CLIMATE CHANGE: CAUSES AND EFFECTS ON AFRICAN AGRICULTURE

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ABSTRACT

Climate is the primary important factor for agricultural production. Science has made enormous efforts in understanding climate change and its causes, and is helping to develop a strong understanding of the current and potential impacts that will affect people today and in the future. This understanding is crucial because it allows decision makers to place climate change in the context of other large challenges facing Africa and the world. This study reviews the causes and effects of climate change on agriculture in Africa. The main interests are findings concerning the present and potential impacts to agricultural systems, role of human adaptations in responding to climate change, and potential changes in patterns of food production.
Keywords: *Climate change, global warming*

INTRODUCTION

The terms climate change and global warming are often used interchangeably (Manstrandrea and Schneider, 2009). Within scientific journals, however, global warming refers to surface temperature increases, while climate change includes global warming and everything else that increasing greenhouse gas amounts will affect. The Intergovernmental Panel on Climate Change (IPCC, 2001) defines climate change as any change in climate over time whether due to natural variability or as a result of human activity. Similarly, Manstrandrea and Schneider (2009) enumerate climate change as a long term alteration in global weather patterns such as increases in temperature and storm activity, often linked to the potential consequence of rising levels of heat trapping gases known as green house gases which retain the radiant energy provided to the earth by the sun in a process known as the green house effect.

Climate Scientists believe that the earth is currently facing a period of rapid warming brought on by rising levels of greenhouse gases in the atmosphere. Greenhouse gases retain the radiant energy (heat) provided to the earth by the sun in a process known as the greenhouse effect. Greenhouse gases occur naturally, and without them the planet would be too cold to sustain life. Since the beginning of the Industrial Revolution in the mid-1700s, however, human activities have added more and more of these gases into the atmosphere (Manstrandrea and Schneider, 2009).

With more greenhouse gases in the mix, the atmosphere acts like a thickening blanket and traps more heat. In 1957, researchers at the Scripps Institution of Oceanography, based in San Diego, California, began monitoring carbondioxide (CO_2) levels in the atmosphere from Hawaii's remote Mauna Loa Observatory located 3,000m above sea level. When the study began, CO_2 concentration in the earth's atmosphere was 315ppm. However, CO_2 concentration has since then increased to 323ppm by 1970 and 335ppm by 1980. By 1988, atmospheric CO_2 had increased to 350ppm (Hernes, 1998). As other researchers confirmed these findings, scientific interest in the accumulation of greenhouse gases and their effect on the environment slowly began to grow.

In 1988, the World Meteorological Organization and the United Nations Environmental Programme established the Intergovernmental Panel on Climate Change (IPCC). The IPCC was the first international collaboration of scientists to access the scientific, technical and economic information related to the risk of human-induced climate change. The IPCC created periodic assessment reports on advances in scientific understanding of the causes of climate change, its potential impacts, and strategies to control the greenhouse gases. The IPCC played a critical role in establishing the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC, which provides an international policy framework for addressing climate change issues. This was adopted by the United Nations General Assembly in Rio, Brazil in 1992 (IPCC, 1996a).

Today, Climate scientists around the world monitor atmospheric greenhouse gas concentrations and create forecasts about their effects on global temperatures. They gather information about climate systems and use this information to create and test computer models that simulate how climate could change in response to changes on earth and in the atmosphere. However, these models can only provide approximations, and some of the predictions based on them often spark controversy within the scientific community. Nevertheless, the basic concept of global warming is widely accepted by most climate scientists (Hernes, 1998; Manstrandrea and Schneider, 2009). This study aims at reviewing the causes and the impacts of climate change on agriculture in Africa, and the adaptive measures that might be taken to ameliorate the negative impacts.

CAUSES OF CLIMATE CHANGE

Climate change is caused by a number of factors, including deforestation, ozone layer depletion, increased CO_2, and greenhouse gas emission into the atmosphere.

Deforestation: Forests provide many social, economic and environmental benefits. They also provide an important defense against climate change (Manstrandrea and Schneider, 2009) in that they facilitate photosynthesis which produces Oxygen (O_2) and consumes huge amounts of CO_2 known for effecting global warming. The number of trees available to absorb CO_2 through photosynthesis has been greatly reduced through deforestation. Human beings cut down trees for timber or to clear land for farming or building. This can both release the carbon stored in trees and significantly reduce the number of trees available to absorb CO_2 (Whitefield, Davidson and Ashenden, 1998; Syrquin, 2008). In Nigeria, the 1994 estimate of carbon uptake from forest and non-forest tree growth as well as from abandonment of managed lands was 36.75 $TgCO_2$ (10.02 $TgCO_2$-C). Similarly, the gross emissions of carbon from biomass harvests and conversion of forests and savanna to agricultural lands was estimated to be 112.23 $TgCO_2$ (30.61 $TgCO_2$-C). This gave a net carbon emission of 75.54 $TgCO_2$ (20.6 Tg CO_2-C) (FME, 2003).

Ozone layer depletion: Ozone is both a natural and man-made gas. Ozone in the upper atmosphere is known as ozone layer and shields both plant and animal life on earth from a possible damage by the sun's harmful ultraviolet and infrared radiation (Whitefield et al., 1998). However, the ozone in the lower atmosphere is a component of smog, and is considered a greenhouse gas (Whitefield et al., 1998). Unlike other greenhouse gases which are well mixed throughout the atmosphere, ozone in the lower atmosphere tends to be limited to industrialized regions (Pell, Sinn and Johansen, 1995; Brady and Weil, 2002). The ozone layer gets depleted when the atmosphere becomes impure due to the release of dangerous gases or repellents from industries, exhaust pipes of vehicles, air conditioning devices and refrigerators. These materials emit substances such as chlorofluorocarbons (CFC), carbon monoxide (CO_2), hydrocarbons, smoke, soots, dust, nitrous oxide and sulphur oxide which deteriorate the ozone layer (Ringius, 1996; Manstrandrea and Schneider, 2009).

CO_2 concentration: CO_2 is released into the atmosphere from natural processes such as eruptions of volcanoes, respiration of animals and the burning or decay of plants and other organic materials. Human activities such as the burning of fossil fuels, solid wastes and wood products to heat buildings, drive vehicles and generate electricity also release CO_2 into the atmospher. Concentration of CO_2 has risen since the industrial revolution of the mid 1700s (Paehler, 2009).

In 2007, the IPCC reported that levels of CO_2 had risen to a record high of 379ppm and are increasing at an average of 1.9ppm per year. In a higher emission scenario, CO_2 is projected to reach 970 ppm by 2100, implying more than tripling the pre-industrial concentrations (Manstrandrea and Schneider, 2009). Such a trend in CO_2 concentrations is very alarming and dangerous, considering its negative impacts especially on agricultural systems. In 1994, in Nigeria, for instance, gas flaring contributed 58.1 million tones or 50.4% of the gross CO_2 emissions from the energy sector. The consumption of liquid and gaseous fuels in the sector led to emissions of 51.3 and 5.4 million tones of CO_2 respectively (FME, 2003).

Greenhouse effect: Greenhouse effect is the capacity of greenhouse gases (for example, water vapour, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydro-chlorofluorocarbons, hydro-fluorocarbons, and perfluorocarbons) in the atmosphere to trap heat emitted from earth surfaces, thereby insulating and warming the planet in a blanketing manner or in a layer of greenhouse gases in the atmosphere. These atmospheric gases concentrate as a result of inventions that burn fossil fuels as well as other activities such as clearing of land for agriculture or buildings, and cause the earth's climate to become warmer than it would naturally (Hernes, 1998; Paehler, 2009). Greenhouse gases occur naturally in the environment and also result from human activities. By far the most abundant greenhouse gas is water vapour, which reaches the atmosphere through evaporation from oceans, lakes and rivers. The amount of water vapour in the atmosphere is not directly affected by human activities. Carbon dioxide, methane, nitrous oxide and ozone all occur naturally in the environment, but they are also being produced at record levels by human activities. Human-made chemicals that act as greenhouse gases include chlorofluorocarbons (CFCs), hydro-chlorofluorocarbons (HCFCs), hydro-fluorocarbons (HFCs), and perfluorocarbons (PFCs).

Aerosols: Aerosols, also known as particulates are air-borne particles that absorb, scatter and reflect radiation back into space. Clouds, windblown dust, and particles that can be traced to erupting volcanoes are examples of natural aerosols. Human activities such as the burning of fossil fuels and slash-and-burn farming techniques contribute additional aerosols to the atmosphere. Although aerosols are not considered a heat-trapping greenhouse gas, they do affect the transfer of heat energy radiated from earth to space. Their effect on climate change is still being debated, but climate scientists believe that light-coloured aerosols have a cooling effect while dark-coloured (soot) contribute to warming (Manstrandrea and Schneider, 2009).

Agriculture: Agriculture is a contributor to climate change. Clearing forests for fields, burning crop residues, submerging land in rice paddies, raising large herds of cattle and other ruminants and fertilizing with nitrogen, all release greenhouse gases to the atmosphere (Rosenzweig and Hillel, 1995).

EFFECTS OF CLIMATE CHANGE ON AGRICULTURE IN AFRICA

Climate Scientists use elaborate computer models of temperature, precipitation patterns, and atmosphere circulation to study climate change. Based on these models, scientists have made many projections about how climate change will affect weather, glacial ice, sea levels, agriculture, wildlife, and human health. Many changes linked to rising temperatures are already being observed. This study reviews only the effects of climate change on agriculture. Climate is the primary important factor for agricultural production, and any significant change in climate on a global scale is likely to impact on local agriculture. Climate change could be particularly damaging to countries in Africa, being dependent on rain-fed agriculture and under heavy pressure from food insecurity and often famine caused by natural disasters such as drought.

Effect on agriculture and land uses: Rosenzweig and Hillel (1995) have opined that climate change of a few degrees may increase agricultural productivity but not necessarily in the same places where crops are grown before the change. Luo et al. (1999) and SWCS (2003) have reported that increased intensity of droughts, floods and changing growing season as a result of climate change may cause declines in soil productivity, food supply and water resources. This will in turn reflect hardships and death in plant and animal ecosystems. Similarly, Manstrandrea and Schneider (2009) reported that semi-arid tropical farmlands in some parts of Africa may become further impoverished due to climate change. A significant effect of climate change due to increased levels of CO_2 would be reflected in the production of both C_3 crops (such as cassava, yam, cowpea, wheat, soybeans, rice and potatoes), and C_4 crops (such as millet, sorghum, sugar cane, and maize). In general, higher increases in productivity can be expected from the C_3 crops compared with the C_4 crops (FME, 2003). Thus, the C_4 crops would be generally adversely affected as many of them are already functioning in near-optimal conditions in today's relatively lower CO_2 levels. C_3 weeds will grow more rapidly and hence compete more severely with a number of C_4 crops. Similarly, expected changes in crop development and phenology can cause shortening or lengthening of crop cycle that could lead to decreases or increases in productivity.

Effect on the soil: Storms are more intense and frequent in a warmer world, thereby making for severe erosion damage of farmlands (SWCS, 2003). As a consequent of climate change, some areas are already receiving heavier and steadier rainfall and such areas are experiencing increased rainfall-induced erosion. On the other hand, in the arid and semi-arid regions, higher temperatures contribute to dry conditions which underlie accelerated wind erosion and floods (FME, 2003). Warmer conditions are likely to speed the natural decomposition of organic matter and to increase the rates of other soil processes, leading to higher air temperatures in the soil. Where dry conditions occur, they will suppress root growth and increase vulnerability to wind erosion, especially if winds intensify (Rosenzweig and Hillel, 1995).

Additional application of fertilizer may be needed to counteract these effects and to take advantage of the enhanced crop growth that can result from increased atmospheric CO_2. This, however, can come at the cost of environmental risk, for additional use of chemicals may impact water and air quality.

Effect on water availability: Agriculture is strongly influenced by water availability. Rosenzweig and Hillel (1995) opine that climate change would modify rainfall, evaporation, run-off and moisture storage. Parts of tropical and subtropical Africa started experiencing droughts since the 1970s (Paehler, 2009; Syrquin, 2008). The World Bank Group (1998) projects that droughts will become longer and more intense in tropical and subtropical Africa. Climate change influences water to evaporate faster from the soils, causing the soils to dry out very rapidly between rains, thereby increasing the need for compatible crop management (Southworth et al., 2002; Pfeifer and Habeck, 2002). Warmer climates increase the demand for irrigation, entailing additional investment for dams, reservoirs, canals, wells, pumps and pipes to develop irrigation networks.

Effect of higher temperatures: In Africa, increased temperatures may accelerate the rate at which plants release CO_2 in the process of respiration, resulting in less than optimal conditions for net crop growth. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep drop in net growth and yield. Another important effect of high temperature is accelerated physiological development, resulting in hastened maturation and reduced yield. IPCC (2001) reports that global surface air temperature is projected to warm from 1.4 to 5.8^{o}C by the year 2100 relative to 1990. In Nigeria, an average of 0.4^{o}C rise in mean annual temperature was recorded over the last two decades of the 20th century in various parts of the country (FME, 2003). The impact of such changes would be felt in multiple sectors, including health, water, biodiversity, agriculture, forestry and fisheries.

Effect on vegetation: A change in the type, distribution and coverage of vegetation may occur given a change in the climate. Some changes in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne CO_2. Larger, faster or more radical changes, however, may result in vegetation stress, rapid plant loss and desertification in certain circumstances (Bachelet et al., 2001). Data available in recent decades indicates that global terrestrial net primary production increased by 6% from 1982 to 1999, with the largest portion of that increase in tropical ecosystems, then decreased by 1% from 2000 to 2009 (Nemani et al., 2003; Zhao and Running, 2010). As plant communities try to adjust to the changing climate by moving toward cooler areas, the animals that depend on them will be forced to move. Development and other barriers may block the migration of both plants and animals.

Effect on pests and diseases: Warmer climates provide more favourable conditions for the proliferation of insect pests and diseases. Altered wind patterns may change the spread of both wind-borne pests and of bacteria and fungi that are the agents of crop diseases. Crop-pest interactions may shift as the timing of developmental stages of both hosts and pests may be altered. Livestock diseases may be similarly affected. Several animals may be predisposed to higher instances of heat stress, increased disease transmission and possible resistance to disease control measures by economically important pests and diseases in most African regions (Manstrandrea and Schneider, 2009). Also, an increase in the frequency of extreme events such as prolonged drought or intense flooding could create conditions that could be conducive to disease or pest outbreaks, and severely disrupt the predator-prey relationships that normally restrict the proliferation of pests (FME, 2003). Warmer and more humid conditions would enhance the growth of bacteria and moulds on many types of stored food, and this would increase food spoilage and create some specific toxicological health hazards.

Effect on food security: IPCC (1996b) assessments of the impact of climate change indicate that some regions are likely to benefit from increased agricultural productivity while others may suffer reductions, according to their location and dependence on the agricultural sector. The IPCC has reviewed the results of many modeling experiments that project future changes in crop yields under climate change. Climate change may increase yields of cereal grains at high and mid latitudes but may decrease yields at lower latitudes. Africa, where per capita food production has declined since the 1960s is likely to face even greater difficulties in a warmer world. A slight negative change in African agriculture which engages up to 70% of human labour and accounts for 40% of its GNP (Paehler, 2009) may cause severe consequences on food security and welfare of the people of the continent.

Effect on natural disasters: Climate change will increase the risk of both floods and droughts. Ninety percent of disaster victims worldwide live in developing countries, where poverty and population pressures force growing numbers of people to live on flood plains and on unstable hillsides (IPCC, 1996b). The vulnerability of those living in risk-prone areas is perhaps the single most important cause of disaster casualties and damage. The recent occurrences of floods across Nigeria, Benin Republic, Pakistan, Brazil, Bangladesh, China, etc plus sporadic cold and warm winters in the world temperate; droughts in parts of Africa and Asia are examples of the impacts of climate change.

CLIMATE CHANGE PROJECTIONS

In its 2007 report the IPCC projected temperature increases for several different scenarios, depending on the magnitude of future greenhouse gas emissions. For a "moderate" scenario-in which emissions grow slowly, peak around the year 2050, and then fall-the IPCC report projected further warming of 1.1 to 2.9^{o}C by the year 2100 (IPCC, 2007). For a "high-emissions" scenario-in which emissions continue to increase significantly and finally level off at the end of the century-the IPCC report projected further warming of 2.4 to 6.4^{o}C by the year 2100. The IPCC cautioned that even if greenhouse gas concentrations in the atmosphere ceased growing, the climate would continue to warm for an extended period as a result of past emissions, and with more dramatic effects than were observed during the 20th century. If greenhouse gas emissions continue to increase, climate scientists project severe climate changes.

Table 1: Predicted effects of global climatic change on agriculture over the next 40 years

Climatic Element	Expected changes by 2050s	Confidence in prediction	Effects on agriculture
CO_2	Increase from 360 ppm to 450-600 ppm	Very high	Good for crops: increased photosynthesis; reduced water use
Sea level rise	Rise by 10-15 cm increased in the south and offset in the north by natural subsistence/rebound	Very high	Loss of land, coastal erosion, flooding, salinization of ground water
Temperature	Rise by 1-2^{o}C. Winters warming than summers. Increased frequency of heat waves	High	Faster, shorter earlier growing seasons, range moving north and to higher altitudes, heat stress risk, increased evapotranspiration
Precipitation	Seasonal changes by + 10%	Low	Impacts on drought risk soil workability, water logging, irrigation supply, transpiration
Storminess	Increased wind speeds, especially in the north. More intense rainfall events	Very low	Lodging, soil erosion, reduced infiltration of rainfall
Climatic variability	Increases across most climatic variables. Prediction uncertain	Very low	Changing risks of damaging events (heat waves, frosts, drought, floods) which affect crops and timing of farm operations

Source: IPCC, 2007b

CONCLUSION AND RECOMMENDATIONS

Responding to the challenge of controlling climate change requires fundamental changes in energy production, transportation, industry, government policies, and development strategies around the world. These changes take time. The challenge today is managing the impacts that cannot be avoided while taking steps to prevent more severe impacts in the future. A wide variety of adaptive actions may be taken to lessen or overcome the adverse effects of climate change on agriculture. They include the following:

Conservation of natural resources: There are various conservation options for protecting the natural resources, some of which include biological diversity conservation, forest conservation, soil and water conservation and energy conservation. Although each resource has its unique set of conservation problems and solutions, all resources are interconnected in a complex web. The goal of conservation is optimum protection of ecosystems or preservation of natural resources by reducing their excess consumption and protecting them from contamination or pollution as well as re-using or recycling them where possible (Ringius 1996, Hernes 1998).

Use of alternative energy sources: Newer technologies for cleaner energy sources are beginning to provide suitable alternatives to previous energy sources that are known for affecting global climate change (Paehler, 2009). Significant reductions in CO_2 emissions can only be achieved by switching away from fossil fuel energy sources to less damaging substitutes. Alternative energy sources such as solar power, wind power, and hydrogen fuel cell are rated as none greenhouse gas emitters. Also, nuclear power energy sources do not release CO_2 at all, but are controversial for reasons of security, safety, and the high cost of nuclear waste disposal. Other alternative energy sources include fuels made from plants such as biodiesel and ethanol. The use of these fuel alternatives can greatly mitigate or curtail the CO_2 emission from automobiles.

Carbon sequestration: This strategy entails keeping carbon dioxide out of the atmosphere by storing the gas or its carbon component somewhere else, a strategy known as carbon sequestration or carbon capture (Manstrandrea and Schneider, 2009). One way to keep carbon dioxide emissions from reaching the atmosphere is to preserve and plant more trees. Trees, especially young and fast-growing ones, soak up a great deal of carbon dioxide from the atmosphere and store carbon atoms in new wood. Worldwide, forests are being cleared at an alarming rate, particularly in the tropics. In many areas, there is little regrowth as land loses fertility or is changed to other uses, such as farming or housing developments. In addition, when trees are burned to clear land, they release stored carbon back into the atmosphere as carbon dioxide. Slowing the rate of deforestation and planting new trees can help counteract the buildup of greenhouse gases.

Carbon dioxide gas can also be captured directly. Carbon dioxide has traditionally been injected into depleted oil wells to force more oil out of the ground or seafloor. The same process can be used to store carbon dioxide released by a power plant, factory, or any large stationary source. For example, since 1996 this process has been used at a natural gas drilling platform off the coast of Norway (Kyoto Protocol, 2008). Carbon dioxide brought to the surface with the natural gas is captured, compressed, and then injected into an aquifer deep below the seabed from which it cannot escape. In most cases, the process of carbon capture would also involve transporting the gas in compressed form to suitable locations for underground storage. Deep ocean waters could also absorb a great deal of carbon dioxide, although the environmental effects may be harmful to ocean life. The feasibility and environmental effects of these options are under studied by international teams.

Carbon Trading: Carbon trading is an approach used to control carbon dioxide (CO_2) pollution by providing economic incentives for achieving emissions reductions. It is sometimes called cap and trade or carbon emissions trading. Carbon trading is administered by a central authority such as a government or international organization which sets a limit or cap on the amount of CO_2 that can be emitted. Companies or other groups are issued permits that require them to hold allowances (or credits) in order to emit an equivalent amount of CO_2. The total amount of allowances and credits cannot exceed the cap, limiting total emissions to that level. Companies that need to increase their allowances must buy credits from those who pollute less. The transfer of allowances is referred to as a trade. The buyer therefore pays to pollute, while the seller is financially rewarded for reducing CO_2 emissions. In theory, those that can easily reduce emissions most cheaply will do so. Carbon trading began in response to the Kyoto Protocol, signed by 180 countries in 1997. The Kyoto Protocol, signed by 180 countries in 1997 called for 37 industrialized countries to reduce their greenhouse gas emissions between the years 2008 to 2012 to levels that are 5% lower than those of 1990 (Kyoto Protocol, 2008). Article 17 of the Kyoto Protocol established emissions trading by allowing countries that have emission units to spare emissions permitted to them but unused (to sell this excess capacity) to countries that are over their emissions limits. In effect, this created a new commodity in the form of emissions and created a carbon market. Since CO_2 is the principal greenhouse gas, emissions trading effectively became carbon trading.

Carbon trading has been steadily increasing in recent years. According to the World Bank's Carbon Finance Unit, 374 million metric tonnes of carbon dioxide equivalent (tCO_2e) were exchanged through projects in 2005, a 240% increase relative to 2004 (110 $mtCO_2e$) (State of the Carbon Market, 2008). In 2008, the carbon market was valued at $47 billion (State and Trends of the Carbon Market, 2008), while in 2009 the World Bank estimated its value at $126 billion (State and Trends of the Carbon Market, 2010).

International Agreements: International cooperation is required for the successful reduction of greenhouse gases. The first international conference addressing the issue was held in 1992 in Rio de Janeiro, Brazil. At the United Nations Conference on Environment and Development, informally known as the Earth Summit, 150 countries pledged to confront the problem of greenhouse gases by signing the United Nations Framework Convention on Climate Change (UNFCCC). To date, more than 180 nations have ratified the UNFCCC, which commits nations to stabilizing greenhouse gas concentrations in the atmosphere at a level that would avoid dangerous human interference with the climate. This is to be done so that ecosystems can adapt naturally to global warming. Food production is not threatened, and economic development can proceed in a sustainable manner.

The nations at the Earth Summit agreed to meet again to translate these good intentions into a binding treaty for emissions reductions. In 1997 in Japan, 160 nations drafted an agreement known as the Kyoto Protocol, an amendment to the UNFCCC. This treaty set mandatory targets for the reduction of greenhouse gas emissions. Industrialized nations that ratify the treaty are required to cut their emissions by an average of 5 percent below 1990 levels. This reduction is to be achieved not later than 2012, and commitments to start achieving the targets are to begin in 2008. Developing nations are not required to commit to mandatory reductions in emissions.

Under the Kyoto rules, industrialized nations are expected to take the first steps because they are responsible for most emissions to date and have more resources to devote to emissions-reduction efforts. In November 2004, Russia approved the treaty, and it went into force in February 2005. By the end of 2006, 166 nations had signed and ratified the treaty. The Kyoto Protocol, which expires in 2012 is only a first step in addressing greenhouse gas emissions. To stabilize or reduce emissions in the 21st century, much stronger and broader action is required. In part, this is because the Kyoto provisions did not take into account the rapid industrialization of countries such as China and India, which are among the developing nations exempted from the protocol's mandatory emissions reductions.

However, developing nations are projected to produce half the world's greenhouse gases by 2035 (Manstrandrea and Schneider, 2009). Leaders of these nations argue that emission controls are a costly hindrance to economic development. In 2007 the European Union (EU) took the initiative in coming up with a new international plan to address global warming. At a "green summit" held in March, the 27 nations of the EU reached a landmark accord that went above and beyond the Kyoto Protocol in setting targets to reduce greenhouse gas emissions. The agreement set ambitious targets for the EU overall, but goals for individual EU nations and rules of enforcement were to be determined through additional negotiations.

In the accord EU leaders agreed to reduce emissions by 20 percent from 1990 levels by 2020 or by as much as 30 percent if nations outside the EU joined in the commitments. They also agreed that renewable sources of energy, such as solar and wind power, would make up 20 percent of overall EU energy consumption by 2020 (an increase of about 14 percent). The accord also called for a 10 percent increase in the use of plant-derived fuels, such as biodiesel and ethanol. In addition to these targets, EU leaders agreed to work out a plan to promote energy-saving fluorescent light bulbs, following the example of countries such as Australia and Chile that are officially phasing out less-efficient incandescent light bulbs.

Other Adaptations: Other adaptive actions that may be taken to lessen or overcome adverse effects of climate change on agriculture include shifting the types of crops, investing in drought-tolerant or heat-tolerant crop varieties, early sowing, switching crop sequences, adjusting the timing of field operations, conservation of soil moisture through appropriate tillage methods, and improving irrigation efficiency. The planting of high yielding varieties of crops as part of the Green Revolution saved an estimated 170 million hectares of forest from cropping in Africa, Latin America and Asia between 1970 and 1990 - saving the equivalent of two to three years of total global carbon emissions (Gregory et al., 2005).

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