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CLIMATE CHANGE: CAUSES, EFFECTS AND MITIGATION MEASURES-A REVIEW

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ABSTRACT

The Intergovernmental Panels on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCCC) have identified climate change as the greatest threat of the century and reported that the earth's average temperature has risen by 0.74^0 C. Furthermore, the present atmospheric concentration of carbon dioxide (CO_2) is 385 ppm (parts per million) far more than at any time in the last 650,000 years resulting in climate change or global warming. Both natural and human causes of climate change including the earth's orbital changes, solar variations, ocean currents, volcanic eruptions et cetera were reviewed. These various causes have resulted in rising sea levels, melting of ice at the world's poles and on its mountains and violent downpours resulting in over flooding and submerging of coastal areas and consequent migration of animal species; heat waves leading to desertification, depletion of water availability, reduced animal metabolism and agricultural food production, loss of biodiversity, food insecurity, decreased animal health et cetera. Some measures identified to have potentials to bring about climate change mitigation including the use of carbon capture & storage (CCS) technology and trading plants for carbon as carbon tracking devises; breeding of fuzzy-leaved crops and irrigation as techniques for cooling the atmosphere. Strategies for climate change adaptation through a multi-dimensional and multi-sectoral approach have become imperative as a result of inequalities between the developed and the developing nations in terms of limited capital resources and expertise. The successes recorded so far through these efforts are encouraging but they have not been able to drastically reduce the rise in atmospheric temperature, hence the consequences abound, especially in the developing countries like Nigeria. Several scholarly articles were scoured and presented and the paper concludes by positing that atmospheric rise in temperature should be brought below 2^0C by 2050 in tandem with Copenhagen and Kyoto Summits accord.

KEYWORDS: Climate change, causes, effects, mitigation, carbon emissions, adaptation.

INTRODUCTION

Global warming, otherwise known as climate change, has been increasingly recognized as the greatest threat of the century (Bowen, Mattia & Stren, 2010; Bloem, Semba, , Kraemer, 2010; Perkins, 2010; Graciano, 2010). Of all the holocausts that have afflicted mankind such as plagues, earthquakes, tsunami, smallpox, HIV/AIDS et cetera, none has the greatest threat to wipe out lives on Earth through either continuous flooding or permanent drought than climate change. It has been projected that about 9 billion people will inhabit the earth by 2050, most of which live in developing countries (Crowley, 2000; McMichael, 2001; Perkins, 2010)). Consequently, the world faces the most pronounced question over how our planet can sustain and feed this population due to climate change with its implications on food insecurity, access to clean water and sanitation, population migration and the threat of an increased number of both natural and man-made disasters (Crowley, 2000; Paehler, 2007). Scientists have tried to divide the causes into two broad categories, natural and human causes. The natural causes are many including earth's orbital changes, solar variations, volcanic eruptions and ocean currents. The human causes include burning of fossil fuels, land-use and deforestation (Paehler, 2007). The effects of these causes can be seen on rising sea levels, melting of ice caps, heat waves, violent downpours, animal metabolism et cetera. The efforts by researchers, scientists as well as the Inter Governmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC) to identify these factors are noteworthy. The impacts of these various factors, their interplay, synergy and tension on climate change, and the potential mitigation and adaptation strategies are hereunder highlighted. Although climate change has been recognized, studied and debated for decades but the recognition of the present high concentrations of green house gases in the atmosphere growing at an unprecedented rate and magnitudes with its obvious devastating consequences is relatively recent and should call for intensified studies.

The objective of the paper was to present an overview from scholarly articles on the causes, effects and impact of identified mitigation measures of climate change on the greenhouse gases (GHGs) emission reduction.

Causes of climate change

The natural variability and climate change fluctuations of the climate system have been part of the Earth's history however, there have been changes in concentrations of GHGs in the atmosphere growing at an unprecedented rate and magnitudes in recent years

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(Crowley, 2000; Paehler, 2007). The causes of climate change can be categorized into two:- natural and man-made causes (Crowley, 2000; Paehler, 2007).

(a)Natural causes

The earth's climate is grossly influenced and changed through natural causes such as ocean current, volcanic eruptions, the earth's orbital changes and solar variations

i) Ocean current

The oceans have been shown to be the major component of the climate system. Ocean currents move vast amounts of heat across the world. Wind push horizontally against the sea surface and drive ocean current patterns. Interactions between the ocean and atmosphere can also produce phenomena called El- Nino which occurs every 2 to 6 years. It has been shown that deep ocean circulation of cold water move from the poles towards the equator and warm water from the equator back towards the poles. Without this movement the poles would be colder and the equator warmer. The oceans play an important role in determining the atmospheric concentration of CO_2. Changes in ocean circulation may affect the climate through the movement of CO_2 into or out of the atmosphere (Brown, 2010; Hoffman, et al.,2010; Shanta Barley, 2010) .

ii) Volcanic activities

Volcanic eruptions are known to throw out large volumes of sulphur dioxide (SO_2), water vapour, dust and ash into the atmosphere. It is known that large volumes of gases and ash can influence climate patterns for years by increasing planetary reflectivity, causing atmospheric cooling Tiny particles called aerosols are produced by volcanoes. Because these reflect solar energy back into space, they have a cooling effect on the earth's surface (Ammann, Washington, Meehl, Buja,. & Teng, 2010; Bowen, 2010; Paehler, 2007;). (See Satellite Imagery of Volcanic Eruption below. Source: ISTOCKPHOTO / LOOPS7)

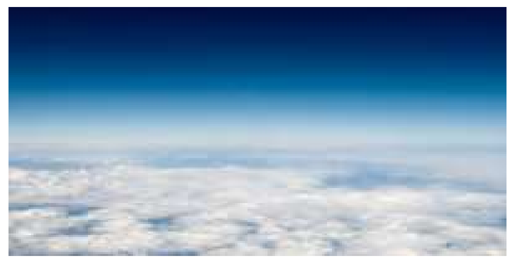
Explosive Volcanism Source: istockphoto / loops7

iii) Earth's orbital changes

The earth makes one revolution around the sun once a year, tilted at an angle of 23.5^0 to the perpendicular plane of its orbital path. Changes in the tilt of the earth can lead to small but climatically important changes in the strength of the seasons, more tilt means warmer summers and colder winters; less tilt means cooler summers and milder winters. Slow changes in the earth's orbit lead to small but climatically important changes in strength of the seasons over tens of thousands of years. Climate feedbacks have been shown to amplify these small changes, thereby producing ice ages (Crowley, 2000; Paehler, 2007; Perkins, 2010) .

iv) Solar variation

The sun is known to be the source of energy for the planet's climate system. Although the sun's energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes. It has been speculated that a portion of the warming in the first half of the 20^{th} Century was due to an increase in the output of solar energy. As the sun is the fundamental source of energy that is instrumental in our climate system, it would be reasonable to assume that changes in the sun's energy output would cause climate to change. But studies by Crowley (2000) and Paehler (2007) have shown that if this were so it would be expected to see warmer temperatures in all layers of the atmosphere. On the contrary, the cooling was observed in the upper atmosphere, a warming at the surface and in the lower parts of the atmosphere. This was shown to be due to greenhouse gases capturing heat in the lower atmosphere. (See Satellite Imagery of different layers of atmosphere below)



Layers of Atmosphere
Source:.istockphoto/@tbradford

Furthermore, climate models that included solar irradiance changes could not reproduce the last century's observed temperature trend without including a rise in greenhouse gases suggesting that GHGs are the main cause of climate change (Paehler, 2007).

v) Cloud's contribution

Perkins (2010) reported that global satellite analysis supported by climate models have revealed that cloud cover accentuate warming because as earth's average temperature rises, clouds will accelerate global warming by trapping more heat. Dessler (2010) analyzed satellite data gathered between 2000 and 2010 to estimate the short-term variations in the amount of visible and infrared radiation emitted to space. He made an allowance by subtracting influences such as earth's surface reflectivity and the heat-trapping effect of atmospheric water vapour as well as how clouds affected the planet's radiation balance as a function of temperature over the decade. The result showed that clouds enhance warming by trapping on average, an extra 0.54 watts per square metre for every 1^0C rise in global average temperature. Dessler (2010) however, posited that uncertainty in the estimate indicates that clouds could actually exert a small cooling effect as temperature rises, although the slight negative feedback wouldn't be nearly enough to cancel out larger, well-constrained positive climatic feedbacks such as water vapour (Dessler, 2010). In the tropics, for example, Nigeria, the North East Trade wind brings cloudless atmosphere called harmattan with dry air and a cooling effect to the atmosphere. A model that can mimic this will have positive impact on climate change mitigation, provided it does not have negative feedback that could cause permanent drought.

b) Human causes

It has been shown (Paehler, 2007) that climate is changing due to man-made greenhouse gases from burning fossil fuels for electricity, cars, trains, aircrafts, homes, flaring of gas at the oil fields like in Nigeria et cetera. Furthermore, land-use and deforestation add pressure to greenhouse gases.

Effects of climate change

The IPCC (2007) report has succinctly identified the most relevant impacts of climate change on human health as "changes in conditions, temperature, rainfall, humidity, and wind likely to alter the intensity and geographical distribution of extreme weather events, raise water levels in coastal regions, alter the distribution of vector insects and mammals, exacerbate health-relevant air pollution, intensify the existing burden of malnutrition, and increase human exposure to toxic substances due to the deterioration of natural and man-made environment" (Graciano, 2010). Some of these effects are highlighted below:-

i) The dance of climate change and nutrition: Effects on Metabolism

Perkins (2010) has reported that the energy efficiency of insects may plummet as temperatures rise due to climate change. He observed that warming could cause insects of some species to starve even when surrounded by prey. Brose and his team (Perkins,2010) collected data on the metabolism and feeding habits of three species of predatory beetles in temperatures ranging from 5^0C to 30^0C. They observed that beetles feeding on insect larvae, which are relatively immobile, caught prey at the same rate in cool and warm conditions, but those fed on mobile prey such as fruit flies, however, captured food more often at higher temperatures because mobile prey were more active in a warmer environment and thus encountered predators more often. The study concluded that despite the higher capture rate, the overall energy efficiency of these predators dropped considerably, due to increase in metabolism, which accentuated energy expenditure (See Satellite Imagery of a predator waiting for its prey below).

Predator waiting for its prey
Source: istockphoto/LHENRIK_L

The team applying ecological model is of the view that future warming could prevent some types of predatory insects from getting enough energy to support their revved-up metabolism (Vucic-Pestic *et al*. (2010). Although the model has not simulated the impact on human metabolism, but one can argue that this in part could account for the present scourge of HIV/AIDS and other energy demanding diseases that are pandemic in the tropics particularly, in the sub-Saharan Africa like Nigeria where atmospheric temperature is high with the corresponding high metabolism and energy expenditure.

ii) Impact on Ski Industry

Toglhofer, Eigner & Prettenthaler (2010) have reported that if recent trends are any indication, climate change in the coming decades will hit the Austrian ski industry hard, with artificial snowmaking unable to keep pace with an anticipated decline in natural snowfall (See Satellite Imagery of Artificial Ski Industry below).

Artificial Ski Industry
Source:© ISTOCKPHOTO / ARTBOYMB

Töglhofer et al.(2010) used economic and meteorological data gathered during the winters of 1973 through to 2007 and assessed how snow conditions at 185 of the nation's ski areas in Austria affected hotel occupancy[1]. They hypothesized that if, over the course of a winter, the number of days with at least one centimetre of snow on the ground dropped by about 12 per cent below average, hotel stays decreased by 0.6 to 1.9 per cent, which at current rates of tourism equals about 300,000 to 800,000 fewer overnighters for that ski season. The researchers found that from the late 1990s through to 2007, the tourism-stifling effect of a snow-poor winter almost disappeared, a trend that might be attributed to the proliferation of artificial snowmaking at many of the resorts. The short-term technological success in bolstering the ski industry may not prove effective much longer, though. In a separate study, Steiger (2010) used regional climate models to estimate future ski-season length and snowmaking requirements for three areas in western Austria. At resorts near Innsbruck, where the average ski slope lies at about 1,500 metres, today's snowmaking equipment, which requires temperatures of -5^0C or lower to function, can generate enough artificial snow to produce an economically viable 100-day ski season only until the 2030s. Resorts with slopes at higher elevations may remain relatively safe until the end of the century, although artificial snowmaking for those regions will be costly, the study suggests (Toglhofer, 2010).

iii) Impact on wind energy

Research has indicated (Ren, 2010) that global warming could reduce the amount of wind energy available at mid- and high-latitude regions. Ren (2010) used eight different global climate models, and compared the amount of wind power available during the last three decades of the twentieth century with the amount that could be extracted during the last three decades of this century. The study revealed that all models showed a decline in available wind power by 2100, with two of the models indicating decreases of approximately 14 per cent if greenhouse gas emissions grow at a moderate rate and rise to 720 parts per million by the end of the century. The study noted that this observation is because the atmospheric warming causes wind energy in mid- and high-latitude regions to decline as average winds there are driven by the difference in temperature between the equator and the poles — a gradient that will decrease as polar warming outpaces that in the tropics and concluded that the earlier the switch to wind energy the more cost-efficient that transition will be (Ren, 2010).(See Satellite Imagery of Wind Turbine below).

Wind Turbine.
Source: © ISTOCKPHOTO / ZENTILLA

iv) **Extreme weather changes**

1. Barley (2010) of National Aeronautical and Space Administration (NASA) has reported that between 1978 and 2007 the number of summers in the southeastern United States affected by drought or heavy rain doubled compared with the previous 30 years, and noted that it was because climate change is intensifying the Bermuda High, an area of high pressure that forms each summer over the Atlantic causing monsoon rain and submerging coastlines. Li *et al*. (2010) analyzed weather and climate data from 1948 and 2007 and found that the intensity of the Bermuda High increased causing it to expand westward at the rate of 1.2 degrees longitude per decade (Stanton & Ackerman, 2007; Pfeffer, Harper & O'Neel, 2008. (See NASA Satellite Imageries of Bermuda High, the Monsoon rain and the Submerging Florida coastlines below).

2.

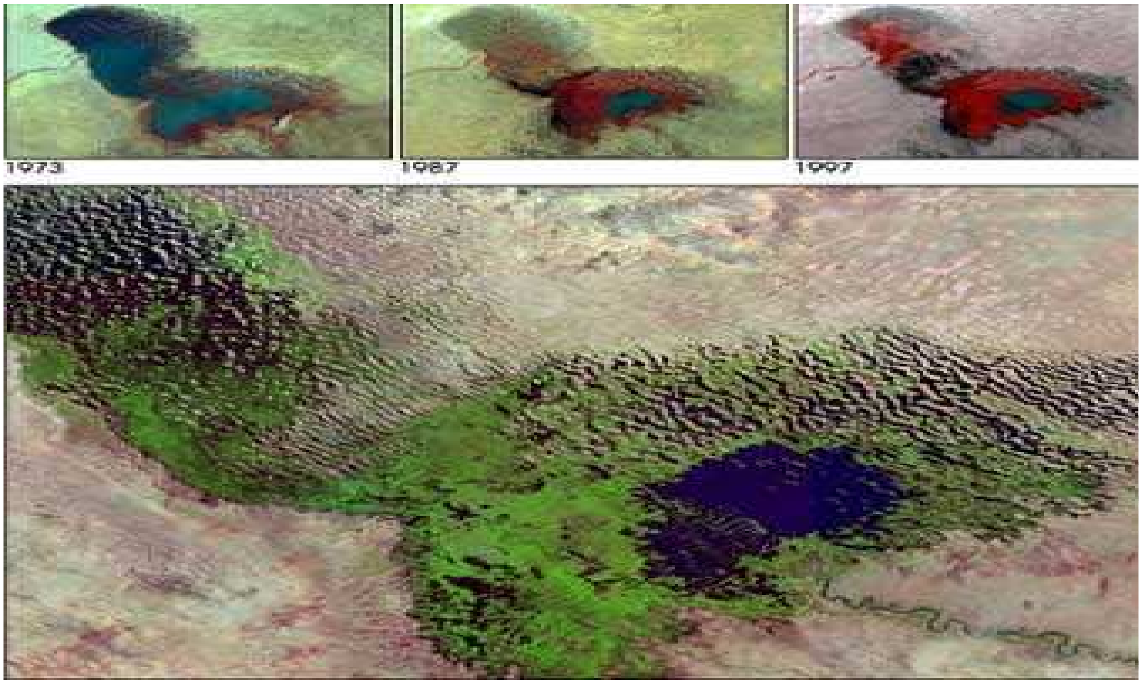
Bermuda High. Source: NASA

Monsoon rain.
Source: © ISTOCKPHOTO/MAC99

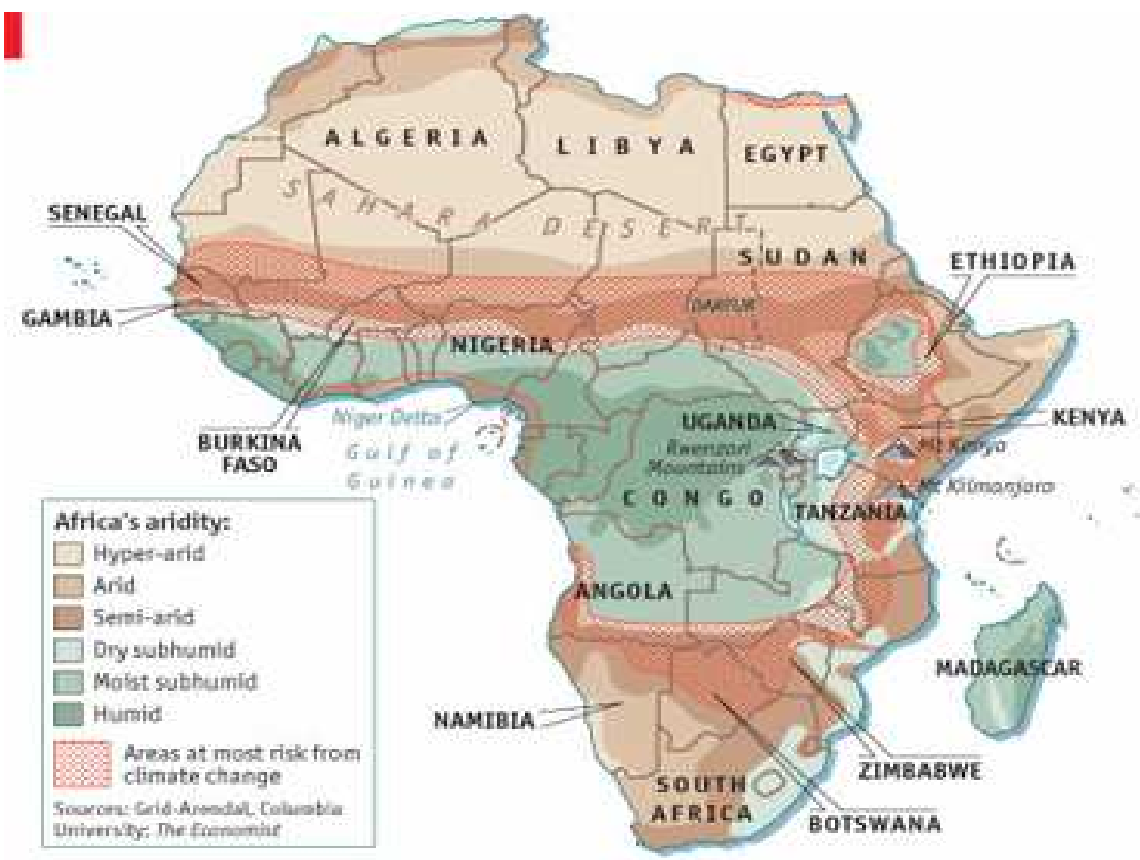
Submerging Florida Coastlines.
Source: ISTOCKPHOTO / ROBERTO ADRIAN

The report also showed that variability in the western extent of the high-pressure system increased by 47 per cent in the past 30 years compared with the previous three decades and noted that southward movement of the western ridge increases the likelihood of rain, whereas northward movement enhances drought. When they used models to mimic the Bermuda High, it was observed that only those forced by rising levels of greenhouse gas (GHG) succeeded - implicating climate change as the cause. Li *et al*.(2010) concluded that future climate change will exacerbate the likelihood of drought or violent thunderstorms in the region, boosting soil erosion and reducing crop yields (Seth, Rauscher, Rojas, Giannini, & Camargo, 2010). The scenario is somewhat similar in Africa and Nigeria in particular. For instance, the negative effects on soil erosion, drying up of lakes such as lake Chad, , desertification in Namibia, food insecurity et cetera are obvious in these regions. In Ethiopia, a report by Oxfam International shows that farmers and pastoralists are the worst hit due to their ruined crops and dying cattle (http://www.climatechangechallenges.org/). It is a truism that water is already in short supply worldwide for instance; irrigation wells are increasingly coming –up empty in the Punjab Plains of India, the China Plains and the American Plains, the world Grain-growing Regions (McKibben, 2008). The warmer weather due to climate change is melting glaciers across the tropics and temperate latitudes in many parts of Asia and South America. These glaciers provide the drinking water for a greater part of the population in the regions (Adams, 2005; Kaser, Großhauser,. & Marzeion, 2010). However, some global warming forecasts predict that, with the ever increasing evaporation, the Great Lakes behind the western dams and other lakes across the globe will never fully fill again (McKibben, 2008;

Workman, 2009). (See the Satellite Imagery below of drying-up lake Chad, desertification in Namibia and the regions that are worst hit in the entire Continental Africa).



Chad-Lake, Satellite picture 2001, the small blue spot is the lake today, the green area is the vegetation on the ground of the former lake. At the top: the contraction process, Source: WIKIPEDIA



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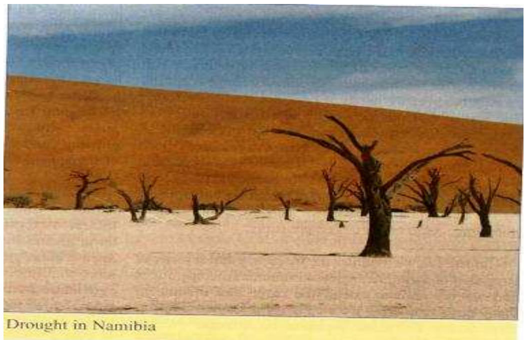
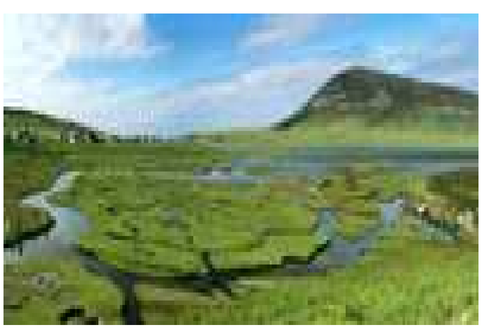


Drought in Namibia
Source:SIGHT AND LIFE Magazine
Source: Connecting the Environment

v) Rising sea level

Work has shown that if sea-levels should rise by a metre or more, then many coastal marshes would be submerged by seawater, even those that continue to accrete sediment (Balsillie & Donoghue, ,2004; Hoffman et al, 2010; Walton, 2010; Walton Jr & Dean, 2010) The researchers maintained that coastal marshes are not just passive casualties of rising sea levels but respond dynamically to changes in inundation, vegetation and sedimentation. The worker concluded that if the sea-level rise is restricted to around 30cm, with minimal ice-sheet contributions over the coming century, many marshes will be able to keep pace with rising seas and maintain their position. However, a sea-level rise of more than a metre would permanently submerge most coastal marshes, including many that will continue to grow by accretion (Brown, 2010). They reported that an increase in air temperature can cause glacier melt-water production to rise and this would exacerbate climate change. The negative impacts of climate change on rising sea level is same in Africa and Nigeria in particular. Victoria Island, Lagos, Nigeria has been threatened by rising sea level. It has been shown that the rise of sea level of only 20cm would imply a displacement of 740,000 people in Nigeria, a rise of 1metre, would lead to a displacement of over 3.7 million people and a rise of 2metre to 10 million homeless people in the country (Paehler, 2007). The UNCCC reported about the menace and alerted that one day the city (Lagos) with over 20 million people might be submerged (Paehler, 2007; Bassey, 2007). (See Satellite Imagery of the effects of rising sea levels and melting of glaciers below).



Over flooding the coast areas
Souece:© ISTOCKPHOTO / Lesley Jacques

Glacier melting. Source: Ansel Adams, 2005

Glacier meltwater. Source:
© ISTOCKPHOTO / SARA_WINTER

Overflowing Sea. Source:© ISTOCKPHOTO / CHRISCRAFTER

* **Mitigation measures**

The entire world has applauded the Copenhagen and Kyoto agreements to bring down the atmospheric temperature rise caused by GHGs emission to below 2^0C by 2050 due to the obvious consequences of its effects. The identified climate change mitigation measures are many including:-

*** Agriculture and its complex effects**

It has been shown that rainforests are capable of absorbing about 20% of carbon from the atmosphere through the photosynthetic process. Accordingly, scientists are currently employing the great potentials of our ecosystem to bring about climate change mitigation (http://www.climatechangechallenge.org/).

i) Use of animal and plant diversity and species

Researchers in Antarctic sea are incubating water along with organisms ranging from viruses to microscopic plants (phytoplanktons) to small marine animals. The research was conducted under three carbon dioxide (CO2) regimes: the pre-industrial, the current level and the maximum level of less than 2^0C rise in temperature as projected for the end of the 21st Century according to IPCC in Copenhagen on climate change. This was to ascertain how an increase in carbon dioxide changes phytoplanktons and how that affects other ecosystem such as zooplanktons, bacteria and viruses (Perkins, 2010) On the land researchers are working with diverse and large number of plant species with a view to combat climate change (Alderman, 2010). Smith, Powlson, Smith, Falloon & Coleman (2000) have demonstrated that fuzzy-leaved varieties of plants could help ameliorate climate change. They explained that hair-like structures on leaves tend to scatter light and reduce leaf temperature on individual plants and thus bring about the cooling effects of the structures and the environment.

Fuzzy-leaved plants.
Source:© ISTOCKPHOTO / JOEYSLIM

Doughty et al.(2010) used a model to simulate the impact of global climate of several scenarios in which reflectance of light from leaves of all plants across the globe was enhanced by varying amounts within certain ranges of wavelengths. They found that the cooling effect was most pronounced at latitudes above 30^0, where each 0.01 rise in albedo – a measure of surface reflectivity, decreased daily high temperatures in agricultural regions by an average of 0.25^0C. The researchers used 16 varieties of soybean and observed that today's hairy-leaved plants would not be able to cool the climate enough to counter global warming expected in the coming decades. It was however, suggested that aggressive breeding of new varieties of fuzzy-leaved plants for use in the high latitudes could bring down global temperature (Doughty et al., 2010; Perkins, 2010).

ii) Irrigation

Research has demonstrated that through enhanced evaporation, irrigation cools the earth's surface and provides a counter balance to global warming, particularly in the higher latitudes but additional warming from the tropics if not checkmated is capable of throwing that balance off-kilter (Perkins, 2010).

Irrigation
Source: © ISTOCKPHOTO / SONGBIRD839

A team led by climate Scientist Benjamin Cook, of NASA's Goddard Institute for Space Studies in New York City compared the irrigation –induced cooling generated during the year 2000 with that expected in 2050 if atmospheric concentrations of carbon dioxide rise to about 40 per cent higher than they are now. The researchers noted that in today's climate, the regions that benefit most from irrigation-induced cooling are North America, India, the Middle East and eastern Asia but the evaporative cooling in these regions will not be equally affected by increased atmospheric warming. The workers explained that in North America for instance, if precipitation declines in areas downwind of irrigated regions as expected, a reduction in the surface water available to soak up energy during evaporation will diminish the cooling effect. On the other hand, the situation is different in China where humidity limits today's evaporative cooling and climate change is expected to lead to a drier atmosphere, which would enhance evaporation and consequently boost the cooling from irrigation (Perkins, 2010). African countries particularly, Nigeria should take advantage of their vast agricultural land to engage in massive irrigation system of agriculture so as to benefit from the irrigation –induced cooling. Accordingly, expansion of various River Basins and FADAMA projects in Nigeria are apt in this regards.

iii) Trading plants for carbon

It has been advocated that in the tropics, a complex trade-off exists between expanding agriculture and keeping carbon locked up on the land (West et al., 2010; Perkins (2010) advised that farmers particularly those in the tropics should focus on boosting crop yields on already cleared land to prevent carbon emissions. This is because in the tropics, farmers engage in bush-burning and other farming practices that boost carbon dioxide emissions. Paul West and colleagues at the University of Wisconsin- Madison used soil and agricultural data gathered worldwide to estimate the carbon that would be lost if natural ecosystems are cleared for farming food or bio-fuel crops. They found that carbon lost from clearing varies widely between the temperate region and the tropics (West *et al*., 2010). In the temperate region each hectare of forest cleared would release about 63 metric tons of carbon, whereas in the tropics the same area would release about 120 metric tons of stored carbon. The paper concluded that farming should be on already cleared land.

iv) Clean biomass systems

Research has shown that a great potential exists for clean biomass systems to reduce greenhouse gas (GHG) emissions.

Carbon emission.
Source: © ISTOCKPHOTO / JILLKYLE

Whiteman and Lehmann (2010) observed that when biomass is burned inefficiently as in conventional cooking stoves, some carbon which was hitherto regarded as carbon-neutral is returned to the atmosphere in the form of methane and carbon monoxide – greenhouse gases that are even more powerful than carbon dioxide, but when these conventional stoves were replaced by cleaner-burning types, a reduction of about 30 per cent greenhouse gases (GHGs) was achieved (Perkins, 2010; Bowen, 2010). The reviewers working on a cleaner biomass gas for domestic uses have found equally positive correlation (r = + 0.6, P<0.05) between conventional cooking stoves and the cleaner biomass gas fuelled version in greenhouse gases (GHGs) emission reduction.

v) Soil science : Effects of soil organic carbon (SOC)

It has been reported that soil organic carbon (SOC) inventories are important tools for studying the effects of land-use and climate change and evaluating climate change policies. Neufeldt (2010) studied carbon stocks and sequestration potentials of agricultural soils in the Federal State of Baden-Württemberg, Germany and showed that no-tillage agriculture (NT) and peat land restoration could contribute to carbon sequestration and greenhouse-gas emission reduction. The researcher observed that on the average, grassland contained 9.5kgCm^{-2} to 0.3 metre depth as compared to only 6.0kgCm^{-2} under cropland indicating strong land-use effects. The SOC content the researcher noted depended strongly on water-logging and elevation, thus reflecting reduced C mineralization under aquatic moisture conditions and low temperatures. The results on simulated effects of NT and peat land restoration indicated that 5 to 14 per cent of total agricultural GHG emissions could be abated with NT, whereas peat land restoration had minor mitigation potential (0.2% to 2.7%) because the total area of cultivated organic soils was too small to have larger impact (Neufeldt, 2005; Smith, Powlson, Smith, Falloon, & Coleman, (2000)). The land-use/land-management strategies for the mitigation of GHG emissions under Kyoto Protocol emphasized such activities including a forestation, reforestation, and bio-energy crop production and that a combination of these strategies will produce better results than a single factor, the report noted (Workman, 2009; Roston, 2009).

* **Natural Phenomena**

Work has shown that natural processes including solar activity, and explosive volcanism are known to have cooled the climate in the past (Brown, 2010). However, mimicking these processes could counteract global warming, though the effects would not be uniform due to extra cooling required in the tropics to balance high latitude warmth (Brown, 2010). Ammann *et al*.(2010) studied the potential of climate engineering approaches that mimic natural processes to counter greenhouse-gas-driven global warming. Their models revealed that injecting sulphate aerosols into the atmosphere and reducing solar insolation using mirrows would have to be much larger in effect than natural forcing so as to effectively off-set global warming (Ammann *et al*., 2010; Perkins, 2010;). The researchers equally noted that in addition to the direct effect that greenhouse gases (GHGs) have on the climate, strong negative feedbacks in sea-ice extent, ocean heat content and winter westerly winds enhance warming particularly in the high latitudes. They, therefore, concluded that if climate engineering would be employed to resolve climate change, then it would be necessary to induce greater cooling over the tropics to balance out polar warming (Ammann *et al*., 2010).

* **Global economic imbalances**

The world economic imbalances affect climate change. Bowen et al (2010) have succinctly posited that climate change is the greatest challenge of the century and that it is all about marker failure on a global scale that must be resolved together with debt and global economic imbalances. On the carbon emission reduction, the authors maintained that the world should move to low-carbon economy. They noted that business as usual would likely lead to a concentration of greenhouse gases (GHGs) that would entail temperatures not seen for tens of millions of years with of course drastic consequences. The researchers gave the present annual GHG emissions to be about 47 billion metric tons of carbon dioxide equivalent and argued that for a 50 per cent probability of keeping the global temperature rise below 2^{0}C in line with Copenhagen Summit Accord for avoiding climate change, emissions would need to fall to about 44 billion metric tons by 2020, well below 35 billion metric tons by 2030, and well below 20 billion metric tons by 2050. The authors concluded by advocating complete decarbonization of electricity production by 2050. They also stressed that strong and sustained investment in emission reduction and carefully designed policies are urgently needed to correct the market failure caused by greenhouse gas emission externalities. Any delay action is dangerous because emission flows build into increased concentrations of GHGs, which are hard to reduce (Bowen *et al*., 2010). It is indeed a paradox that Africa's share of these GHGs emission is less than 4% of the global average, yet suffer most from its consequences, a typical case of negative external effects, an externalization of costs (Paehler, 2007; Bassey, 2007).

* **Government policies on adaptation to climate change**

Climate change is clearly a threat to humanity and better and effective policy options for tackling obstacles and barriers are critical to climate adaptation and practical climate change mitigation. Various frameworks have been developed to help policymakers and scientists identify barriers that could delay adaptation to climate change (UNFCCC, 1994; Sperling, 2003; Huq , Reid & Murray, 2006; IPCC, 2007; Roston, 2009; Moser & Ekstrom, 2010; Perkins, 2010; Kirwan et al., 2010). Susanne Moser and Julia Ekstrom both at the University of California scoured hundreds of academic papers to gather data on barriers to climate adaptation and possible responses from which they developed a framework based on common phases of rational decision-making: understanding the problem, developing, assessing, and selecting appropriate responses, and managing and evaluating the implementation of those responses. Their findings resulted in a multi-phase schema filled with concepts that is very flexible enough to be applied to any type of climate adaptation. In a nutshell, the schema emphasizes on spotting where some of the most challenging obstacles to climate adaptation lie and the right framework to assess what barriers are the most intractable and the policymakers with the opportunity to better allocate resources and to strategically design processes to overcome the obstacles (Moser & Ekstrom, 2010; Kirwan et al., 2010; Huq , Reid & Murray, 2006). Africa is indeed exposed to a number of resource-consuming stressors (ranging from HIV/AIDS to food insecurity to corruption to permanent crises and conflicts), thus comparatively few resources remain to react proactively on the climate change challenge. Climate change is indeed an external shock to the continent caused by the externalization of costs of a third party. Payments and assistance can be considered as a reasonable way to compensate Africa for the negative climate change impacts (Paehler, 2007). For instance, during the German – African Summit in Accra, Ghana, 2007, initiated by the Federal President of Germany, the former Nigerian President, Olusegun Obasanjo, appealed for international assistance in order to enable the African continent cope with the consequences of climate change. He observed that all countries should adhere to the respective international agreements. The dominant role of agriculture in Africa makes it obvious that even minor climate deteriorations can cause devastating socioeconomic consequences (Paehler, 2007).

The difference between the developed and the developing countries in climate change mitigation approaches is worthy of note. While the developed countries have the technological capacity including the use of Carbon Capture & Storage (CCS) Technology, the developing nations don't have such capabilities. For instance, Robin Hood Tax (http://www.robinhoodtax.org.uk) which is a 0.05% tax was suggested on European banks that would raise over £100bn to help developing countries to adapt and cope with the devastating effects of climate change in their regions. This has become pertinent as developing countries particularly, Africa produces the least GHGs, yet bears the greatest brunt of the consequences of climate change (Bassey, 2007). The IPCC reported that the world average temperature has continued to rise but that the extent, duration and severity of its consequences will strongly depend on how quickly and effectively the greenhouse gases can be drastically reduced, thus complete decarbonization of electricity production to 'kick start' massive reduction of carbon emissions should be sorely pursued in tandem with Copenhagen and Kyoto accords.

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