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GLOBAL WARMING: IMPLICATIONS AND ANTICIPATORY ADAPTIVE MEASURES

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Abstract: Our earth is warming up. There is no denying to this fact that the gradual heating up of our globe has a tremendous effect on the climate. It in turn has affected the biotic factors that make up our biosphere, eventually directing the course of our socio-economic development. Some workers are, however, optimistic about this natural phenomenon. Various ways have been suggested to mitigate the effects of global warming, but the damage already done cannot be revoked. Hence, the thing that we are left with is to go for anticipatory adaptive measures so as to tone down the intensity of future implications of global warming.

Key words: global warming, anticipatory adaptive measures, climate change, biophysical impacts

Introduction

There is a sudden uproar all-round the world about the increasing global temperature. Atmospheric CO_2 is accelerating upward from decade to decade. In the past decade, the average annual rate of increase was 1.91 parts per million (ppm). This rate of increase is more than double what it was during the first decade of CO_2 instrument measurements at the Mauna Loa Observatory. The concentration of CO_2 had gone from 350 ppm in 1950 to 385 ppm in 2009 [ESRL, 2009]. Statistically, the scientists all round the globe agree on appoint that our earth is definitely warming up. The change on earth is defined as "a change in the climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over comparable time period" [UNFCCC, 1997]. In this definition human has been accounted as the sole reason for the changes in the climate, which is opposable if we take into account the solar activities.

Global warming cannot be simply and wholly attributed to the increase in the green house gases (GHGs) due to human-activities. Solar activities and related aspects have to be given due consideration, at the same time. Since the solar activities are by the far, under-estimated and the activities of the human are more evident, we seem to direct all our attention and resources towards the "anthropogenic causes" of global warming. In this paper we have tried to sum up the impacts of the global warming and tried to take a holistic approach and discussed. The factors contributing largely to global warming have been dealt with in details to give a fair picture of the global scenario.

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Material and methods

This paper is a compilation of a large number of works done on global warming both by Indian as well as foreign researchers. The paper has been prepared with a simple, yet necessary perspective of summing up the effects of climate change due to global warming on vegetation and other living organisms and the ultimate effect on the socio-economic aspect. In due course, it is our belief that certain misconception and under-estimation of certain facts can be overcome. All the factors that appear to be contributing to global warming have been discussed with examples from different parts of the world to give a crystal clear picture.

Results and discussion

1. Biophysical Impacts (Tab. 1)

1.1. Climatic and Geological aspects

Temperature has evidently increased all throughout the globe. There has been an increase in global temperature over the years [IPCC, 2007] report. With the increase in global temperature, the temperature of the sea water has risen, decreasing the solubility of carbon-dioxide on its surface which ultimately increases partial pressure of CO_2. Consequently, uptake of CO_2 by ocean water has reduced, thereby increasing greenhouse effect. RAWAT & RAWAT (1998) and NEGI & al. (2003) observed that monsoon rains have declined over the past seven decades, whereas, the local rains have substantially increased, while studying rainfall pattern in Doon valley. Also, precipitation is likely to increase in the mid and the high latitudinally placed regions in the northern hemisphere [LEGGETT, 1990]. With the increase in the evaporation the amount of water-vapour in the atmosphere is bound to increase which will consequently increase the humidity, affecting the overall precipitation regime. Clouds account for the cooling effect in the Earth’s atmosphere. But if more clouds are formed at the higher altitudes (which are cooler), they will emit less radiation, supplementing to greenhouse effect and thereby increasing the temperature [RAMANATHAN & al. 1989]. Also it has been suggested by CHARLSON & al. [1987] that emission of di-methyl sulphide (DMS) by marine planktons, which serve as condensation nuclei, might act as global thermostat. This will increase in cloudiness and lead to cooling of the ocean surface. But this might also affect the activity of the plankton, thereby closing the loop.

According to the IPCC (2001), the pattern of wind is likely to change. The inter-decadal Pacific Oscillation and the Pacific Decadal Oscillation bring about variability in the climate of Pacific Basin. Likewise, North Atlantic Oscillation (NAO) accounts for the westerly over the Atlantic and the extra-tropical Eurasia, which are likely to become strong. A similar Antarctic Oscillation affects the westerly in the southern hemisphere which has shown an increase in the strength over the past 15 years. There would be a shutdown in the thermohaline and thermocline circulation.

The increase in the percentage of the atmospheric will cause an increased amount of CO_2 to dissolve in to the ocean. This leads to the formation of carbonic acid that lowers the pH of the ocean [UNEP, 2002]. In India, the Gangotri glacier has been receding at an average rate of 19m per year over the last 65 years [SHANKER & SRIVASTAVA, 1999]. Hence, melting of ice-caps and receding of glaciers will lead to increase in the level of the sea and submerge the low-lying coastal regions, consequently.

Climatic models have shown that drought is likely to increase from 5% to 50% by the year 2050 A.D. The hardest hit regions would be north Africa, south Africa, western Arabia, south east Asia, Mexico, Central America, south west USA, and the Mediterranean belt [IPCC, 1990]. The frequency and intensity of drought have been observed to increase in the recent decades. Also, part of the Amazon rain forest will turn into desert by 2050. Another concern is the possibility of a positive feedback loop, i.e., global warming can cause further warming in a vicious circle. Melting ice-caps appears to be causing the release of large amount of CO_2 and methane from decaying vegetation trapped beneath. It also could lead to increased heat absorption as ice reflects more because of its higher albedo than land and water.

1. 2. Edaphic factors

The decomposition of the soil depends upon the temperature of the soil, the presence/population of effective soil micro-flora and fauna, the type of litter (lignin: N ratio, carbon content etc.), availability of soil moisture in adequate amount, species composition and structure of plant community. It is an established fact that the colder biomes are much more sensitive and responsive towards global warming than the warmer ones. As a whole, litter decomposition in colder biomes is likely to increase, along with a steady influx of CO_2 into the atmosphere. The Q_{10} value, which is taken to be 2 for biological processes, is found to be 3-4 in the arctic regions [ROBINSON & al. 1983]. The decomposition rate has been found to be more in the colder and wetter sites of higher altitudes than the warmer and drier sites of the lower altitudes [MURPHY & al. 1998]. IPCC (1990) states that it is not possible to predict reliably either the geographical distribution of changes in soil-water or the net effect of these changes on carbon fluxes and storage in different ecosystems': with the increase in the temperature, summer monsoon rainfall has increased over the Indo-Gangetic plains between 1829 and 1999, whereas, it has been estimated that the Indian sub-continent is to experience a decline of 5-25% in the winter rainfall [BHARDWAJ & PANWAR, 2003], which would have a profound effect on the soil moisture status.

Climate change impact on water quality is the result of precipitation above the infiltration capacity of the soil or the exceedance of the water holding capacity of the soil volume causing drainage of water through soil-profile. Increase in precipitation amount or frequency of storm even with decreased total amounts in each storm can have serious implications for surface run-off, drainage and water quality [HATFIELD & PRUEGER, 2004]. Nitrogen and Phosphorus cannot be applied in the soil when the probability of rainfall immediately after application is high [EGHBALL & al. 2002].

1.3. Biological factors

Species diversity will decline. Forests will be rapidly destroyed without their restoration or replacement. Species will be lost as climate and habitat migrate out from under them. Also the specific ecotypes- specific combination of genes accumulated for each locale by selection through many generations – will also be lost. Forests will be substituted by savannahs, shrub lands and grasslands.

If we study the adaptation pattern in the world of fauna and flora we get to see the following:

Swamp Adaptations in plants

Stilt roots for support in swampy areas, breathing roots or pneumatophores in mangrove species (either seasonal or permanent) might be seen to fulfill the oxygen requirement of roots [CHANDRASHEKARA & SREEJITH, 2003]. This is in particular to the areas where the water table has increased and hence plants and trees exhibit such type of swamp adaptations.

Phenological Adaptations

Climate change has led to an advance in phenology in many species. Synchrony in phenology between different species within a food chain may be disrupted if an increase in temperature affects the phenology of the different species differently, as is the case in the winter moth egg hatch–oak bud burst system. *Operophtera brumata* L. (winter moth) egg hatch date has advanced more than *Quercus robur* L. (pedunculate oak) bud burst date over the past two decades. Disrupted synchrony will lead to selection, and a response in phenology to this selection may lead to species genetically adapting to their changing environment [MARGRIET & al. 2007]. BROWN (2003) reported the early flowering of meadow foxtail and coxfoot 7-10 days earlier in 2002 than in 2001.

Seed dispersal

Different palaeo-ecological records predict that a 2.5 °C warming equates to an altitudinal displacement of more than 400 m and a latitudinal displacement in northern Europe by more than 300 Km [HUNTLEY, 1991] which allows them to adapt to the long distance seed-dispersal mechanism.

Other adaptations

According to GRIME (1979), we should expect the competitive species that dominate many ecosystems to be replaced by more ruderal species which might show various adaptations, like shortening of life-span, greater commitment of resources to propagule production and exploiting disturbed situations. The reproductive phenology of the plants is likely to change like inbreeding depression, ovule abortion, non-viable pollen production, etc. [KHANDURI & al. 2003] Also the dates of cultivation are likely to change by $\pm$ one month in the warmer world. It is observed that if moisture is available, an increase in the temperature commonly increases rate of respiration by 10-35% or more per 1°C rise in temperature. In the warmer world, both the temperature and the moisture is higher which would increase the respiration rates of the living organisms, consequently reducing both net primary production and net ecosystem production [WOODWELL & WHITTAKER, 1968].

There are two schools of thought regarding the effect of global warming on the rate of photosynthesis. One says that increased level of CO_2 in the atmosphere with higher precipitation and temperature will increase photosynthetic rates in plants upto a certain limit. This will increase the net productivity or yield. For example, KELLOMAKI & al. (1997) reported that a combination of temperature increase of 0.4 °C per decade, 10% increase in annual sum of precipitation and 33 μ mol per decade increase in atmospheric CO_2 will increase timber yield by 30% in one rotation. Another group of scientists say that the warming in continental centers will increase the arid zones globally at the expense of currently forested areas which will lower the net production [WOODWELL & WHITTAKER, 1968].

The polar bear (*Ursus maritimus*), also known as the Great White Bear, Ice Bear, and Nanook, is the largest of the world's bear species. Polar bears live only in the Arctic and are completely dependent upon the sea ice for survival. Scientists have already recorded thinner bears, lower female reproductive rates, and reduced juvenile survival in the Western Hudson Bay, polar bear population in Canada, which is at the southern edge of the species' range and the first to suffer impacts from global warming. This mighty hunter now faces likely extinction by the end of this century because its sea ice habitat is literally melting away due to global warming [Centre for Biological Diversity, 2005]. *Atalopedes campestris* (skipper butterfly), a cold-intolerant species, has expanded its territory and now has a range edge between Yakima and Ellensburg as the winters have become warmer in the northern California [CROZIER, 2004].

Tab. 1. Impacts of global warming on the biophysical aspects

PARAMETERS		POSSIBLE CHANGES
Climate and Geological	Temperature	Increase
	Precipitation	Increase in local rains, decrease in monsoon rains in the tropics. Increase in the mid and high altitudes of the northern hemisphere
	Humidity	Increase
	Cloudiness	At high altitude it would be more, leading to positive GHE, in sea-surface it would show negative GHE
	Atmospheric and Oceanic circulation	Wind direction to change, westerly to become stronger, in both north and south hemisphere, shut down of thermohaline and thermocline circulation
	Ice-cap and Glaciers	Melting at steady pace, increase in sea level
	Ocean Acidification	Acidity will increase
	Drought and Desertification	5-50% increase by 2050 A.D. in the lower latitudinally placed regions in the north hemisphere
	Hurricanes, Storms and tsunamis	Will increase with time
	Compounding Effects	Further warming in vicious circle
Edaphic factors	Litter Decomposition rate	Likely to increase in the colder biomes; in the tropical regions, it is likely to increase unto a certain limit and then decrease
	Soil Fertility	Decrease with increased run-off and high rate of erosion
	Soil Moisture Content	Will increase in higher altitude and decrease in lower altitude (depending upon soil type)
Biological factors	Species composition	Change according to Location, Climatic and Edaphic conditions: a. extinction
		b. change in migratory habits and migration to suitable sites
		c. habitat fragmentation
	Adaptations in plant communities	
	a. Phenological Adaptation	Stilt roots
	b. Seed Dispersal Mechanism	Plants likely to adapt themselves to long distance seed-dispersal mechanism.
	Other Adaptations	Early blooming, fruiting, shortening of life-span, etc.
	Respiration Rate	Increase
	Photosynthesis Rate	Increase upto a certain level and then decrease

2. Socio-economic Aspects (Tab. 2)

Worldwide, hundreds of millions of people would be displaced by the inundation of low-lying coastal plains, deltas, and islands in this very century if efforts to reduce the GHGs are not successful (Tab. 3). The situation will be grave due to spread of aridity and eventually impoverishment [LEGGETT, 1990].

Taking into account the composite effect of climate, geology and edaphic factors, the agricultural production is likely to be highly affected. The summers of 1988 A.D. was recorded to be unusually hot the drought that followed caused a loss of 30% in the grain production in North America [IPCC, 1990).

In many cases the amount of food available to the population at large may not be greatly reduced, but certain sectors of the population may be significantly affected in terms of entitlement to food, either by reduced income or lack of resources by subsistence agriculture [STRZEPEK & SMITH, 1995]. Cities, Hydro-power projects, irrigated agriculture, shipping, the various uses of waterways, fish and fisheries, the transport, dilution and treatment of sewage, and the circulation of coastal and oceanic water are all dependent upon the flow of fresh water from the land. As water resources go on diminishing, there is an increased risk of conflicts amongst and within Nations [IPCC, 1990].With the increase in global warming; there will be a simultaneous increase in natural disasters. This, combined with the inter- and intra-national conflicts will cause extreme psychological disturbances to the survivors and the people involved in the conflicts [CHAMBERLIN, 1980].

Financial institutions, including the two largest insurance companies, Munich Re and Swiss Re warned that 'the increasing frequency of severe climatic events, coupled with social trends could cost almost US$150 billion in the coming decades' [UNEP, 2002]. Production of non-wood produce from forests will decrease due to insufficient accumulated winter chilling, thereby affecting the economy of the tribals severely in India [TEWARI, 1994].

During summers the need of the energy will heightened and in winter it is speculated to go down, affecting production of energy accordingly, if low and mid latitudes of northern hemisphere would become warmer [ROSENBERG & CROSSON, 1991].

Climate change will directly or indirectly affect the human health in various ways. The distribution of a range of diseases currently confine largely to the tropics, viz., malaria, trypanosomiasis, kalaazar, filariasis, and various worm-infestations are correlated to the temperature and could be affected by climate change as vectors of these pathogens would have an extended habitat range. Distribution of other non-parasitic communicable diseases yellow fever, dengue, plague and dysentery is also related to temperature [GILLETT, 1981]. Development and multiplication of various parasites within their hosts depend on the mean ambient temperature [GARNHAM, 1964].

Tab. 2. Impacts of global warming on the socio-economic status of human beings

PARAMETERS	POSSIBLE CHANGE
Human Settlement and Society	Millions of people to become homeless due to inundation of low-lying coastal regions
Agriculture and Food Production	Production potential of mid and higher latitudes will increase and that of the lower latitudes will decrease in the northern hemisphere
Food Entitlement	Per capita will decrease
Conflicts between Nations	Will rise over sharing resources, particularly water
Mental health	Will deteriorate with increasing natural disasters and conflicts

Tab. 3. Land and population at risk due to 1 meter sea level rise

Country	Land at risk		Population at risk	
	Sq. Km	%	Sq. Km	%
Bangladesh	25000	17.5	13	**11.0**
Egypt	4200-5250	12-15	6.0	**10.7**
Senegal	6042-6073	3.1	0.1-0.2	**1.4-2.3**
Malayasia	7000	2.1	NA	**NA**
Nigeria	18398-18803	2.0	3.2	**3.6**
China	125000	1.3	72.0	**6.5**
Venezuela	5686-5730	0.6	0.06	**0.3**
Uruguay	94	<0.1	0.01	**0.4**
Argentina	>3430-3492	>0.1	NA	**NA**
TOTAL	**194852-196498**	**-**	**94.4-94.5**	**-**

(Source: NICHOLLS & LEATHERMAN, 1995)

Adaptations

There are two types of responses to climate change and its consequences: Mitigation and Adaptation. Mitigation means retarding or limiting or eradicating the ‘causes’ completely; whereas, adaptation means acclimatization to the ‘effects’, rather than the causes. Broadly adaptations are of 2 types – ‘Autonomous’ i.e., biophysical adaptation to climate change by living organisms and ‘Fostered’ i.e., adaptations driven by policies [PARRY & CARTER, 1998]. Again fostered adaptations are of 2 types- ‘Reactive’ (policies taken as response to the changes) and ‘Anticipatory’ (policies taken in advance to anticipated climate change) [SMITH & al. 1996].

Amongst the said steps, anticipatory adaptations policies should be given priority as they give maximum assurance in minimizing potential negative impacts of climate change advance.

Why should we go for adaptations?

Mitigation and adaptation are complementary responses and both are needed to offset the effects of climate change on earth. But mitigating measures show many problems and have less feasibility during implementation, particularly in cases directly effecting economic development as adaptations deals with the impacts rather than the causes, it is more realistic. Again, anticipatory adaptations are preferred in case of uncertain and irreversible impacts, dependent on climate whose rate of change is very rapid, or threaten human health and safety and which may cause risk if we are to follow short term approaches depending upon sudden climate extremes (Tab. 4a). Anticipatory policies are to be examined before and after implementation to assess net benefit, flexibility, urgency, further research and equity and political feasibility (Tab. 4b).

Anticipatory measures are to be preferred over reactive measures because reactive measures cannot offset the negative consequences of climate change, once they occur, thereby affecting both biophysical and socio-economic aspects. Besides these (Tab. 4c), anticipatory adaptations provide more time to living beings as well as the society to adapt themselves to the changing climate.

Tab. 4a. Issues Involved in Determining the Need for Anticipatory Adaptation

Issues and Concerns	**Characteristics**
Uncertainty	Timing magnitude, direction of climatic change, impacts and their results are uncertain [SMIT, 1993]
Irreversibility	Certain impacts cause long term damages that require anticipatory adaptation
Effective life of policy	Long term decisions made today may need to be reduced down or toned down in future
Importance of climatic trend	Recent knowledge of storms or droughts should be taken into consideration to modify the long term anticipatory steps [GLANZ, 1988]
Rate of climate change	Reactive adaptation to a rapidly changing climate will be more difficult than to a gradually changing climate
Health and safety	Anticipatory steps can be said to be effective only if it does not harm or affect the health and condition of the ecosystem as a whole and jeopardize the safety of its components

(Source: SMITH & al. 1998)

Tab. 4b. Criteria involved in Designing and Implementing Anticipatory Policies

Criteria	**Properties/ Structures**
Benefit/ Cost Analysis	Discounted benefits of adaptation measures should substantially exceed the discounted cost to get the highest priority. A newly designed policy may not be appropriate if it does not take into account the special needs, e.g., threat to spp. extinction
Urgency	If the rate of change of climate is rapid rather than gradual, then the anticipatory policies should be implemented quickly to draw maximum benefit from it
Flexibility	It should be flexible enough to enable a resource to adapt itself successfully to a wide range of future climatic pattern, since the direction and the magnitude of climate change is uncertain
Use of Planning	Small adaptation policies with marginal action on pre-determined policies should be used so as to enhance the reacting ability of a resource system to climate change, within a low cost range
Mitigation Effect	It should be designed in such a way that it has a dual effect, i.e., these should help to mitigate climate-change impact to some extent, simultaneously with adaptation to climate change
Research	Appropriate research should be incorporated in the designing of the policy, though in case of urgency, there is little scope as it takes years to develop a model based on sustained climatic effects on various factors
Equity and Values	Every sector of a society should be treated and considered equally during policy designing, irrespective of their economic status. Policies should conform to the needs and wants of the human within the limitation of resources

(Source: STRZEPEK & SMITH, 1995)

Tab. 4c. Possible Anticipatory Adaptation Policies in Different Sectors

Sectors	Parameters	Possible anticipatory adaptation policies
Coastal Zone Management	Wetland Preservation	Healthy Wetlands are to be preserved so as to store the water of excessive precipitation
	Integrated Development	Identification of land areas to be affected by climate change and compilation of all data in an integrated form
	Improved Coastal Model	New and improved model to be made based on the prior evaluation of responses
	Land Use Planning	Perseverance of landscape, plans for shoreline development
Water Resources	Conservation	Drip irrigation, sprinkler irrigation, etc. are to be mass introduced by the government in agriculture
		Recycling of sewage water
	Market Allocation	Market based allocation of water
	Pollution Control	Assurance of quality and safety limits of water
	River Basin Planning	Sediment sluicing, maintenance of proper height of dam, length of canal, etc.
		International demarcations and compromise on common water resources
		Environmental concerns and socio-economic factors are to be given due consideration
	Drought Contingency Planning	Conservation of wetlands, building of reservoirs, ensuring efficient water use, prediction of drought years, etc.
Human health	Weather/ Health Watch/ Warning Systems	Prediction of possible outbreaks of diseases related to weather change
	Public health Improvement	Integrated pest management steps to combat large scale spread of contagious diseases
	Improvement of Surveillance System	Compilation and computation of future outbreaks based on previously collected relevant data
Ecosystem	Biodiversity	Ecological diversity and balance as well as the diverse gene pool are to be maintained
		Preservation of endangered spp. ex situ, preservation of their natural habitat, artificial regeneration
		Afforestation, reforestation and plantation (natural CO_2 sink)
Agriculture	Protection and Enhancement of Migration Corridor	Corridors and buffer-zones around the reserved areas should be protected
	Watershed Protection	Reforestation of areas in watershed to prevent bank erosion, siltation and soil loss
	Irrigation Efficiency	Improved irrigation methods are to be adopted to decrease water consumption, after computing cost benefit analysis
	Development of New Crop-Types	Development of better heat and drought tolerant crops

(Source: SMITH & TRIPAK, 1989)

Conclusion

Summing up what we have compiled in this work, we can conclude that it is a fact that climatic change due to global warming cannot be denied and already substantial losses have been faced with by the earth and its inhabitants. But again there remains extensive scope for further research and experimentations into the causes of global warming. Though certain impacts are positive, most of them that we see and can estimate are negative and pose to be threat to our very civilization on earth. Hence arises, the need to mitigate the same and adopt preventive measures. But, once the damage has been done, it becomes difficult to restore the situation. Therefore, it is advisable to adopt measures that are in anticipation to the changing climate, based on previous records and data of changes on earth. Anticipatory adaptive measures provide time and scope for better acclimatization and are more practical and feasible with respect to implementation.

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