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Full Length Research Paper

Impact of climate change on agriculture in Africa by 2030

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Concerns about climate change are global and real. As all communities try to get adapted to the challenges of their local climate, they are today sensitive to its variations. Third World countries, particularly Africa are threatened by the predicted effects of climate change because of their economic dependence on climate for development whose backbone is agriculture. There is strong evidence from the World Meteorological Organization (WMO), Intergovernmental Panel on Climate Change (IPCC) and United Nations Environmental Programme (UNEP) that the observed increases in greenhouse gases particularly Carbon dioxide (CO_2) may lead to global warming, sea level rise and space-time changes in climatic zones and seasons on the globe. To come up with climate change associated impacts on agriculture in Africa, the study evaluated climate related researches conducted on snow capped mountains in Africa (Mt Kilimanjaro), fishing in inland lakes (Lake Victoria, Baringo), Agriculture in the Semi-arid lands of East Africa and irrigation projects in Africa (Gezira in Egypt) It was established that Africa is already experiencing the devastating impacts of climate change as seen in frequent floods and droughts and shift in marginal agricultural systems. If the predicted temperature increase of 4.5 degrees centigrade is realized by the year 2030, then agricultural systems in Africa will be seriously affected particularly the food security section. There will be reduced land for agriculture because the high agricultural potential areas will become arid, Coastal areas will be submerged, affecting fishing and human settlement, there will be increased desertification and disappearance of ice and snow on the mountains. The effects of climate change may include: reduced agricultural land use due to submergence of coastal regions and increased aridity in the tropical high agricultural potential regions, there will be increased incidences of farm pests and diseases, over cultivation, food insecurity and poverty especially in Tropical regions. Africa will face serious challenges in her endeavor to adapt to new mechanisms of food production for sustainable development

Key words: Carbon dioxide sink, marginal agriculture, Sahelian drought, human activities, climate change.

INTRODUCTION

Climate change

The global temperature has increased in recent times, as has the atmospheric concentration of CO_2,CH_4 and other gases. Greenhouse gases cause a warming of the world because these gas molecules absorb outgoing long-wave radiation and therefore less radiation is lost to space. The global climate has fluctuated considerably since the last deglaciation period and major changes in climate have occurred at approximately the same time all over the world. The similarity in time for the changes in climate indicates a global forcing.

Climate change is defined as fluctuations in the patterns of climate over long periods. Though the climatic history of the world is not well understood, it is documented that during the last 55 million years, the earth has been cooling and that during the last one million years, there have been alternating of glacial and interglacial episodes evidenced by the 'Little Ice Age 1645 - 1715 and the "Tropical Age 1870 - 1930 (Ford, 1982).

The current signs of global climate change have resulted from an average increase in the world temperature of just 0.7 degrees centigrade since 1900 (Nkemdirim, 2003). Due to these warming, glaciers and the polar ice

caps are beginning to melt, causing sea level rise. Increased temperatures also cause significant changes in weather patterns with extremes of rainfall and strong winds. These changes can result in increased frequencies of droughts, floods and storms in different parts of the world.

Today, the earth is tending towards warmer climates characterized by frequent prolonged droughts such as 1968 - 73 Sahelian drought and the devastating floods such as the 1997 - 98 El Nino flood in equatorial East Africa, caused by the abnormal warming of the eastern pacific waters. Climate change can result from a variety of natural causes such as solar output, sunspot activity, Milankovitch episodes and Vulcanicity or from human activities such as deforestation, overgrazing and increased atmospheric Carbon- dioxide through burning of fossil fuels, or from both the natural and human activities (Nkemdirim, 2003). Tropical climate fluctuates on various time scales, from interannual to thousands of years.

Scientific evidence shows that the net climate resulting from the change will largely be driven by atmospheric greenhouse gases (Nkemdirim 2003). The Inter-governmental Panel on climate change (IPCC 2001) identified the following major trends in climate:

The global average surface temperature has increased by 0.6^{O}C. The 1990s appear to have been the warmest ten years since instrumental records began in1727.The rate and duration of the present warming is larger than any other time in the last 1000 years. Annual land precipitation has increased in the middle and high latitudes of Northern Hemisphere by between 0.5 and 1.0% per decade over the subtropics and equivalent rainfall has declined by about 0.3%. Snow cover on mountains within the tropics such as Mount Kilimanjaro and Mount Kenya in Africa and Mount Quelccaya in the Southern Andes in South America have decreased by about 50% since 1960 in response to land surface temperature increases.

The trends discussed above are powerful enough to be seen as indicators of progress towards new climate. From the consistent agreement between model respon-se to the increase in greenhouse gases and observed rate and magnitude of present temperature rise, the IPCC and World Meteorological Organization (WMO) conclud-ed that attribution of present climate patterns to green-house gases is reasonable based on realistic scenarios of future economic and human growth.

The IPCC and WMO also extra polated that the Earth's temperature could raise between 1.5 and 4.5^{O}C by the end of the 21st century (Nkemdirim, 2003). The main cause of climate change in Africa is predicted to be greenhouse gases, of which Carbon dioxide is the most important of the greenhouse gases. Primarily fossil fuel burning and deforestation produce it. Levels of Carbon oxide in the atmosphere increased by 25% in 1992 and were expected to increase by a further 30% by the year 2040 (Machta, 1972). Current predictions indicate that the greenhouse gases will cause temperature increase amounts between 1.5 and 4.5^{O}C. These seemingly low figures will be enough to have a major effect on climate.

For example, in temperate regions, winters would tend to be shorter and warmer while summers would be longer and hotter. Evaporation rates would increase and overall rainfall would rise by an estimated 7 – 11% a year. The tropics would become wetter but the subtropics, which are already dry, would become drier (UNEP, 1990).

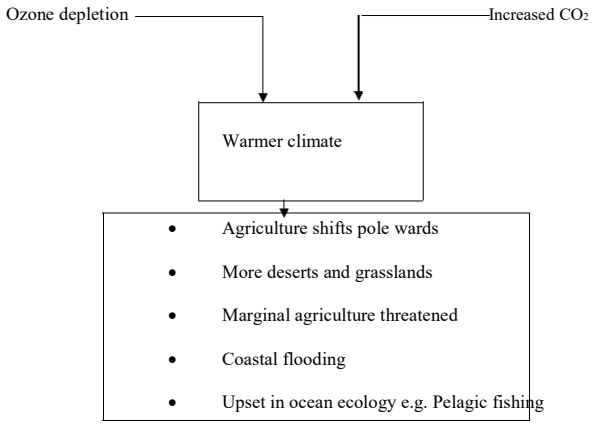
Ozone depletion is another predicted cause of increased temperatures. Ozone gas (O_3) is produced naturally from oxygen in the stratosphere. Natural forces also break it down with the result that the gas is constantly being created and destroyed. The speed at which these reactions occur determine how much ozone there is in the atmosphere. Several chemicals used or produced by Industries greatly affect the speed at which ozone is broken down. They include Chlorofluorocarbons (CFCs), which are used as propellants in aerosols, in refrigeration technology, as foam blowing agents in the plastic industry and as solvents in electronics. Other gases that break-down ozone include: nitrous oxide, Fluorine, bromine and Nitrogen from farm fertilizers (Ford, 1982). Scientists predict that if these chemicals continue to be produced at current rates, ozone levels in the upper atmosphere will fall by a few%ages during the first half of the 21st century (UNEP, 1989). If this happens, there will be inc-reased levels of the portion of the electromagnetic spec-trum known as ultra violet Beam (UV-B) on the surface of the earth. If ozone levels were to fall by 10%, the amount of UV-B reaching the earth's surface would incr-ease by about 20%.

It is predicted that increases in UV-B and carbon dioxide may cause a rise in global temperatures of between 1.5 to 4.5^{O}C by the year 2030 (Machta, 1972).

The warmer climate would disrupt natural ecosystems with grasslands and deserts expanding in area and forests reducing in area. The tropics would become drier and agriculture would shift to the temperate regions. A warmer climate may also exacerbate existing environmental problems such as desertification, drought and soil erosion (UNEP, 1989). Ecological hazards such as floods (the case of Bangladesh in 2002, 2003, and 2004) storms and forest fires (the case of Indonesia Oct. 1997) might become common. Evidence of ozone depletion has already been detected in the South Pole where there is a hole in the Antarctic ozone.

Measurements reveal that the South Pole Ozone levels had fallen by 40%, since 1958 (Machta, 1972). Sci-entist around the world now agree that the climate chan-ges which we are all experiencing are real and are cau-sed by human activities. Climate change affects the whole world though the poorest people who contribute least to global warming are the ones who will suffer the most. Since the 1980s, Scientists have been predicting the serious consequences of climate change (Ford, 1982). Climate change will put over 100 million people at risk of hunger by 2080 with 80% of them being in Africa (Carter, 2007).

Effects of ozone depletion and increased carbon dioxide on global agriculture



Human activities are also emerging as serious factors causing climate change particularly in Africa. Land use changes such as, deforestation, overgrazing and burning of vegetation not only add to the carbon load but also cause change in energy and moisture fluxes, with noticeable consequences on weather and climate patterns at local and regional levels (Ngaira, 2003). Deforestation and vegetation burning can cause a higher frequency of droughts, and this has been documented as one of the causes of frequent drought in the Sahel region (Charney, 1975). The increasing aridity around the Moshi region in Tanzania and the rapid disappearance of Ice caps on mountains in equatorial East Africa (Kilimanjaro, Kenya and Elgon) has been attributed to land use changes particularly deforestation and charcoal burning (Thompson, 2000).

Tropical climate fluctuates on various time scales, from interannual (exemplified by the strong 1997 - 1998 El Nino) to thousands of years (such as the greening of the Sahara from ~5500 years ago). At present, 75% of the world's inhabitants live in the tropics. Because instrumental records are short, paleoclimate records are essential to understanding the full range of tropical climate variability, its effects on Earth's energy budget, water vapor cycle and agriculture.

Current climatic zones of Africa

Africa can broadly be divided into four (4) climatic zones based on a combination of temperature, precipitation (ppt) and evapotranspiration Figure 1. The zones are:

i) Arid and semi-arid (Sahel region, Kalahari and Namib deserts).
ii) Tropical Savanna grasslands (Sub-saharan Africa and Central Southern Africa).
iii) Equatorial (The Congo region and the East African highlands).

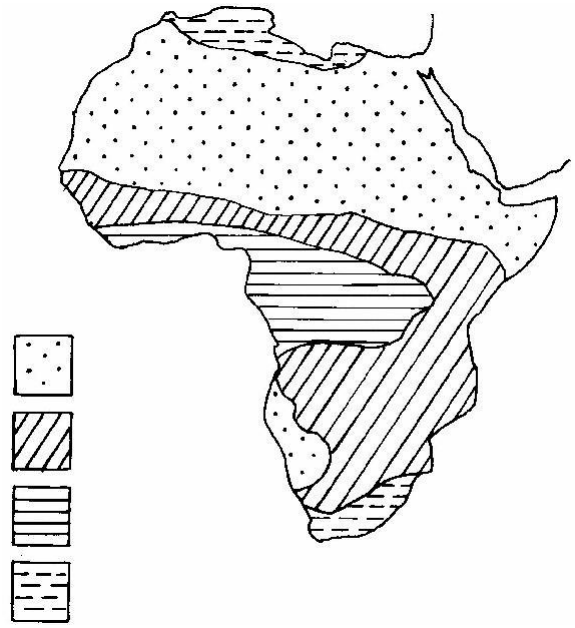


Figure 1. Africa- current climatic zones.

iv) Temperate (The South Eastern tip of South Africa).

The ecosystems found in the four climatic regions are adapted to the prevailing climatic conditions, such that little and erratic rainfall is not a threat to agriculture. However, the large seasonal and annual total variations evident in most areas of the continent together with recent high intensities and large rainfall storm totals cause considerable environmental problems such as the 1997 - 1998 El Nino floods, the 1968 - 1973 Sahelian drought, soil erosion and soil leaching which can alter Africa's agricultural activities. They can also shift agricultural zones to the disadvantage of the continent whose 80% of the total land area is already moisture constrained (Goudie, 2001).

Agricultural activities in Africa are mainly controlled by rainfall amounts and distribution. As shown in Figure 2.
(i) Commercial cash crop cultivation: which include Tea, Coffee, Wheat, Pyrethrum, Bananas Rubber, Palm oil and Sugar-cane. These crops need high rainfall of over 1000 mm well distributed throughout the growing season. They are grown in the equatorial zones of Africa. (ii) Irrigated agriculture: located mainly in the Arid and Semi-arid regions where Perennial rivers such as the Nile, Niger and Perkerra flow. Crops grown include Cotton in the Gezira scheme, Groundnuts in the Niger delta and Papaws in the Perkerra irrigation scheme. (iii) Marginal crop cultivation such as millet, sorghum, cowpeas, cassava and Nomadic pastoralism where traditional livestock breeds such as zebu cattle, East African goat, Red maasai sheep and camels are kept, are practiced in the ASAL. Fishing: Both Pelagic and Demersal are situated around the continent's coastal zones.

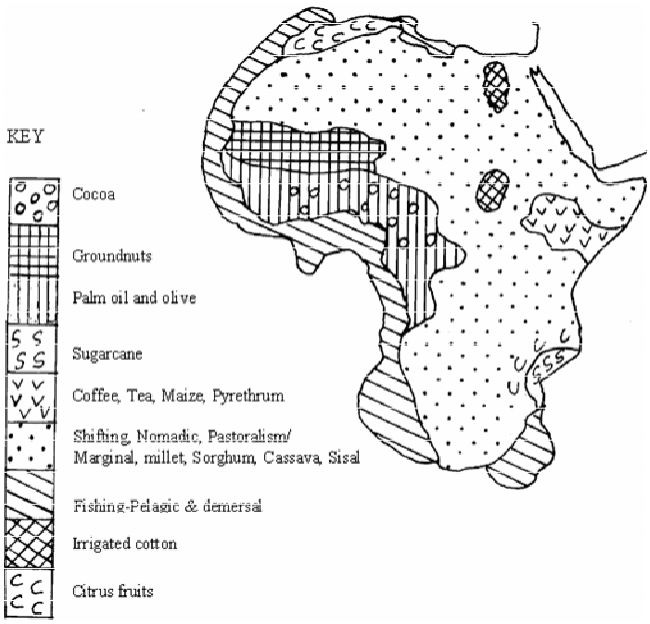


Figure 2. Agricultural systems in Africa today.

METHODOLOGY

The following case study areas were selected for analysis; snow cover on Mt Kilimanjaro between 1912 – 2000, drought trends in semi-arid areas of Kenya 1962 – 2000, effect of droughts on Lake Baringo (Kenya) 1976 – 2000 and predicted effects of increased temperature of between 1.5 and 4.5 degree centigrade by 2030.

RESULTS

Mt Kilimanjaro is the highest mountain in Africa with a height of 5895m above sea level; it is located in the Moshi area of Tanzania at latitude of 3 degrees south of the equator. It has for long been snow capped and a source of many rivers such as Una and Weruweru that flow from the ice capped peaks of Kibo and Mawenzi. The climate of this area is equatorial with average annual rainfall of over 2000 mm. As late as 1990, ice could be seen at heights as low as 2700 m above sea level on the mountain. By 2001 the ice had retreated to 5685 m above sea level according to a report by Green Peace an international environmental organization. L Thompson of Ohio State University who provided evidence of terminal melting of Kilimanjaro ice caps confirmed these trends. Between 1976 and 2000 Mt Kilimanjaro lost 49% of the ice. Today there is only very little ice on the mountain at a height of 5685 m. About one half of the ice disap-peared between 1953 and 2002 due to warmer tempera-tures and reduced rainfall. The consequences of loss of ice have caused many rivers, which used to flow from the mountain such as Weruweru and Una to dry up. The little rainfall, which is being received in Moshi area, has turned the region semi-arid.

The Semi-arid areas in Kenya have experienced prolonged droughts and erratic rainfall since 1960. Ngaira 1999 analyzed trends in annual rainfall in the region between 1962 – 2000 and identified the following; that the region experienced droughts every after 2 – 3 years in the 1960s, 1970s and 1980s. Prolonged droughts exceeding five years were experienced in the 1990s towards the 2000s. Prolonged droughts caused recession of Lake Baringo from 130 square km in 1990 to 110 square km in the year 2000; the annual fish catch dropped from 380 metric tones in 1990 to 7 metric tones in the year 2000, rain fed crop cultivation was abandoned in 1992 due to persistent crop failure. The region though lying within the equatorial zone now receives annual rainfall of 750 mm which is characteristic of semi-arid areas. It was concluded that most of the equatorial Kenya is becoming drier.

If the current rate of emission of green house gases in the atmosphere, particularly carbon dioxide could cause a rise in global temperatures of between 1.5 to 4.5^{o}C in the year 2030 as predicted by WMO, 2003, IPCC, 2006, UNEP, 1989, then these seemingly low figures will be enough to have major effects on climate. Evaporation rates would increase and overall rainfall would decrease by an estimated 7 to 11% per year (UNEP, 1989). The warmer climate would disrupt natural ecosystems and their water balances, with grasslands and deserts expanding in area while forests reducing in area due to water deficiency. The Tropics would become drier and agriculture would shift to the temperate regions.

Increased temperatures may exacerbate existing environmental problems such as coastal flooding due to sea level rise. Scientist calculated that ocean expansion could cause a rise in sea level of between 20 to 140 cm. If the average temperature increased by 1.5 to 4.5^{o}C. This scenario would adversely affect pelagic fishing especially the Dolphins, Banito, sail fish, barracuda and Tunny in the Indian and Pacific Oceans (WMO, 2002). Temperature rise of 3^{o}C could increase sea level by about 80 cm, enough to flood huge unprotected coastal land, this may have devastating effects on settlement along both the Eastern and Western Coast of Africa. Warmer sea surface temperature (SST) will increase tropical storm frequency and intensity (Nkemdirim, 2003) this would affect water quality.

If the predicted temperatures will increase by the year 2030, then climatic zones would likely change and support very limited agricultural land which will likely support mainly marginal farming and Nomadic pastoralism-Figure 3.

Effect of a warmer climate on agriculture in Africa

Figure 4 illustrates the most likely effects of increased temperatures on agriculture in the 21st century. The current ecological hazards of droughts, soil erosion and desertification may worsen making the current arid areas

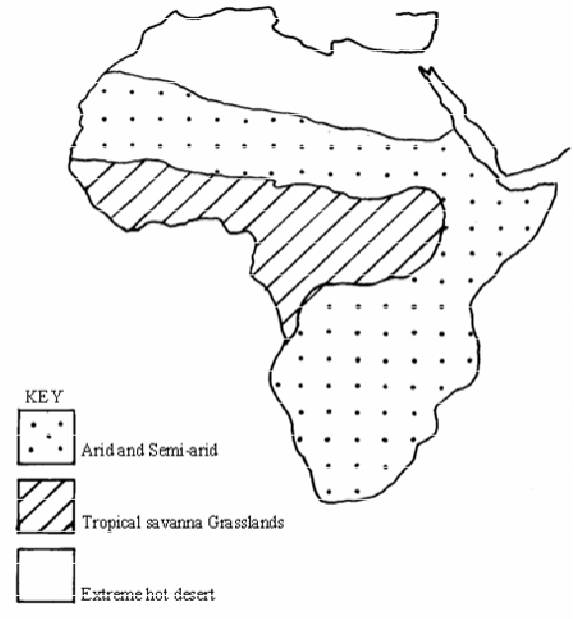


Figure 3. Africa Climatic Zones (2030).

more arid and uninhabitable.

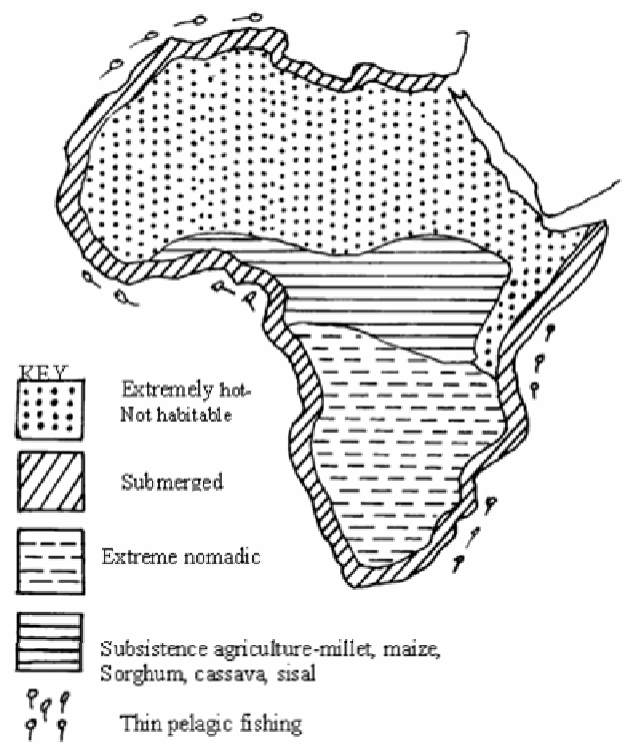


Figure 4. Africa agricultural zones (2040)

Challenges of climate change on agriculture in Africa in the 21st century

i) A warmer climate will disrupt and interfere with the natural ecosystem stability and adaptation such that grassland and desert ecosystems will expand in area while the rich forest ecosystems will reduce in area.
ii) Marginal agricultural as practiced in the Arid and semi-arid (ASAL) regions will probably suffer most because the ASAL will be hotter and the natural ecosystems may not easily adapt to new harsh conditions. These may lead to extinction of ASAL ecosystems mainly the drought resistant crops.
iii) The current ecological hazards of droughts desertification and soil erosion may worsen making the areas where they occur un inhabitable in future.
iv) A warmer climate would lead to coastal flooding due to sea level rise. Scientists calculate that ocean expansion could cause a rise in sea levels of between 20 and 140 cm if the average temperature increased by between 1.5 to 4.5^{O}C. This scenario would adversely affect marine fishing especially Pelagic fishing (fishing those species which live near the surface of the ocean such as, Dolphin, Banito, sail fish, Barracuda and Tunny).
v) A warmer climate would also have major adverse effects on water use and availability in the tropics making large reservoirs and other irrigation projects dry up and become useless long before their normal 50 years lifetime has elapsed. Africa has some of the major irriga-tion projects such as the Gezira for cotton.
vi) Temperature rise of 3^{O}C could increase sea levels by about 80cm, enough to flood huge areas of unprotected coastal land. Nearly a third (1/3) of all human beings live within 60km of a coastline, therefore, a rise in sea level of ½ a meter could have devastating effects on settlement patterns causing many people to move and many cities and ports to be submerged.
vii) On the overall, changes in agricultural patterns caused by climate change will produce negative effects throughout societies in third world countries; Africa included thus altering their economic viability and development as discussed.

A warmer climate will adversely affect food security in Africa, for example, 96% of Egypt is desert and 97% of the population is concentrated only on 4% of the Irrigated land (Jackson, 1989). If the Nile Waters used for Irrigation dries up, then there will be no food and the people of Egypt will migrate to other habitable regions in the temperate lands.

Challenges on socio-economic sustainability for Africa in the 21st century

i) There will be serious food insecurity problems resulting from disruption of natural ecosystems with grassland and deserts expanding in area, the coastal region being submerged while most perennial rivers such as the Nile flowing through the deserts will probably dry up, inhibiting irrigation. Famine and starvation cases will increase.

ii) Human population will definitely reduce. People currently living a long the coast, in arid and semi arid lands will be forced to migrate to the climatically habitable continents. The Arabs in North Africa may move to Europe.
iii) There will be a halt on industrialization since cash crop cultivation, which is the basis of industrialization in Africa, will be drastically reduced.
iv) Giant irrigation projects such as the Gezira in Sudan may disappear due to drying up of the Nile River.

Conclusion

Since the main causes of climate change discussed in this paper are anthropogenic in nature (increased carbon dioxide and ozone gas depletion). It is only prudent that anthropogenic remedial measures are employed to halt further changes in climate. International, Regional and local action is urgently needed to minimize both green house heating and ozone gas depletion. Because it takes decades for human action to produce any affect on the structure of the atmosphere, the action to reverse the trend must be aggressive, focused and massive.

Recommendations

While it is not practical to reverse the state of carbon dioxide load in the atmosphere and the already depleted Ozone layer, it is possible to halt and or minimize future production of excess Carbon dioxide and use of chloro-fluoro carbons, which destroy the ozone gas. These could be done by:
i) Halting or preventing the predicted 30% increase in green house gases caused by deforestation and fuel burning. This could be facilated by:
a) Making more use of Geothermal and solar energy which Africa is well endowed with instead of cutting trees and burning of wood for fuel wood.
b) Since the vegetated earth (biosphere) is one of the major Sinks of carbon dioxide, massive afforestation and agro-forestry farming programmes could be encouraged to provide enough vegetation to take up the excess carbon-dioxide. Carbon dioxide which is already in the atmosphere could in theory be mopped up by planting more trees on the Earth which would in turn convert atmospheric carbon dioxide into woody tissues as reported by Green peace, an international Environmental Organization in Morocco in 2001.
ii) Halting depletion of Ozone layer by stopping the use of Chlorofluoro carbons (CFCs). Already a number of conventions have been put in place to act against Ozone layer depletion. They include:

a) The 1985 Vienna convention for the Protection of ozone layer
b) The 1992 Kyoto protocol pledged signatories to limit emissions of CFCs.
c) The Intergovernmental Panel on Climate Change (IPCC).
iii) Already several developed countries have restricted the use of made of CFCs or the amounts produced. For example, the United States banned the use of CFCs in aerosols in 1978. The European Union (EU) made up of ten countries introduced its own regulations and have in effect banned CFC production completely (Nkemdirim 2003).
iv) Kenya Forestry Research Institute (KEFRI) in Kenya carries activities, which include:
a) Afforestation for rehabilitation of Water catchments and dry land areas.
b) Agro-forestry such as farm forestry for rehabilitation of farmlands.
c) Natural indigeneous Forest conservation for example, the Nandi, the Tinderet, Chepalungu and the Mau for conservation and preservation of biodiversity.

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