphere over a prolonged period causing harm to the environment. Therefore an imbalance is created between incoming and outgoing energy. Earth's average temperature has risen by 1.4 ^{0}F over the past century and it's projected to rise another 2 -11.5 ^{0}F over the next hundred years. Similar estimates were provided by Intergovernmental Panel on Climate Change (IPCC, 1990) when it was predicted that as the current scenario continues the global mean temperature will increase by 1^{0}C above the present value by the year 2025 and 3 ^{0}C by the end of next century.

Climate Change refers to a statistically significant variation in either the mean state of the climate or its variability, persisting for an extended period (typically decades or longer.) According to United Nations Framework Convention on Climate Change(UNFCCC): Climate change is '*a change of climate which is attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*.' Adverse effects of climate change"means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare".

Concentration of Greenhouse gases: Changes in the concentration of Greenhouse gases (Table 1), which occur both naturally and as a result of human activities, also influence Earth's climate. Carbon dioxide concentration has risen from pre-industrial levels of 280 parts per million by volume (ppmv) to about 390 ppmv in 2010. Since 1958 alone the concentrations have risen by 75 ppmv. That is the increase is almost 40% since pre-industrial times.

Table 1.Current greenhouse gas concentration

Gas	Pre-1750 tropospheric concentration	Recent tropospheric concentration	Absolute increase since 1750	Global warming potential	Atmospheric life time (years)
Carbon dioxide	280 ppm	390.5 ppm	110.5 ppm	1	30-95
Methane	700 ppb	1871 ppb	1171 ppb	25	12
Nitrous oxide	270 ppb	323 ppb	53 ppb	298	114
Tropospheric ozone	25 ppb	34 ppb	9 ppb	430	hrs-days
CFC-12	zero	535 ppt	535 ppt	10,900	100
HCFC-22	zero	220 ppt	220 ppt	1,810	12

(Source: Blasing, 2012)

However recently, on August, 2014, the concentration of CO_2 has increased upto397.26 ppm (figure 1, Mauna Loa Observatory, United States).

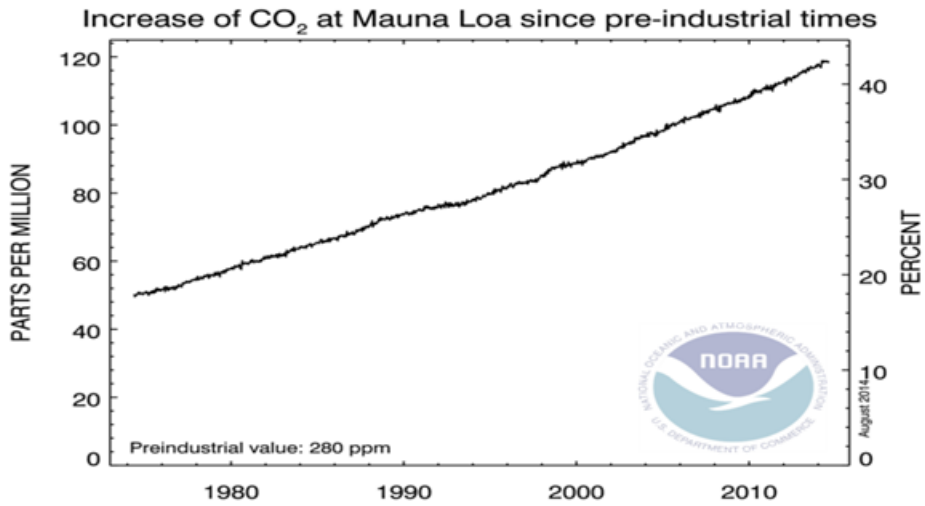

Figure.1: Atmospheric increase of CO_2 over 280 ppm in weekly averages of CO_2 observed at Mauna Loa.

EFFECT OF GLOBAL WARMING ON THE EARTH'S CLIMATE

Detailed researches of climatic events of the past 150 years have revealed that the temperatures have risen all over the globe, with the warming occurring in two phases. The first phase was from 1919 to 1940, with an average temperature gain of 0.35°C, and the second phase was from 1970 to the present, exhibiting temperature gains of 0.55°C. Records show that the past 25 years have been the warmest time of the past 5 centuries (figure 2). The global warming has resulted in the warming of the oceans, rising of the sea levels, melting of glaciers, and diminished snow cover in the Northern Hemisphere.

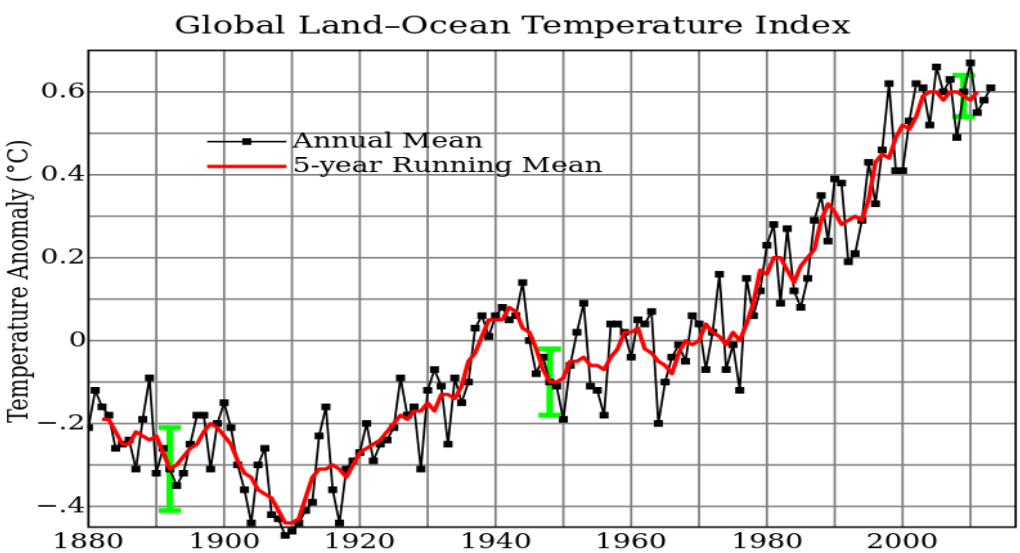

Figure.2: Global mean land-ocean temperature changes from 1880–2013, relative to the 1951–1980 mean. The black line is the annual mean and the red line is the 5-year running mean. The green bars show uncertainty estimates. (Source: NASA GISS, 2013)

IMPACT ON AGRICULTURE

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation and the interaction of these elements. Changes in crop phenology provide important evidence of the response to recent regional climate change. A significant advance in phenology has been observed for agriculture and forestry in large parts of the Northern Hemisphere (Rosenzweig, 2007). Studies have shown that increased CO_2 leads to

fewer stomata developing on plants (Woodward and Kelly, 1995) which leads to reduced water usage (Bert *et al*., 1997). A study published in *Science* suggests that, due to climate change, "southern Africa could lose more than 30% of its main crop, maize, by 2030. In South Asia losses of many regional staples, such as rice, millet and maize could top 10%".Droughts have been occurring more frequently because of global warming and they are expected to become more frequent and intense in Africa, southern Europe, the Middle East, most of the Americas, Australia, and Southeast Asia (Dai, 2011). Their impacts are aggravated because of increased water demand, population growth, urban expansion, and environmental protection efforts in many areas (Mishra and Singh, 2011). Droughts result in crop failures and the loss of pasture grazing land for livestock (Ding *et al.*, 2011)

IMPACT ON WATER RESOURCES

Climate change will affect water resources through its impact on the quantity, variability, timing, form, and intensity of precipitation. Additional effects of global climate change that have important implications for water resources include increased evaporation rates, a higher proportion of precipitation received as rain, rather than snow, earlier and shorter runoff seasons, increased water temperatures, and decreased water quality in both inland and coastal areas. These processes, in association with a shifting pattern of precipitation, may affect the spatial and temporal distribution of runoff, soil moisture, groundwater reserves etc. and may increase the frequency of droughts and floods.

Impact on flood and drought: Warmer average global temperatures mean greater evaporation, with a warmer atmosphere able to hold more moisture aloft that can fall as precipitation, increasing the potential for flooding. Change in climate can impact ecosystems in a variety of ways. For example with every 2^0F of warming there would be 5-15% reduction in current crop yield and 3-10% increase in amount of precipitation which would eventually lead to increased flood events. More global warming will lead to more evaporation which will cause more rains. Animals and plants cannot easily adapt to increase rainfall. Plants may die due to it and animals may migrate to other areas, which can cause entire ecosystem out of balance. There is evidence of prominent increases in the intensity and/or frequency of many extreme weather events such as heat waves, tropical cyclones, prolonged dry spells, intense rainfall, tornadoes, snow avalanches, thunderstorms, and severe dust storms in the region (Cruz *et al.*, 2007).

There are a number of factors that contribute to flood risks implied by a warmer climate, including: i) more frequent wet spells in middle/ high latitude winters, ii) more intense mid-latitude storms, iii) increased frequency of extreme precipitation events; iv) increased magnitudes of precipitation events of high intensity; and v) land use changes and surface degradation (for example, deforestation and urbanization).

Melting Glaciers: The melting of glaciers will create a wide range of problems for life thriving on earth. Melting of glaciers will lead to rise in the level of the sea which will lead to flooding and this will in turn create havoc as it will it endanger several species of plants and animals thus hampering the balance of the ecosystem. Moreover these large glaciers reflect light back into the space and with their meltdown earth will be further warmed. For instance the NASA satellite survey of Arctic has revealed that the ice coverage in 2002 was lowest in 20 yrs of arctic satellite monitoring. These observations are vital as it covers the whole arctic region and not just the areas accessible to researchers on surface. Their study also predicts that the Arctic Ocean will completely be devoid of summer ice before the end of 21st century. Syed Husnain, thechief author of the International Commission on Snow and Ice Report, WWF (2005) has reported that 67% of Himalayan glaciers are retreating and within 40 years most of glaciers will vanish. Out of 244 glaciers, 87% are showing net retreating i.e. losing 36 cubic miles of ice per year.Arctic temperatures increased by about 5 degrees during the 20th Century - 10 times faster than the global average.Snow cover has declined by some 10 percent in the mid-high latitudes of the Northern Hemisphere since the late 1960s and, in the Russian Arctic, buildings are collapsing because of thawing permafrost under the foundations.The dramatic changes occurring in the Arctic are being felt around the world. Melting glaciers contribute to rising sea levels, and also increased flash floods as river basins fill more quickly and with a greater volume of water, with the resulting impacts on freshwater availability.

Rising Sea Level: Coastal areas and islands are among the most densely inhabited areas in the world. Their proximity with sea makes them more prone to adverse effects of rising sea level such as loss of land due to inundation, flooding, erosion, salt-water intrusion and loss of fisheries and aquaculture. In most climate-change models, sea levels are predicted to rise by 9 to 88 centimeters by 2100, due to the thermal expansion of the oceans and the melting of polar ice-caps. The IPCC projects that global warming causes thermal expansion of water which will be the main component of expected sea level rise in 21st century in recent years. Enormous pressures have been put on Asia 's ecosystems to support the ever growing demand for natural resources. The most affected areas are coastal and marine ecosystems, forests and mountainous regions and the flora and fauna within them. Climate change will have a profound effect on the future distribution, productivity, and health of forests throughout Asia. For example northeast China may become deprived of conifer forest. Grassland

productivity is expected to decline by as much as 40 – 90 per cent for an increase in temperature of 2-3 °C combined with reduced precipitation, in the semi-arid and arid regions of Asia. Fisheries in both fresh water and sea water could be affected. Fisheries at higher elevations are likely to be adversely affected by lower availability of oxygen due to a rise in surface air temperatures. In the plains, the timing and amount of precipitation could also affect the migration of fish species from the river to the floodplains for spawning, dispersal, and growth (FAO 2003). Sea level rise and changes in sea water temperature, salinity, wind speed and direction, strength of upwelling, mixing layer thickness and predator response to climate change have the potential to substantially alter fish breeding habitats and food supply for fish and ultimately the abundance of fish populations in Asian waters with associated effects on coastal economies (Cruz *et al*., 2007).

Projected sea level rise could flood the residence of millions of people living in the low lying areas of South, Southeast and East Asia such as in Viet Nam, Bangladesh, India and China (Wassmann*et al*., 2004, Stern 2006, Cruz *et al*., 2007) and 30 percent of coral reefs could be lost in the next 10 years (Cruz *et al*., 2007). The loss may be as high as 88 per cent (59 per cent of global) in the next 30 years (Sheppard 2003; Wilkinson 2004).

Coral Bleaching*:* Warmer sea surface temperatures lead to coral bleaching, which is whitening of coral 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 a significant die-off of corals in some locations. It has been estimated that 10% corals have been lost, 30% are in critical condition and 30% are still under thermal stress (Down to Earth, August 1999).

Ocean Acidification: The oceans serve as a sink for carbon dioxide, taking up much that would otherwise remain in the atmosphere, but increased levels of CO_2 have led to ocean acidification. About one-third of the carbon dioxide emitted by human activity has already been taken up by the oceans (NRC, 2008). As carbon dioxide dissolves in sea water, carbonic acid is formed, which has the effect of acidifying the ocean, measured as a change in pH. The uptake of carbon emissions since the year 1750 has led to an average decrease in pH of 0.1 units (IPCC, 2007). Projections using the Special Report on Emission Scenario by IPCC suggest a further reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century.

IMPACT ON BIODIVERSITY

Extinction of species due to global warming may either be due to loss of habitat, inability of organisms to adapt to rapid climate change and lastly climate change harbors pathogens against which organisms have no immunity. For instance global warming has boosted fungal epidemic in midwife toads - *Alytesobstetricans*(Spain) and harlequin frog species *Atelopus* (Costa-Rica). The chytrid fungus *Batrachochytriumdendrobatidis* is a fatal pathogen of amphibians that that interferes with their ability to control water loss. These changes in climate can impact biodiversity either directly or indirectly through many different impact mechanisms. Range and abundance shifts, changes in phenology/ physiology/behaviour, and evolutionary change are the most often cited species-level responses. At the ecosystem level, changes in structure, function, patterns of disturbance, and the increased dominance of invasive species is a noted concern. Having a clear understanding of the exact impact mechanisms is crucial from the perspective of evaluating potential management actions. Subpopulations at the warmer edges of species ranges are being extirpated, causing a loss in genetic diversity (Thomas, 2005).

IMPACT ON HEALTH

Distribution of pathogens was earlier restricted due to seasonal temperature variations, but rise in temperature and increased moisture has resulted in their extended distribution, leading to higher rates of infection. For instance there has been 60% rise in bubonic plague in New Mexico because of wetter and warmer conditions than normal, also outbreak of distemper killed many lions in Tanzania in 2009 because warmer climate favored the spread distemper spreading flies. The major reasons for such outbreaks are; firstly, global warming provides conducive habitats for disease causing mosquitoes. Thus causing increase in transmission of infections via these carriers. Secondly, GHGs such as tropospheric ozone have been responsible for the depletion of stratospheric ozone, which would results in higher exposure to ultra violet rays of the sun, leading to an increase in the incidents of skin cancer, cataract and also suppression of the immune system. World Health Organization (2009) estimated that climate change was responsible for 3% of diarrhea, 3% of malaria, and 3.8% of dengue fever deaths worldwide in 2004. Total attributable mortality was about 0.2% of deaths in 2004; of these, 85% were child deaths. In Asia, the principal impacts of climate change on health will be on epidemics of malaria, dengue, and other

vector-borne diseases (Martens *et al* . 1999). The global burden of climate change-attributable diarrhea and malnutrition are already the largest in the world in Southeast Asian countries including Bangladesh, Bhutan, India, Maldives, Myanmar and Nepal in 2000. Illness and death are expected to increase from diarrheal diseases due to drought and flooding, and are also expected from increased amounts of cholera bacteria in coastal waters. An increase in the frequency and duration of severe heat waves and humid conditions during the summer is likely to increase the risk of mortality and morbidity, principally in the old and urban poor populations of temperate and tropical Asia (Epstein *et al.,* 1995) and high temperatures and poor urban air quality, such as in Chongqing, China and in Jakarta, Indonesia, could contribute to widespread heat stress and smog induced illnesses in urban populations (Cruz *et al.,* 2007).

INCREASE IN EXTREME EVENTS

A connection has been found between global warming and changes in the intensity, frequency and extent of disturbances such as fire, cyclone, drought and floods. This will place existing vegetation under stress and favor establishment of species able to rapidly colonize denuded areas. In many cases this will mean the spread of weed species and major changes in the distribution and abundance of many indigenous species. Large scale evaporation will be the major cause of droughts in many places particularly Africa. Although, its reeling under the huge pressure of water crisis, increased global warming would further make the situation worse and will cause malnutrition. Hurricanes frequency in western Atlantic has increased to 3% since 1970. The hurricanes belonging to category 4 and 5 on Saffir-Simpson scale are frequently occurring from the last 30 years (IPCC 4th assessment report). El-Niño are occurring after a period of 2 years due to global warming instead of normal gap of 4-5 years.

ADAPTATION ISSUES IN WATER RESOURCES SECTOR

- Hydrological Design Practices
- Surface Water and Ground Water resources assessment (Basin Scale)
- Water resources planning
- Surface Water and Ground Water resources Development
- Operation Policies including real time operations of existing as well as
- proposed water resources projects
- Flood and Drought Management (Short term and Long term strategies)
- Cropping pattern and water demands for irrigation
- Water Demand Management in different sectors
- Water Use efficiency
- Groundwater Management in coastal areas
- Evacuation and rehabilitation

MANAGEMENT OPTIONS TO MITIGATE CLIMATE CHANGE

- Minimum tillage or zero tillage with residue cover in surface for improving soil quality and conserving soil moisture.
- Cover cropping, in-situ residue management and restoration of degraded lands for soil moisture conservation and improved C-sequestration.
- Agroforestry with multipurpose trees, crops and animal components for improving hydrology.
- Integrated farming systems and watershed development with animal, fishery and hedge row cropping for soil and moisture conservation and nutrient recycling.
- Screening short duration varieties for their drought resistance.
- Popularization of technologies like system of rice cultivation and aerobic rice cultivation for water saving and mitigation of green house gas (GHG) emission.
- Rain water harvesting: in-*situ* (land configuration, mulching etc.) and ex-*situ* (Ponds, micro water harvesting structure -*jalkund*etc).
- In-*situ* biomass management in shifting cultivation (cover about 1.6 million hectare in NER) instead of biomass burning to reduce CO_2 emission and improve hydrology.
- Promotion of technologies that enhance biological N fixation and improve nutrient and water use efficiency to reduce N_2O emission and dependence on non-renewable energy.
- Change in planting dates and crop varieties are other adaptive measures to reduce impacts of climate change to some extent.

MITIGATION AND ADAPTATION IN AGRICULTURE

The Intergovernmental Panel on Climate Change (IPCC) has reported that agriculture is responsible for over a quarter of total global greenhouse gas emissions (IPCC 2007). Agriculture's share in global gross domestic product (GDP) is about 4

percent which suggest that agriculture is highly Green House Gas intensive. Innovative agricultural practices and technologies can play a role in climate mitigation and adaptation. This adaptation and mitigation potential is nowhere more pronounced than in developing countries where agricultural productivity remains low; poverty, vulnerability and food insecurity remain high; and the direct effects of climate change are expected to be especially harsh. Creating the necessary agricultural technologies and harnessing them to enable developing countries to adapt their agricultural systems to changing climate will require innovations in policy and institutions as well. In this context, institutions and policies are important at multiple scales.

Travis and Daniel (2010) suggest six policy principles:

[1]. the best policy and institutional responses will enhance information flows, incentives and flexibility.
[2]. Policies and institutions that promote economic development and reduce poverty will often improve agricultural adaptation and may also pave the way for more effective climate change mitigation through agriculture.
[3]. Business as usual among the world's poor is not adequate.
[4]. Existing technology options must be made more available and accessible without overlooking complementary capacity and investments.
[5]. Adaptation and mitigation in agriculture will require local responses, but effective policy responses must also reflect global impacts and inter-linkages.
[6]. Trade will play a critical role in both mitigation and adaptation, but will itself be shaped importantly by climate change.

STRATEGIES TO COMBAT CLIMATE CHANGE

All the nations face the risk of climate change although some might face catastrophic losses before others. In order to counteract the potential of massive risks three basic strategies have been put forth,

1) The waiting strategy envisages that before taking any substantive measures to combat warming we should wait, since all the data is not yet in. However, such an approach would create future problems as it might be found that the problem is real, the steps that would be taken for its mitigation then would be costly and painful than the measures that could be taken at the earlier stages. That is taking no action at all would be taking an unacceptable risk.
2) The worst case scenario strategy says that we should assume that the most extreme predictions are valid and act accordingly. This encompasses taking every possible step like decreasing fossil fuel burning, halting deforestation, encouraging reforestation, etc.
3) The compromise strategy says that we should follow a path that is environmentally safe and promotes generalwellbeing. It advocates a middle of-the-road approach. The focus of it is to develop policies, increase conservation, raise energy efficiency, hamper use of fossil fuels and lay more stress on sustainable use of renewable resource.

One way to discourage use of fossil fuel is to impose 'carbon tax' on their consumption. A carbon tax is levied in proportion to the amount of carbon emitted during consumption of fossil fuel. Such a tax will encourage development of non- carbon emitting technology. Another suggestion is to institute a standardized system of emission permits, both at national and global level that would allow organizations to emit certain amount of greenhouse gases into the atmosphere. Lastly, by controlling deforestation will not only abate the greenhouse effect via providing sinks that absorb CO_2, but will also preserve biodiversity, ameliorate climatic extremes and help to protect soil.

CONCLUSION

Hence it can be concluded that even though there is less scientific and political consensus concerning the severity of the threat of global warming. Still, in the case of greenhouse gases emission, every contribution towards the ultimate solution counts, as the beauty of all actions taken will offer numerous other benefits. This is a classical example of win-win strategies.

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