**CHAPTER ONE**

**1. INTRODUCTION**

**1.1. Greenhouse gas effects**

**Greenhouse gases**

Greenhouse gases (GHGs) are gases released into the atmosphere through human activity that trap heat and thereby contribute to the warming of the planet. All GHGs contribute to climate change, but not all GHGs have the same level of impact – the relative potential to contribute to global warming is based on both their atmospheric ‘life’ (how long the gas will stay in the atmosphere) and their ability to absorb infrared radiation. The global warming potential indicates the level of impact each gas has on the climate relative to the impact of carbon dioxide (CO2). Carbon dioxide is the greenhouse gas that is most often mentioned in the context of climate change. This attention is due to the fact that CO2 is the most prevalent greenhouse gas released by human activity and 75% of the increase in atmospheric CO2 concentration since pre-industrial times is due to fossil fuel combustion, with the largest contribution from energy, industry and cement manufacture. In 2004, for example, almost 50 billion tons of greenhouse gases were released, of which about 77% was CO2. Methane contributed about 14%, and nitrous oxide made up about 8%, while the rest was made up of small amounts of HFCs, PFCs, and sulfur hexafluoride. Because CO2 is so prevalent, it is one of the most important emissions to address when mitigating climate change. Other gases, however, make a significant contribution to global warming despite lower emission levels. Nitrous oxide, for example, remains in the atmosphere longer than CO2 and it absorbs 296 times more infrared radiation than CO2.



**Table 2**: Human activities that emit GHGs



**Figure 4**: Sources of GHG emissions

Source: IPCC, 2007, 4th Assessment Synthesis Report Summary for Policymakers, p.5.

The primary greenhouse gases in the [Earth's atmosphere](http://en.wikipedia.org/wiki/Earth%27s_atmosphere) are [water vapor](http://en.wikipedia.org/wiki/Water_vapor) (H2O), carbon dioxide (CO2), methane (CH4), [nitrous oxide](http://en.wikipedia.org/wiki/Nitrous_oxide) (N2O), and [ozone](http://en.wikipedia.org/wiki/Ozone) (O3). These gases trap most of the outgoing thermal energy radiated by the earth’s surface. These greenhouse gases acts a thermal blanket around the globe, resulting in temperature increase.

Anthropogenic  carbon dioxide (CO2) emissions (i.e., emissions produced by human activities) come from  [combustion](http://en.wikipedia.org/wiki/Combustion) of [carbon based fuels](http://en.wikipedia.org/wiki/Carbon_based_fuel), principally [wood](http://en.wikipedia.org/wiki/Wood), [coal](http://en.wikipedia.org/wiki/Coal), [oil](http://en.wikipedia.org/wiki/Oil), and [natural gas](http://en.wikipedia.org/wiki/Natural_gas). Apart from water vapor, which is the most common greenhouse gas, there are six main greenhouse gases:

* Carbon dioxide
* Methane
* Nitrous oxide
* Hydrofluorocarbons
* Perfluorocarbons
* Sulphur hexafluoride.

The first three occur naturally in the atmosphere, while the last three are synthetic, and are either used in industry or created as a by-product of industrial processes.

**Carbon dioxide (CO2)**

Increases of the main greenhouse gas - carbon dioxide (CO2) - stem from burning petrol, coal, oil and natural gas, and from some activities, such as clearing trees and other vegetation and ploughing the soil.

CO2 is the main contributor to climate change, and accounts for about two thirds of greenhouse gases produced by human activities.

As part of the natural carbon cycle, plants remove CO2 from the atmosphere as part of photosynthesis while humans and other animals release carbon dioxide into the atmosphere by animals as they breathe. However, activities like burning fossil fuels and intensive agriculture are increasing atmospheric concentrations beyond natural and historical limits.

## Methane (CH4)

Methane is not as abundant as CO2, but is 21 times more effective at trapping heat making it a very potent greenhouse gas. It is released when vegetation decomposes in oxygen free environments (such as a fire or landfill), as well as from animals in digesting their food.

**Nitrous oxide (N2O)**

Nitrous oxide also occurs naturally in the environment, but human activities increase its atmospheric concentrations. Sources of nitrogen include fertilizer, legumes, organic matter in soil and manure. These emissions are greatest when soils are warm and waterlogged, and in those with high carbon and nitrate contents. One unit of nitrous oxide is equivalent to 310 units of carbon dioxide. To make measuring and accounting of greenhouse gases easier , all greenhouse gases are converted to a common unit, called CO2 equivalent or CO2.

Since about 1750 human activity has increased the concentration of carbon dioxide and other greenhouse gases. Measured atmospheric concentrations of carbon dioxide are currently 100 ppm higher than pre-industrial levels. Natural sources of carbon dioxide are more than 20 times greater than sources due to human activity, but over periods longer than a few years natural sources are closely balanced by natural sinks, mainly photosynthesis of carbon compounds by plants and marine plankton. As a result of this balance, the atmospheric mole fraction of carbon dioxide remained between 260 and 280 parts per million for the 10,000 years.

It is likely that anthropogenic (i.e., human-induced) warming, such as that due to elevated greenhouse gas levels, has had a discernible influence on many physical and biological systems. Future warming is projected to have a range of [impacts](http://en.wikipedia.org/wiki/Effects_of_global_warming), including [sea level rise](http://en.wikipedia.org/wiki/Sea_level_rise), increased frequencies and severities of some [extreme weather](http://en.wikipedia.org/wiki/Extreme_weather) events, loss of [biodiversity](http://en.wikipedia.org/wiki/Climate_change_and_ecosystems), and regional changes in [agricultural productivity](http://en.wikipedia.org/wiki/Climate_change_and_agriculture).

The main sources of greenhouse gases due to human activity are:

* Burning of [fossil fuels](http://en.wikipedia.org/wiki/Fossil_fuel) and [deforestation](http://en.wikipedia.org/wiki/Deforestation) leading to higher carbon dioxide concentrations in the air. Land use change (mainly deforestation in the tropics) account for up to one third of total anthropogenic CO2 emissions.
* Land use changes, and covered vented landfill emissions leading to higher methane atmospheric concentrations. Many of the newer style fully vented septic systems that enhance and target the fermentation process also are sources of [atmospheric methane](http://en.wikipedia.org/wiki/Atmospheric_methane).
* Agricultural activities, including the use of fertilizers, that lead to higher nitrous oxide concentrations.

**What is the greenhouse effect?**

In order to understand why climate change is occurring, it is essential to understand the greenhouse effect. The Earth receives most of its energy from the sun in the form of short wave radiation. Much of this incoming solar radiation passes through the atmosphere to reach the Earth’s surface. The Earth absorbs some of this energy and radiates some back into the atmosphere in the form of infrared radiation. Outgoing infrared radiation has a longer wavelength than incoming solar radiation and can therefore be absorbed by certain gases in the atmosphere. The main gases that absorb infrared radiation are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and haloflourocarbons (HFCs). These gases trap some of the infrared radiation and re-radiate it back to the Earth’s surface, causing a warming effect known as the “greenhouse effect”. The greenhouse effect is necessary to life on Earth as we know it; without it, the Earth’s surface would be about 35ºC (95ºF) cooler on average.

Over the past 200 years, however, the burning of fossil fuels and the destruction of forests has caused the concentrations of heat-trapping greenhouse gases to increase significantly in our atmosphere. With more of these gases in the atmosphere, more radiation is absorbed and re-radiated back to Earth as heat. Thus, as the concentrations of these gases continue to increase in the atmosphere, the Earth's temperature also continues to increase. In the 20th Century, global temperatures have increased by 0.7ºC (1.3ºF). If concentrations of greenhouse gases in the atmosphere continue to increase, the average temperature at the Earth's surface could increase from 1.8 to 4 ºC (3 to 7ºF) above 2000 levels by the end of this century.

**How fast has greenhouse gas emissions grown in recent years?**

Human emissions of greenhouse gases have grown at an accelerating rate in recent decades, increasing 70% between 1970 and 2004, according to the IPCC 2007 report. Consequently, the amounts of CO2 in the atmosphere have increased by 31%.

* There is a strong correlation between the rise in global temperature and the increasing concentration of carbon dioxide in the atmosphere. As CO2 increased from 1850 to 2000, average atmospheric temperature increased by about 1oC . Atmospheric CO2 continues to rise each year.
* Once released, greenhouse gases remain in the atmosphere until they are either absorbed by plants or animals or degraded by sunlight or by chemical reactions with other molecules. But molecules of CO2 remain in the atmosphere for approximately 100 years, which is why it is so hard to reverse global warming once it gets started.

**1.2. Ozone depletion**

Ozone is a naturally occurring gas found in very small traces in the earth’s atmosphere. The earth’s ozone is found in two areas. Ozone molecules make up a very sparse layer in the upper atmosphere (stratosphere), which is about 17 to 48 km above the earth’s surface. This is called the ozone layer. The presence of ozone can be a good or a bad thing depending on where it is present.

Approximately 90% of Earth’s ozone is to be found in the stratosphere, but 10% exists in the troposphere. In the troposphere, concentrations of ozone tend to increase with altitude, suggesting a stratospheric source. It is generally accepted that periodically, meteorological conditions in the upper troposphere and lower stratosphere are such that ozone from the stratosphere is injected into the troposphere.

In the stratosphere, ozone acts as a protective layer shielding the earth from harmful ultraviolet radiation. In the troposphere, ozone acts as a harmful pollutant and sometimes causes photochemical smog. More than a trace of this gas in the troposphere can damage human lungs and tissues, and also harm plants. Ozone is also a greenhouse gas and contributes to the greenhouse effect.

The level of ozone in the atmosphere is naturally fluctuating by small amounts all the time. It is affected by the seasons, changing wind patterns and other natural factors. For billions of years, a delicate balance has been maintained by nature. However, today, many human activities are harming the ozone layer and are leading to a decrease in the ozone levels in the upper atmosphere. The decrease in the amount of ozone in the upper atmosphere is known as ozone depletion. The chemicals causing this are called Ozone Depleting Substances (ODS). Depletion of the ozone layer allows potentially dangerous ultraviolet (UV) rays into the lower atmosphere. Most life forms on earth would suffer from the excess UV radiation. The ozone layer absorbs harmful ultraviolet radiation before it reaches the ground. Ozone depletion in the stratosphere results in more UV radiation reaching the earth’s surface. High levels of UV radiation have a direct effect on human life, animal life, plants, materials, etc.

In 1974, we discovered that chlorofluorocarbons (CFCs) – then commonly used in refrigeration and as propellants for spray cans – can have a detrimental effect on ozone (Molina and Rowland, 1974). In the stratosphere, CFCs decompose by the action of short wavelength solar radiation splitting off chlorine atoms, which in turn start chain reactions that break down ozone. We concluded that CFCs could cause a depletion of the ozone layer, potentially affecting human health and the environment.

Chemicals known as chlorofluorocarbons (CFCs), used in the cooling systems of refrigerators, freezers, and air conditioners, are the primary cause of ozone depletion. These chemicals contain chlorine and fluorine molecules. When these molecules escape in to the air they raise in the atmosphere until they reach the level of the protective ozone layer.

CFC+ uv Cl**.**

Cl**.** + O3 O2 + ClO

ClO + uv Cl**.** + O

O3 and O2 both absorb ultraviolet but at slightly different wavelengths. O3 absorbs in a region from 240 - 280 nm and O2 absorbs wavelengths shorter than 175 nm. The energy absorbed in both cases is used to effect chemical change rather than re-emitted.

The UV radiation absorbed by O2 in the stratosphere actually splits the O2 into oxygen atoms. Each of these oxygen atoms combines with other oxygen atoms to form O2 or with O2 to form O3. O3 absorbs UV at the higher wavelengths (240-280 nm) to split into O and O2. The O released by O3 may recombine with an O to form O2 or with water to form 2OH radicals. One chlorine atom can destroy over 100,000 molecules of ozone, and the result of this disruption is a markedly lower than expected concentration of stratospheric ozone at various points around the world.

Some of the effects of ozone depletion on various life forms and materials are:

**Humans and animals**: Ozone depletion may increase the rate of skin cancer and cause the skin to freckle and age faster. It will increase the frequency of cataracts and other eye diseases in humans and animals. The ability of the human system to fight diseases (immune system) will also be weakened.

**Plants:** Increased UV radiation affects plants by reducing leaf size and increasing germination time. This could decrease crop yield of corn, rice, soybeans, peas, sorghum and wheat.

**Food chains:** There may be a reduction in the growth of microscopic phytoplankton when UV radiation penetrates deep below the surface of oceans. These tiny floating producers form the base of ocean food chains and food webs, and help remove CO2 from the atmosphere. The food chain of the terrestrial ecosystems will also be affected as over half the land plants are adversely affected by high levels of UV.

**Materials:** Increased UV radiation damages paints and fabrics, causing them to fade faster. Plastic furniture, pipes, etc., exposed to the sun, also deteriorate faster.

**1.3. Global warming**

It is the warming of the earth’s atmosphere as a result of increases in the concentrations of one or more greenhouse gases. It is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation.

# 1.4. Climate change Vs Climate variability

**What is Climate Change?**

Any significant change in measures of climate (such as temperature or precipitation) lasting for an extended period of time (typically decades).

**United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as:**

“A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere”.

**Climate change** refers to long-term (decades or longer) trends in climate averages such as the global warming that has been observed over the past century, and long-term changes in variability (e.g. in the frequency, severity and duration of extreme events).

Variability on time scales longer than a few decades (longer than a standard climatic averaging period) is usually referred to as **climatic change**.

**Climate variability** refers to shorter term (daily, seasonal, annual) variations in climate, including the fluctuations associated with El Niño (dry) or La Niña (wet) events.

Variability on time scales of a few years to a few decades (i.e., shorter than a climatic averaging period) is usually referred to as **climatic variability**.

It is the variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

**Climate Vs Weather**

Climate describes the average or typical conditions of temperature, relative humidity, cloudiness, precipitation, wind speed and direction, and other meteorological factors that prevail globally or regionally for extended periods.

Weather describes the hourly or daily conditions that people experience each day. That is why “**Climate is what you expect** and **weather is what you get**.”

**1.5. Why climate change is a global issue?**

Global climate change is an environmental problem in today’s modern world because of the colossal threat, risks and effects that it poses to the global weather patterns, global warming, natural ecosystems, biodiversity, the oceans and seas, and the future of human life and existence on planet earth (Freestone and Streck ,2009). This is mainly caused by anthropogenic greenhouse gas (GHG) emissions of carbon-dioxide (CO2) mainly from the burning of fossil fuels (coal, oil, and natural gas), deforestation and emission of other GHGs. With about 75% of the global GHGs from energy related activities; CO2 is said to be the largest contributor (Freestone and Streck, 2009).

In the 20th century human population quadrupled from 1.6 billion people to 6.1 billion. Carbon dioxide emissions, which trap heat in the atmosphere, grew 12-fold from 534 million metric tons in 1900 to 6.59 billion metric tons in 1997. In 1995, the 20% of the world’s population living in countries with the highest per capita fossils fuel carbon dioxide emissions contributed 63% of the total global emissions. The 20% in the lowest emission, countries contributed just 2% of the total. The USA with only 4.6 of the world’s population produces one fourth of the global green house emissions (2001 data). Climate change will have a serious impact including increased storms, flooding and soil erosion, accelerated extinction of plants and animals, shifting agricultural zones, and a threat to public health due to increased water stress and tropical disease. These conditions could increase environmental refugees and international economic migration.

Climate change impacts on population dynamics in Ethiopia thus can be perceived in the notion that: increase in migration and displacement of people affected by climate change impacts; people to be affected due to health related impacts such as emergence of new vector-borne diseases and more incidences of malaria and diarrhea; the increase in hunger and malnutrition in communities; exposing population living in low elevations to sea level rise and storms; water scarcity and shortage; affecting the productive labor potential or working-age adults and exacerbating economic disruption and social unrest.

**Generally, climate change becomes a global issue due to the following reasons:**

* Climate change will have significant impacts on development, poverty alleviation, and the achievement of the Millennium Development Goals (MDGs).
* Hard-fought progress made in achieving these global goals may be slowed or even reversed by climate change as new threats emerge to water and food security, agricultural production, nutrition, and public health.
* Countries and regions that fail to adapt will contribute to global insecurity through the spread of disease, conflicts over resources, and a degradation of the economic system.

**CHAPTER TWO**

**2. Drivers of climate change**

The cause of climate change can be divided in to two categories, humans, and natural causes.

## 2.1. Natural cause of climate change

The earth’s climate is influenced and changed through natural causes like volcanic eruptions, ocean currents, the earth’s orbital changes, and solar variations.

### 2.1.1. Volcanic eruptions

When a volcano erupts, it throws out large volumes of Sulphur dioxide (SO2), water vapor, dust, and ash in to the atmosphere. Tiny particles called aerosols are produced by volcanoes reflect solar energy.

### 2.1.2. Ocean Current

The oceans are a major component of the climate system. Ocean currents move vast amount of heat across the planet. Winds push horizontally against the sea surface and drive ocean current patterns.

There is deep ocean circulation of cold water, from the poles towards the equator and movement of warm water from the equator back towards the poles. Without this movement, the poles are colder and the equator warmer. The ocean plays an important role in determining the atmosphere concentration of CO2. Changes in ocean circulation may affect the climate through the movement of CO2 in to or out of the atmosphere.

### 2.1.3. Earth orbital changes

The earth makes one full orbit around the sun each year. It is tilted at an angle 23.50 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 summer and colder winters; less tilt means cooler summers and milder winter.

**2.1.4. Continental Drift**

|  |
| --- |
| Millions of years ago, all the continents were merged in one large land mass known as Pangaea. This was about 250 million years ago. They gradually began to drift apart and formed the separate continents that we are familiar with today. The formation of separate continental land masses changed the flow of ocean currents and winds, and isolated Antarctica. |

This continental drift leads to climate change, as it brings about a change in the following.

* Physical feature of the lithosphere
* Position of the land masses
* Mountains and water bodies

## 2.2 Anthropogenic drivers

Anthropogenic climate change is arguably one of the biggest problems that confront us today. There is wide agreement that climate change will affect the lives of all people around the world in areas such as food production, access to water, health, and the environment. Indeed, it has been estimated that millions could suffer hunger, water shortages, diseases, and coastal flooding as a result of global warming (IPCC 2007; Stern 2007).

Human activities contribute to climate change by causing changes in Earth’s atmosphere in the amounts of greenhouse gases, aerosols (small particles), and cloudiness. The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide gas to the atmosphere. Greenhouse gases and aerosols affect climate by altering incoming solar radiation and out-going infrared (thermal) radiation that are part of Earth’s energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to a warming or cooling of the climate system. Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

**2.2.1. Technological development and transportation**

Transportation accounts for more than 2/3 of U.S. oil consumption and transportation vehicles emit 27 percent of the nation’s GHG emissions (a further 9% of U.S emissions are emitted from vehicle manufactured and motor fuel production). Since 1990, transportation sector emissions have grown more in absolute terms than any other sector.

**2.2.2. Increased world industrial activities**

Increased industrial activity since the Industrial Revolution is one of the main causes of air pollution. With growing populations and industries, the need for energy has increased multifold. To meet this increased power requirement, mega-power projects have come up. The use of coal in thermal power stations has led to the increase in air pollutants such as various oxides of carbon, sulphur and nitrogen. Apart from these, thermal power stations produce large quantities of fly ash as a by-product, which covers large areas of land with a fluffy, sooty layer.

Industrial activity is essential to generate goods for the development of the nation, to meet the needs of the people, and to generate employment. At the same time, it must be accepted that industrial activities release pollutants that contaminate air, water bodies and land, and adversely affect the quality of human and other life. While industries are vital for development, it is equally important to be aware of the impacts of industries on environment. A proper understanding of this can help ensure that these impacts are minimized. The first and most obvious way in which industries affect the environment is the pollution caused by factories. The most visible are the water, solid-waste and air pollution that can be felt and seen. The nature and composition of industrial waste and pollutants vary widely from industry to industry and even within the same industry. The waste generated depends on the raw materials, processes, and operating factors.

The extraction and mining of raw materials, and the processing of the raw material, e.g., ores into metal, have major environmental impacts. For instance, if limestone is to be mined for cement production, large areas of land will get degraded. If cotton is to be grown for making cloth, hectares of agricultural land may have to be made productive with chemical fertilizers, and heavily sprayed with chemical pesticides to get a good crop. If wood is to be fed to a paper factory, hectares of trees or bamboo will have to be cut down. These all activities leads to the increase in atmospheric CO2.

**Location of the industry**: A polluting industry should not be located in an ecologically sensitive

area or near human settlements.

**2.2.3. Material and energy consumption growth**

Energy is an essential ingredient of all activity on earth. Human society has progressed because it has learnt to harness and use more and more energy. Due to certain gases emitted by fuel combustion trap heat, experts predict that by the year 2100, the average global temperature will have increased by anywhere between 1°C and 4.5°C. So it is important that we take a close look at energy where it comes from, how we use it, what the environmental impacts are, and what we can do about it.

**2.2.4. Land use change and deforestation**

Deforestation is the single most measured process of land-cover change at a global scale. During the industrial era, global forest area was reduced by 40%, with three quarters of this loss occurring during the last two centuries (Millennium Ecosystem Assessment 2005*a*). Forests have completely disappeared in 25 countries, and another 29 have lost more than 90% of their woodlands. Although forest cover and biomass in Europe and North America is currently increasing following radical declines in the past, the deforestation of natural forests in the tropics continues at an annual rate of more than 10 x 106 ha/yr. Deforestation and forest degradation affect 8.5% of the world’s remaining forests, nearly half of which are in South America. Deforestation and forest degradation have been more extensive in the tropics over the past few decades than in the

rest of the world.

Trees help to regulate the climate by taking up CO2 from the atmosphere, and immense amounts of carbon are stored in the world's forests. When forests are cut down, the carbon stored in the trees is released into the atmosphere as CO2, adding to the greenhouse effect. On top of that, when a forest is destroyed, it can no longer absorb CO2 from the atmosphere.

# CHAPTER THREE

# 3. AN over view of climate change impacts

**3.1. Observed and projected impacts on natural ecosystem**

An ***ecosystem***is a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit.

***Ecosystem services*** are the benefits people obtain from ecosystems. They include the following:

* + **Provision services**: food, water, timber, and fiber
  + **Regulated services** that affect the climate, floods, disease, waste, and water quality
  + **Cultural services** that provide recreational, aesthetic, and spiritual benefits
  + **Support services** such as soil formation, photosynthesis, and nutrient cycling.

**Biodiversity** refers to the number of plant and animal species existing within a given region as well as the genetic variety within each species. It is a main component of sustainable development, b/se it is an indication of a region’s ability to renew its natural resources. Desertification, climate change, and introduction of non-native species have drastically reduced the biodiversity of many regions throughout the world.

Changes in natural ecosystems, loss of biodiversity, and extinction of species are among the first observable impacts of climate change. Changes in plant flowering dates and bird migrations and distributions have already been widely recorded. While some of the more mobile species (birds and larger animals) may be able to migrate rapidly enough in response to changing climate patterns, many ecosystem components, including many tree species, have much lower mobility.

In general, biodiversity is threatened by overconsumption in developed nations and by poverty in underdeveloped Nations.

## 3.2. Impacts of climate change on agricultural system

Most of Africa relies on rain-fed agriculture. As a result, it is highly vulnerable to changes in climate variability, seasonal shifts, and precipitation patterns.

Any amount of warming will result in increased water stress. Roughly 70 percent of the population lives by farming, and 40 percent of all exports are agricultural products (WRI 1996). One-third of the income in Africa is generated by agriculture. Crop production and livestock husbandry account for about half of household income. The poorest members of society are those who are most dependent on agriculture for jobs and income (Odingo 1990; FAO 1999).

Climate change will affect numerous sectors and productive environments, including agriculture, forestry, energy, and coastal zones, in developed and developing countries. Developing economies will be more affected by climate change, in part because of their greater exposure to climate shocks and in part because of their low adaptive capacity. But no country is immune. And of the developing countries, many in Africa are seen as being the most vulnerable to climate variability and change.

Agricultural productivity is one of many factors driving the greater vulnerability of developing countries. The impacts of climate change on health add to the human and economic losses, especially in developing countries. A cycle of descent into poverty could emerge from the confluence of climate change, environmental degradation, and market and institutional failures. In Ethiopia a season with starkly reduced rainfall depressed consumption even after four to five years. Climate change will create large incremental risks.

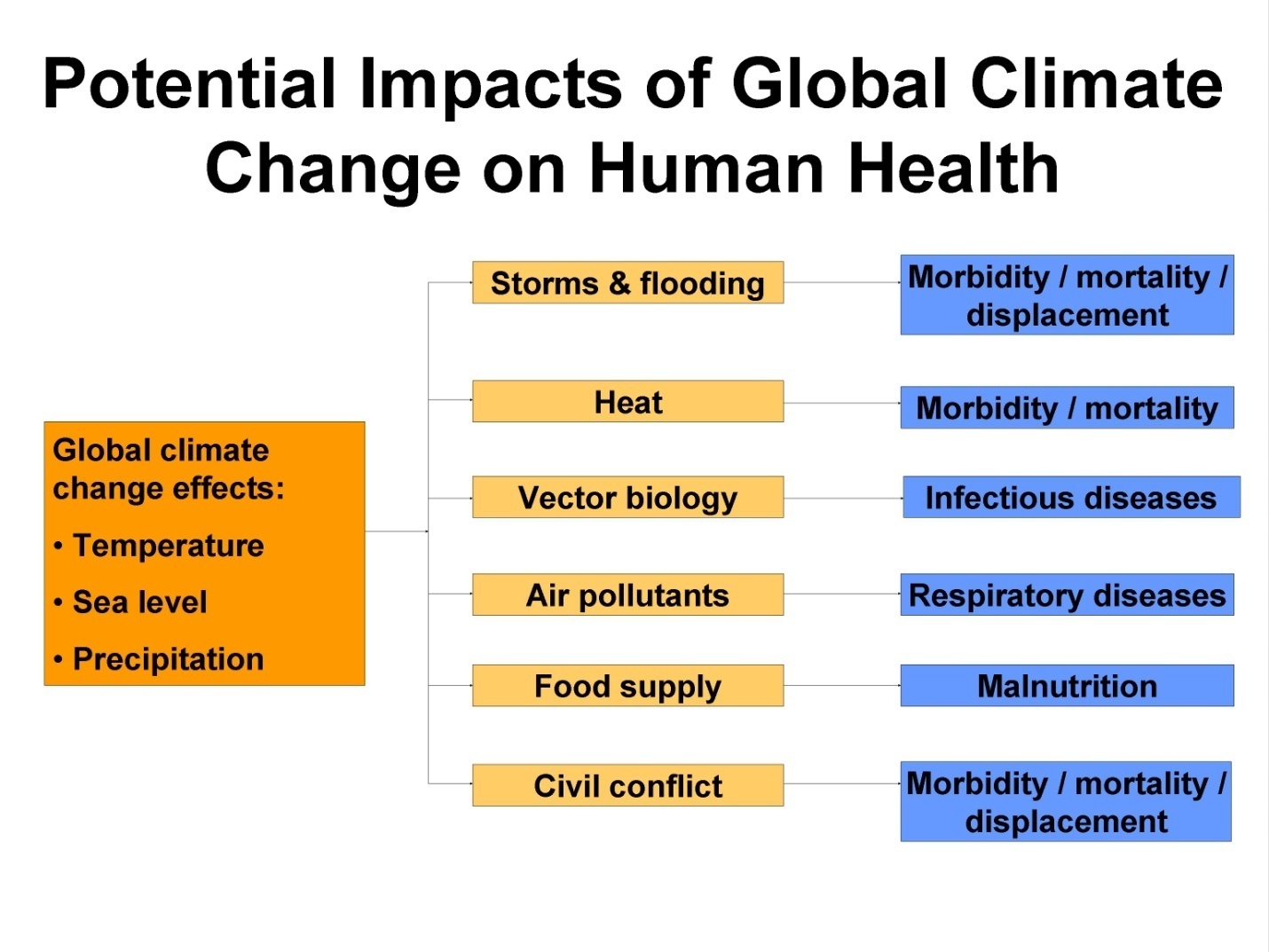
Ethiopia has experienced at least five major national droughts since 1980, along with literally dozens of local droughts. Cycles of drought create poverty traps for many households, including agro-pastoral and pastoral households, constantly thwarting efforts to build up assets and increase income. The human impacts of current climate shocks provide a widely ignored backdrop for understanding the human development implications of climate change.

Impacts of climate change on the agriculture and livestock sectors encompass:

* Shortening of maturity period and decrease in crop yield;
* Change in livestock feed availability;
* Effects on animal health, growth and reproduction;
* Impacts on quality and quantity of forage crops;
* Change in distribution of diseases;
* Changes in decomposition rate;
* Expansion of tropical dry forests and the disappearance of lower montane wet forests; expansion of desertification.

## 3.3 Impact of climate change on human health

## Over the 21st century, climate change is likely to adversely affect hundreds of millions of people through increased coastal [flooding](http://en.wikipedia.org/wiki/Flood), reductions in water supplies, increased [malnutrition](http://en.wikipedia.org/wiki/Malnutrition) and increased health impacts.



## 3.4. Climate change impacts on sustainable development

## Sustainable development

The generally accepted and used definition as given by the Brundtland Commission is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Sustainable development requires that the future generations have, at least, the same quality of life as the current generations. Three critical components in promoting sustainable development are economic growth, social equity, and environmental sustainability.

Many economists and policy makers in developing countries often perceive a trade-off between economic growth and environmental sustainability. However, there is a growing evidence to show that environmental conservation for sustainability of natural resources is not a luxury but a necessity when considering long-term economic growth and development, particularly in the least developed countries.

The decline and degradation of natural resources such as land, soil, forests, biodiversity and ground water, resulting from current unsustainable use patterns, are likely to be aggravated due to climate change in the next 25 to 50 years.

The environmental interpretation of sustainability focuses on the overall performance or health of ecological systems. Enhancing human capital, preserving cultural capital and diversity, empowering and involving vulnerable communities could ensure a socially sustainable development path. Thus, environmental and social sustainability is critical and one enhances the other. There is general agreement among scholars and global climate negotiators that economic development (particularly removal of poverty in developing countries), ecological integrity (sustainability), and social justice (equity) are three pillars of sustainable development. Sustainable development is equivalent to investment in capital stock (including human capital), natural capital (natural resources and biodiversity), and social capital (Banuri and Weyant, 2001). Gradually, the need to integrate development, equity, and sustainability under the umbrella of sustainable development is being recognized and accepted by the policy makers.

The international communities conduct different declarations related to thesustainable development issues. Some of the declarations are:

1. **Stockholm Declarations (1972)**

In 1972, Stockholm, Sweden, hosted the first United Nations Conference on the Human Environment, which was attended by 113 delegates and two heads of state (Olaf Palme of Sweden and Indira Gandhi of India). This conference raised a generation's awareness of an issue hitherto little talked about, the global environment. The Stockholm conference secured a permanent place for the environment on the world's agenda and led to the establishment of the United Nations Environment Program (UNEP). The conference and its aftermath made known the international nature of the environment and introduced the idea of the relationship between development and the environment. It has been said that the only way to unite the countries of the world is for them to face a common enemy; perhaps environmental degradation will be that enemy.

The United Nations Conference on the Human Environment, having met at Stockholm from 5 to 16 June 1972, having considered the need for a common outlook and for common principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment,

Proclaims that:

1. Man is both creature and moulder of his environment, which gives him physical sustenance and affords him the opportunity for intellectual, moral, social and spiritual growth. In the long and tortuous evolution of the human race on this planet a stage has been reached when, through the rapid acceleration of science and technology, man has acquired the power to transform his environment in countless ways and on an unprecedented scale. Both aspects of man's environment, the natural and the man-made, are essential to his well-being and to the enjoyment of basic human rights the right to life itself.

2. The protection and improvement of the human environment is a major issue which affects the well-being of peoples and economic development throughout the world; it is the urgent desire of the peoples of the whole world and the duty of all Governments.

3. Man has constantly to sum up experience and go on discovering, inventing, creating and advancing. In our time, man's capability to transform his surroundings, if used wisely, can bring to all peoples the benefits of development and the opportunity to enhance the quality of life. Wrongly or heedlessly applied, the same power can do incalculable harm to human beings and the human environment. We see around us growing evidence of man-made harm in many regions of the earth: dangerous levels of pollution in water, air, earth and living beings; major and undesirable disturbances to the ecological balance of the biosphere; destruction and depletion of irreplaceable resources; and gross deficiencies, harmful to the physical, mental and social health of man, in the man-made environment, particularly in the living and working environment.

4. In the developing countries most of the environmental problems are caused by under-development. Millions continue to live far below the minimum levels required for a decent human existence, deprived of adequate food and clothing, shelter and education, health and sanitation. Therefore, the developing countries must direct their efforts to development, bearing in mind their priorities and the need to safeguard and improve the environment. For the same purpose, the industrialized countries should make efforts to reduce the gap themselves and the developing countries. In the industrialized countries, environmental problems are generally related to industrialization and technological development.

5. The natural growth of population continuously presents problems for the preservation of the environment, and adequate policies and measures should be adopted, as appropriate, to face these problems. Of all things in the world, people are the most precious. It is the people that propel social progress, create social wealth, develop science and technology and, through their hard work, continuously transform the human environment. Along with social progress and the advance of production, science and technology, the capability of man to improve the environment increases with each passing day.

6. A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences. Through ignorance or indifference we can do massive and irreversible harm to the earthly environment on which our life and well being depend. Conversely, through fuller knowledge and wiser action, we can achieve for ourselves and our posterity a better life in an environment more in keeping with human needs and hopes. There are broad vistas for the enhancement of environmental quality and the creation of a good life. What is needed is an enthusiastic but calm state of mind and intense but orderly work. For the purpose of attaining freedom in the world of nature, man must use knowledge to build, in collaboration with nature, a better environment. To defend and improve the human environment for present and future generations has become an imperative goal for mankind-a goal to be pursued together with, and in harmony with, the established and fundamental goals of peace and of worldwide economic and social development.

7. To achieve this environmental goal will demand the acceptance of responsibility by citizens and communities and by enterprises and institutions at every level, all sharing equitably in common efforts. Individuals in all walks of life as well as organizations in many fields, by their values and the sum of their actions, will shape the world environment of the future.

Local and national governments will bear the greatest burden for large-scale environmental policy and action within their jurisdictions. International cooperation is also needed in order to raise resources to support the developing countries in carrying out their responsibilities in this field. A growing class of environmental problems, because they are regional or global in extent or because they affect the common international realm, will require extensive cooperation among nations and action by international organizations in the common interest.

The Conference calls upon Governments and peoples to exert common efforts for the preservation and improvement of the human environment, for the benefit of all the people and for their posterity.

**Principles**

States the common conviction that:

**Principle 1**

Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being, and he bears a solemn responsibility to protect and improve the environment for present and future generations. In this respect, policies promoting or perpetuating apartheid, racial segregation, discrimination, colonial and other forms of oppression and foreign domination stand condemned and must be eliminated.

**Principle 2**

The natural resources of the earth, including the air, water, land, flora and fauna and especially representative samples of natural ecosystems, must be safeguarded for the benefit of present and future generations through careful planning or management, as appropriate.

**Principle 3**

The capacity of the earth to produce vital renewable resources must be maintained and, wherever practicable, restored or improved.

**Principle 4**

Man has a special responsibility to safeguard and wisely manage the heritage of wildlife and its habitat, which are now gravely imperiled by a combination of adverse factors. Nature conservation, including wildlife, must therefore receive importance in planning for economic development.

**Principle 5**

The non-renewable resources of the earth must be employed in such a way as to guard against the danger of their future exhaustion and to ensure that benefits from such employment are shared by all mankind.

**Principle 6**

The discharge of toxic substances or of other substances and the release of heat, in such quantities or concentrations as to exceed the capacity of the environment to render them harmless, must be halted in order to ensure that serious or irreversible damage is not inflicted upon ecosystems. The just struggle of the peoples of ill countries against pollution should be supported.

**Principle 7**

States shall take all possible steps to prevent pollution of the seas by substances that are liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea.

**Principle 8**

Economic and social development is essential for ensuring a favorable living and working environment for man and for creating conditions on earth that are necessary for the improvement of the quality of life.

**Principle 9**

Environmental deficiencies generated by the conditions of under-development and natural disasters pose grave problems and can best be remedied by accelerated development through the transfer of substantial quantities of financial and technological assistance as a supplement to the domestic effort of the developing countries and such timely assistance as may be required.

**Principle 10**

For the developing countries, stability of prices and adequate earnings for primary commodities and raw materials are essential to environmental management, since economic factors as well as ecological processes must be taken into account.

**Principle 11**

The environmental policies of all States should enhance and not adversely affect the present or future development potential of developing countries, nor should they hamper the attainment of better living conditions for all, and appropriate steps should be taken by States and international organizations with a view to reaching agreement on meeting the possible national and international economic consequences resulting from the application of environmental measures.

**Principle 12**

Resources should be made available to preserve and improve the environment, taking into account the circumstances and particular requirements of developing countries and any costs which may emanate- from their incorporating environmental safeguards into their development planning and the need for making available to them, upon their request, additional international technical and financial assistance for this purpose.

**Principle 13**

In order to achieve a more rational management of resources and thus to improve the environment, States should adopt an integrated and coordinated approach to their development planning so as to ensure that development is compatible with the need to protect and improve environment for the benefit of their population.

**Principle 14**

Rational planning constitutes an essential tool for reconciling any conflict between the needs of development and the need to protect and improve the environment.

**Principle 15**

Planning must be applied to human settlements and urbanization with a view to avoiding adverse effects on the environment and obtaining maximum social, economic and environmental benefits for all. In this respect projects which arc designed for colonialist and racist domination must be abandoned.

**Principle 16**

Demographic policies which are without prejudice to basic human rights and which are deemed appropriate by Governments concerned should be applied in those regions where the rate of population growth or excessive population concentrations are likely to have adverse effects on the environment of the human environment and impede development.

**Principle 17**

Appropriate national institutions must be entrusted with the task of planning, managing or controlling the 9 environmental resources of States with a view to enhancing environmental quality.

**Principle 18**

Science and technology, as part of their contribution to economic and social development, must be applied to the identification, avoidance and control of environmental risks and the solution of environmental problems and for the common good of mankind.

**Principle 19**

Education in environmental matters, for the younger generation as well as adults, giving due consideration to the underprivileged, is essential in order to broaden the basis for an enlightened opinion and responsible conduct by individuals, enterprises and communities in protecting and improving the environment in its full human dimension. It is also essential that mass media of communications avoid contributing to the deterioration of the environment, but, on the contrary, disseminates information of an educational nature on the need to project and improve the environment in order to enable mal to develop in every respect.

**Principle 20**

Scientific research and development in the context of environmental problems, both national and multinational, must be promoted in all countries, especially the developing countries. In this connection, the free flow of up-to-date scientific information and transfer of experience must be supported and assisted, to facilitate the solution of environmental problems; environmental technologies should be made available to developing countries on terms which would encourage their wide dissemination without constituting an economic burden on the developing countries.

**Principle 21**

States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

**Principle 22**

States shall cooperate to develop further the international law regarding liability and compensation for the victims of pollution and other environmental damage caused by activities within the jurisdiction or control of such States to areas beyond their jurisdiction.

**Principle 23**

Without prejudice to such criteria as may be agreed upon by the international community, or to standards which will have to be determined nationally, it will be essential in all cases to consider the systems of values prevailing in each country, and the extent of the applicability of standards which are valid for the most advanced countries but which may be inappropriate and of unwarranted social cost for the developing countries.

**Principle 24**

International matters concerning the protection and improvement of the environment should be handled in a cooperative spirit by all countries, big and small, on an equal footing.

Cooperation through multilateral or bilateral arrangements or other appropriate means is essential to effectively control, prevent, reduce and eliminate adverse environmental effects resulting from activities conducted in all spheres, in such a way that due account is taken of the sovereignty and interests of all States.

**Principle 25**

States shall ensure that international organizations play a coordinated, efficient and dynamic role for the protection and improvement of the environment.

**Principle 26**

Man and his environment must be spared the effects of nuclear weapons and all other means of mass destruction. States must strive to reach prompt agreement, in the relevant international organs, on the elimination and complete destruction of such weapons.

1. **Rio Declaration on Environment and Development (1992)**

The Rio Declaration on Environment and Development, often shortened to Rio Declaration, was a short document produced at the 1992 [United Nations](http://en.wikipedia.org/wiki/United_Nations) "Conference on Environment and Development" (UNCED), informally known as the [Earth Summit](http://en.wikipedia.org/wiki/Earth_Summit). The Rio Declaration consisted of 27 principles intended to guide future [sustainable development](http://en.wikipedia.org/wiki/Sustainable_development) around the world.

Reaffirming the Declaration of the United Nations Conference on the Human Environment, adopted at Stockholm on 16 June 1972, and seeking to build upon it, with the goal of establishing a new and equitable global partnership through the creation of new levels of cooperation among States, key sectors of societies and people. Working towards international agreements which respect the interests of all and protect the integrity of the global environmental and developmental system. Recognizing the integral and interdependent nature of the Earth, our home.

UNCED addressed environmental issues, such as the protection of air, land and water; conservation of biological diversity, forests, and natural resources; and sound management of wastes and technology. It was a unique opportunity for world leaders to curtail the human activities that are threatening our planet and bringing about pollution of land, ocean and atmosphere, drought, desertification through land degradation, thinning of the ozone layer, global warming and the threat of rising sea levels, and the extinction of plant and animal species. Also included were the concerns that have led to serious differences between countries: patterns of development that cause stress to the environment, poverty in developing countries, economic growth, unsustainable patterns of consumption, and demographic pressures and their impact on the international economy.

**The 27 Principles of the Rio Declaration**

**Principle 1**

Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.

**Principle 2**

States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas

beyond the limits of national jurisdiction.

**Principle 3**

The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.

**Principle 4**

In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.

**Principle 5**

All States and all people shall cooperate in the essential task of eradicating poverty as an indispensable requirement for sustainable development, in order to decrease the disparities in standards of living and better meet the needs of the majority of the people of the world.

**Principle 6**

The special situation and needs of developing countries, particularly the least developed and those most environmentally vulnerable, shall be given special priority. International actions in the field of environment and development should also address the interests and needs of all countries.

**Principle 7**

States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of

Sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command.

**Principle 8**

To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.

**Principle 9**

States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies.

**Principle 10**

Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

**Principle 11**

States shall enact effective environmental legislation. Environmental standards, management objectives and priorities should reflect the environmental and developmental context to which they apply. Standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries.

**Principle 12**

States should cooperate to promote a supportive and open international economic system that would lead to economic growth and sustainable development in all countries, to better address the problems of environmental degradation. Trade policy measures for environmental purposes should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade. Unilateral actions to deal with environmental challenges outside the jurisdiction of the importing country should be avoided. Environmental measures addressing transboundary or global environmental problems should, as far as possible, be based on an international consensus.

**Principle 13**

States shall develop national law regarding liability and compensation for the victims of pollution and other environmental damage. States shall also cooperate in an expeditious and more determined manner to develop further international law regarding liability and compensation for adverse effects of environmental damage caused by activities within their jurisdiction or control to areas beyond their jurisdiction.

**Principle 14**

States should effectively cooperate to discourage or prevent the relocation and transfer to other States of any activities and substances that cause severe environmental degradation or are found to be harmful to human health.

**Principle 15**

In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

**Principle 16**

National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting

international trade and investment.

**Principle 17**

Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority.

**Principle 18**

States shall immediately notify other States of any natural disasters or other emergencies that are likely to produce sudden harmful effects on the environment of those States. Every effort shall be made by the international community to help States so afflicted.

**Principle 19**

States shall provide prior and timely notification and relevant information to potentially affected States on activities that may have a significant adverse transboundary environmental effect and shall consult with those States at an early stage and in good faith.

**Principle 20**

Women have a vital role in environmental management and development. Their full participation is therefore essential to achieve sustainable development.

**Principle 21**

The creativity, ideals and courage of the youth of the world should be mobilized to forge a global partnership in order to achieve sustainable development and ensure a better future for all.

**Principle 22**

Indigenous people and their communities and other local communities have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development.

**Principle 23**

The environment and natural resources of people under oppression, domination and occupation shall be protected.

**Principle 24**

Warfare is inherently destructive of sustainable development. States shall therefore respect international law providing protection for the environment in times of armed conflict and cooperate in its further development, as necessary.

**Principle 25**

Peace, development and environmental protection are interdependent and indivisible.

**Principle 26**

States shall resolve all their environmental disputes peacefully and by appropriate means in accordance with the Charter of the United Nations.

**Principle 27**

States and people shall cooperate in good faith and in a spirit of partnership in the fulfillment of the principles embodied in this Declaration and in the further development of international law in the field of sustainable development.

## 3. Johannesburg Declaration

The Johannesburg Declaration was a principal outcome of the Summit. The declaration is a collection of general political statements, reaffirming a commitment to agreements made at the Rio de Janeiro summit and at the Stockholm Summit on the Human Environment 30 years prior. International cooperation, decreasing world poverty, special attention for developing nations, empowering women, and maintaining [biodiversity](http://www.eoearth.org/article/Biodiversity), among other things, are outlined as key points to building a sustainable future. The document is meant to serve as a contract for the participants of the summit, binding them to the outlined agreements.

A Plan of Implementation laid down more specific goals for the nations and organizations that participated in the summit. Some of these goals include:

* The establishment of a solidarity fund to wipe out poverty. This fund would be sustained by voluntary contributions; however, developed nations are urged to dedicate 0.7% of their national income to this cause.
* Cutting in half by 2015 the proportion of the world’s population living on less than a dollar a day. This is a reaffirmation of a [UN Millennium Summit goal](http://www.eoearth.org/article/Millennium_Development_Goals_%28MDGs%29).
* Cutting in half by 2015 the number of people who lack clean drinking water and basic sanitation
* Substantially increase the global share of [renewable energy](http://www.eoearth.org/article/Renewable_energy)
* Cut significantly by 2010 the rate at which rare plants and animals are becoming extinct
* Restore (where possible) depleted [fish stocks](http://www.eoearth.org/article/Marine_fisheries) by 2015, and
* Halving the number of people suffering from hunger.

The results of the Johannesburg Summit have been criticized in subsequent years as being too vague and for setting weaker goals than those agreed upon in previous summits. The resolutions passed at the summit also lack the provisions for substantial enforcement, making it difficult to assess what progress was actually made. NGOs such as the Global Peoples Forum and Friends of the Earth have set forth recommendations to strengthen the Johannesburg goals, and The Earth Charter Initiative has proposed an Earth Charter as a replacement for the current political declaration.

Kofi Annan, UN Secretary-General, outlined five topic areas which were to be the key points of discussion at the summit: at johannesberg declaration(known as "Rio+10".)

(1) Water and sanitation,

(2) [Energy](http://www.eoearth.org/article/Energy),

(3) Human health,

(4) Agricultural productivity, and

(5) [Biodiversity](http://www.eoearth.org/article/Biodiversity) and ecosystem management.

**CHAPTER FOUR**

**4.** **Climate change mitigation strategies**

**4.1 Carbon sequestration**

**What is carbon sequestration?**

Carbon sequestration in terrestrial ecosystem can be defined as the absorption of CO2 from the atmosphere by photosynthesis or technology based sequestration activities such as deep sea bed storage of liquefied CO2 (Bass *et al*., 2000).

The term “carbon sequestration” is used to describe both natural and deliberate processes by which CO2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations.

The United Nations Framework Convention on Climate Change (UNFCCC) defines carbon se-questration as the process of removing carbon from the atmosphere and depositing it in a reser-voir. It entails the transfer of atmospheric CO2, and its secure storage in long-lived pools (UNFCCC, 1997).

On the other hand, Carbon sequestration (CS) refers to the provision of long-term storage of carbon in the terrestrial biosphere, underground, or the oceans so that the buildup of carbon dioxide (the principal greenhouse gas) concentration in the atmosphere will reduce or slow. The removal of greenhouse gases from the atmosphere into sinks (i.e. soil) is one way of addressing climate change. Increasing the quantity of carbon sequestered or stored in soils and biomass is an alternative to reducing emissions of carbon and other greenhouse gases (GHG) in an overall strategy to mitigate global climate change and its negative economic and environmental effects.

**Forest Ecosystems and Climate Change Mitigation Options**

The forests ecosystems covering about 4.1 billion hectares globally (Dixon and Wisniewski, 1994) are a major reserve of terrestrial Carbon stock. Globally, the coverage of the forest is de-creasing at the net rate of about 9.4 M ha/year mostly due to deforestation of the tropical rainfor-est. The deforestation and conversion of TRF into agricultural ecosystems results in emission of 1.6-1.7 Pg C/year into the atmosphere (IPCC, 2000).

The forest ecosystems play an important role in the climate change mitigation because forests can act as both sources and sinks of atmospheric CO2. This ecosystem has essentially three car-bon pools: the living biomass, detritus (debris from dead plants and animals) and soils. The Car-bon stored in the forest is most directly affected by forest management systems. Management of forests can assimilate CO2 via photosynthesis, and store carbon in biomass and in soil (Watson *et al*., 2000; Brown, 1998; Brown *et al.*, 1996). Available estimates suggest that forests may miti-gate additionally from 1 to 2 Gt Carbon (one billion metric tons of carbon) per year between 1995 and 2050 (Brown *et al*., 1996; Kauppi *et al*., 2001). Forests help to remove carbon dioxide from the air by storing it in their leaves, wood, roots and soils. But when the forests are de-stroyed, this stored carbon dioxide is released into the atmosphere, where it contributes to cli-mate change. In fact, deforestation and land use change contributes approximately 20 to 25 per-cent of the carbon emissions that cause climate change. Because the trees absorb carbon dioxide as they mature, reducing deforestation provides an important ecosystem service; carbon seques-tration.

In general, the management of forest resources can be categorized into three classes based on the rate of increase in atmospheric CO2. These categories are described in detail as follow: (1) Management for carbon emission avoidance or conservation, (2) Management for carbon storage or sequestration, and (3) Management for carbon substitution (Brown *et al*., 1996).

**1. Emission avoidance**

The aim of managing forests for carbon emission avoidance is to conserve existing carbon pools in forest vegetation and soil through options such as controlling deforestation or logging, protect-ing forest in reserves, changing harvesting regimes (reduced impact logging), and controlling other human disturbances such as fire and pest outbreaks. Reducing tropical deforestation and forest degradation rates would require action to reduce the pressures for land and commodities while increasing the protection of remaining forests for the purposes of conservation and timber production. Global action to mitigate carbon emissions by conserving carbon pools may lead to more interest and success in controlling deforestation and making agriculture more sustainable.

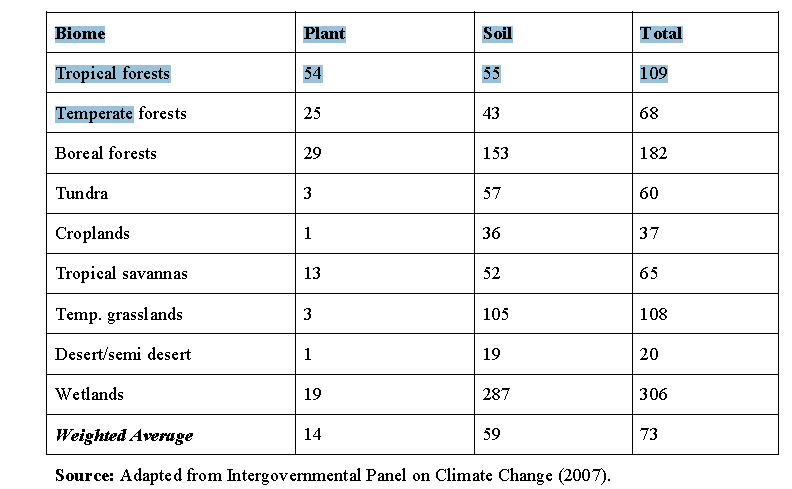
**2. Sequestration**

Management for carbon sequestration means increasing the amount of carbon stored in vegeta-tion (above ground biomass and below ground biomass), dead organic matter and soil (litter, dead wood, and mineral soil), and durable wood products. Increasing the carbon pool in existing forests can be accomplished by silvicultural treatments, protecting secondary forests and other degraded forests whose biomass and soil carbon densities are less than their maximum value and allowing them to sequester carbon by natural or artificial regeneration, and to establish planta-tions on bare lands or agroforestry practices for environmental protection and local needs (Lugo *et al*,. 1993; Allen *et al*., 1995).

**3. Substitution**

Management for carbon substitution focuses on increasing the transfer of forest biomass carbon into products (e.g., construction materials and biofuels) rather than using fossil-fuel-based energy and products and cement-based products. Substitution management has the long term potential of mitigation (Marland, 1992).

**Table 4.1: Average Carbon Stocks for Various Biomes** (**in tons)**



**Global terrestrial carbon sequestration potential**

|  |  |
| --- | --- |
| **Carbon sink** | **Potential (billion tonnes per year)** |
| Arable lands | 0.85-0.90 |
| Biomass crops for biofuel | 0.50-0.80 |
| Grasslands and rangelands | 1.70-1.70 |
| Forests | 1.00-2.00 |
| **Total** | **4.05**-**5.40** |

*Source:* adapted from Rice, 1999.

In response to this imbalance, land is being set aside for the creation of carbon sinks in new-growth forests, grasslands are being rehabilitated, and conservation agriculture on cultivated soils is being promoted as important climate mitigation measures. Because the creation of sinks involves changes in land and forest management practices and difficult land-use policy decisions, the food and agriculture sector will be critical for the success or failure of many carbon sink initiatives.

Carbon sequestration involves increasing the carbon storage in terrestrial systems, above or below ground. The main thrust of efforts to use agriculture to manage greenhouse gases has so far been to increase above-ground sequestration, primarily through planting trees, which allows large per-hectare amounts of carbon to be sequestered. New-growth forests are an especially important form of carbon sink, because of the amount of carbon dioxide that they absorb.

Recent studies have shown that well-managed grasslands and conservation agriculture can work as well or better as techniques for sequestering carbon (Mannetje, L.’t. 2006). If the carbon stock in soils has been depleted as a consequence of past land-use changes and agricultural activities, changes in soil management practices can trigger a process of carbon accumulation below ground, over time. Eventually, the system reaches a new carbon stock equilibrium or saturation point, and no new carbon is absorbed, but until then carbon sequestration is low-cost and can be readily implemented.

Practices that increase carbon sequestration have additional benefits, including increased root biomass, soil organic matter, water, and nutrient retention capacity and, hence, land productivity. Investments in improved land management leading to increased soil fertility and carbon sequestration can often be justified by their contributions to agronomic productivity, national economic growth, food security and biodiversity conservation (FAO, 2004a).

The following are the four feasible options for carbon sequestration:

1. Reforestation and afforestation,
2. Rehabilitating degraded grasslands,
3. Rehabilitating cultivated soils, and
4. Promoting conservation agriculture.

Enhancing carbon sequestration in degraded dry lands and mountain slopes by any of these methods could have direct environmental, economic, and social benefits for local people, with consequent improvement in their food security status.

**Reforestation and afforestation**

Cleared land is at high risk of erosion and loss of soil moisture, so fast-growing cover crops should be planted as soon as possible after clearing, even if they are subsequently replaced by something else. In addition to reducing the risk of erosion, these crops will absorb some CO2 and can later be ploughed under to enhance the fertility and water-retention capacity of the soil.

Increasing the extent of protected areas and natural parks is another way of augmenting carbon stores. Preserving forests is therefore a vital part of any strategy to mitigate climate change. Forest dependent people and vulnerable people living on degraded land can provide forest related environmental services with carbon sequestration potential, as long as appropriate compensation is paid. Such services include the incorporation of reforestation and afforestation in sustainable upper watershed management schemes, and the introduction of integrated agroforestry farming systems that include planting fast maturing tree crops and woodlots to prevent soil erosion, restore the soil’s water retention capacity and contribute to farm income, as well as sequestering carbon.

**Rehabilitating degraded grasslands**

Rain forests and grasslands (or rangelands as they are also called) are the world’s last remaining land resources still to exist in more or less their natural state. Both are in danger of degradation and disappearance through inappropriate use, overexploitation, and destruction, posing a major threat to the capacity of the earth’s climate system to mitigate global warming (FAO, 2007e).

Grasslands cover about 25 percent of the world’s surface and contribute to the livelihoods of more than 800 million people, including many poor smallholders and pastoralists. In this ecosystem, vegetation and large herbivorous mammals have co-evolved to keep the system in equilibrium. Scattered stands of trees form a natural part of the ecosystem, but there are no closed forests. Grasslands are particularly adapted for grazing livestock, and pastoral farming systems are important, especially in more arid parts. Mixed farming systems are also important. However, overgrazing, reduction of fallow, water scarcity, and cutting of trees for fuel and timber are degrading the land, creating energy scarcities and increasing the prevalence of poverty and food insecurity for many rural people. With better management, these grasslands can produce feed stocks for manufacturing biofuel for local markets, give their inhabitants more secure and sustainable livelihoods that will be resilient in variable and uncertain weather conditions, and provide carbon sequestration services to the world.

Several aspects of dryland soils work in favour of carbon sequestration in arid regions. Dry soils are less likely to lose carbon than wet soils, as lack of water limits soil mineralization and therefore the flux of carbon into the atmosphere. As a result, carbon’s residence time in dryland soils is long, sometimes even longer than it is in forest soils. Although carbon sequestration in these regions occurs at low rates, it may be cost-effective, particularly taking into account all the side-benefits resulting from soil improvement and restoration (FAO, 2004a).

Improved grassland management through the incorporation of trees, improved species, fertilization, and other measures can reverse carbon losses, lead to net sequestration and yield additional benefits, particularly by preserving/restoring biodiversity. In 1991, up to 71 percent of the world’s grasslands were reported to be degraded to some extent (Dregne, Kassa and Rzanov, 1991).

Overgrazing is the greatest cause of degradation in grasslands, and the overriding human influenced factor in determining their soil carbon levels. In many systems, improved grazing management practices, such as optimizing stock numbers and rotational grazing, will therefore result in substantial increases in carbon pools. Among the many other technical options are fire management, protection of land and enhancement of grassland production, such as through fertilization and the introduction of deep-rooted/legume species.

**Rehabilitating cultivated soils**

The relatively low CO2 emissions from arable land leave little scope for mitigation, but there is great potential for net sequestration of carbon in cultivated soils. According to Lal, the carbon sink capacity of the world’s agricultural and degraded soils is 50 to 66 percent of the total carbon loss since 1850 (Lal, 2004b).

Under conventional cultivation practices, the conversion of natural systems to cultivated agriculture results in soil organic carbon losses of about 20 to 50 percent compared with pre-cultivation stocks in the surface metre (Paustian *et al.,* 1997). Non-conventional cultivation practices allow soil quality to improve and soil organic carbon levels to increase. Such practices can be grouped into three classes: agricultural intensification, conservation agriculture and erosion reduction. Sustainable intensification practices include improved cultivars, well-managed irrigation, organic and inorganic fertilization, management of soil acidity, green manure, and cover crops in rotations, integrated pest management, double cropping and crop rotation. Increased crop yields result in more carbon accumulation in crop biomass. The higher residue inputs associated with higher yields favour enhanced soil carbon storage (Paustian *et al.,* 1997). IPCC provides an indication of the “carbon gain rate” that can be obtained from some of these practices (IPCC, 2007b).

**Promoting conservation agriculture**

Conventional tillage involves the use of mechanical implements to break up the soil. The simplest such implement is the hand hoe. Mechanized soil tillage allows higher working depths and speeds and involves the use of such implements as tractor-drawn ploughs, disk harrows, and rotary cultivators. This initially increases fertility because it mineralizes soil nutrients and makes it easier for plants to absorb them through their roots. In the long term, however, repeated ploughing and mechanical cultivation breaks down the soil structure and leads to reduced soil organic matter and loss of soil nutrients. This structural degradation of soils results in compaction and the formation of crusts, leading to soil erosion. This process is dramatic under tropical climatic situations, but can also be noticed all over the world. The heavy machinery used for tillage in intensive crop agriculture has particularly detrimental effects on soil structure.

Conservation agriculture increases soil organic matter and this in turn increases the amount of carbon stored in the soil.

**4.2 Reduced emission**

**REDD+**

REDD+ stands for countries' efforts to reduce emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks.

Deforestation and forest degradation are the second leading cause of global warming, responsi-ble for about 15% of global greenhouse gas emissions, which makes the loss and depletion of forests a major issue for climate change. In some countries, such as Brazil and Indonesia, defore-station and forest degradation together are by far the main source of national greenhouse gas emissions. 80 percent of the Earth’s above ground terrestrial carbon and fourty percent of below ground terrestrial carbon is in forests (Calmel *et al*., 2010). In addition to the large contribution of deforestation and forest degradation to global emissions, combating both has been identified as one of the most cost effective ways to lower emissions. Currently, there appears to be a con-sensus that the issue of deforestation and forest degradation must be effectively tackled as it would otherwise limit the options available to reduce greenhouse gas emissions, greenhouse gas concentrations and increases in temperature to acceptable levels. Any reduction in the rate of de-forestation and forest degradation has the benefit of avoiding a significant source of carbon emis-sions and reducing other environmental and social problems associated with deforestation. Un-like afforestation and reforestation activities, which generally cause small annual changes in car-bon stocks over long periods of time, stemming deforestation causes large changes in carbon stocks over a short period of time. Most emissions from deforestation take place rapidly, whereas carbon removal from the atmosphere through afforestation and reforestation activities is a slow process. In addition to mitigating climate change, stopping deforestation and forest degradation and supporting sustainable forest management conserves water resources and prevents flooding, reduces run-off, controls soil erosion, reduces river siltation, protects fisheries and investments in hydro power facilities, preserves biodiversity and preserves cultures and traditions.

Generally reducing emissions from deforestation and forest degradation (REDD+) refers to projects which achieve environmental sustainability through the following five main types of ac-tivities:

(i) Reducing emissions from deforestation;

(ii) Reducing emissions from forest degradation;

(iii) Conserving forest carbon stocks;

(iv) Managing forest sustainably; and

(v) Increasing forest carbon stocks

**Reducing agricultural and forestry emissions of carbon dioxide**

The primary source of carbon emissions in the food and agriculture sector is land conversion from forested area to cultivated or grazing land. Carbon emissions can be reduced through more efficient energy use by mechanized agriculture and agro-industries, and through adoption of alternatives to the common practice of burning crop residues after harvest. However, the amounts involved are minor compared with the potential contribution that reducing the rate of deforestation could make.

As already noted, intentional land conversion and deforestation, also referred to as anthropogenic land-use change, currently accounts for an important share of greenhouse gas emissions. Moreover, the reduction in global forested area caused by land clearing and unsustainable logging (in which cut trees are not replaced with new plantings) has reduced the capacity of the world’s forests to store carbon. Evidence shows that Amazon deforestation, related to agricultural expansion for livestock grazing and the production of livestock feed and biofuel crops, already contributes substantially to global anthropogenic CO2 emissions (Carvalho *et al.,* 2004).

The actions required include creating economic alternatives to reduce the incentive for clearing forests or using forest resources unsustainably, promoting second-generation biofuels to avoid land clearing for biofuel crops, and enforcing more strictly the regulations that discourage potential investors from setting wildfires to clear land for commercial development.

Controlling frontier expansion in tropical rain forests can make an important contribution to climate change mitigation, but often the sole option for preserving forested area is through intensifying agricultural production on the better land. It has been demonstrated that when intensification involves increased fertilizer inputs, the related emission increases are far less than the avoided emissions of organic carbon from the forests that have been preserved (Vlek, Rodriguez-Kuhl and Sommer, 2004).

Use of carbon offset schemes to pay rural households for sustainable management of the forested areas that they rely on for fuel and other forest products can provide the incentive to stop them cutting wood to sell as timber, fuel wood or charcoal. To be effective, however, this approach needs to be accompanied by public or private sector investment in alternative sources of timber and cooking fuel to meet the growing demand.

**4.3 Carbon trading**

Carbon trading is a system whereby countries or individual companies are set emission targets. Those that cannot meet their targets can buy credit from countries or companies that bear theirs.

In economics, carbon trading is a form of emissions trading that allows a country to meet its carbon dioxide emissions reduction commitments, often to meet Kyoto Treaty requirements, in as low a cost as possible by utilizing the free market. It is a means of privatizing the public cost or societal cost of pollution by carbon dioxide.

Carbon trading is the term applied to the trading of certificates representing various ways in which carbon related emissions reduction targets might be met. Participants in carbon trading buy and sell contractual commitments or certificates that represent specified amounts of carbon-related emissions that either: are allowed to be emitted; comprise reductions in emissions (new technology, energy efficiency, renewable energy); or comprise offsets against emissions, such as carbon sequestration (capture of carbon in biomass).

**CHAPTER FIVE**

**5. Climate change adaptation strategies**

## 5.1. Vulnerability to climate change

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as: the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Although most scholars agree on the broad definition of vulnerability as “the capacity to be

harmed,” the use of the term varies among disciplines and research areas.

Downing (1999) separates hazard (as the potential threat to humans and their welfare) and vulnerability (as exposure and susceptibility to losses); together, hazard and vulnerability add up to risk (the probability to hazard occurrence), with disaster as the realization of a risk.

Vogel (1999) quotes Blaikie et al. (1994:9) who define *vulnerability* as “the characteristics of a person or group in terms of their capacity to *anticipate*, *cope* with, *resist* and *recover* from the impacts of natural hazards” and states that “vulnerability can be viewed along a continuum from resilience to susceptibility.”

The ordinary use of the word ‘vulnerability’ refers to the capacity to be wounded, i.e., the degree to which a system is likely to experience harm due to exposure to a hazard (Turner II *et al*., 2003).

The fundamental policy options for limiting the adverse impacts of anthropogenic climate change are mitigation of climate change, which refers to confining global climate change by reducing the emissions of greenhouse gases or enhancing their sinks, and adaptation to climate change, which moderates the adverse effects of climate change through a wide range of actions that are targeted at the vulnerable system or population. A third policy option, which has attracted limited interest so far is compensation for climate impacts, typically conceived as transfer payments (or other assistance) from those countries who disproportionately contributed to climate change to those who disproportionately suffer from it (e.g., Paavola and Adger, 2002). All three response options rely on information about the vulnerability of key systems to climate

change but their specific information needs differ significantly. Mitigation and compensation need to distinguish the incremental impacts of anthropogenic climate change from the impacts of natural climate variability since they are primarily concerned with the former; this distinction is

less relevant for adaptation. While aggregated estimates of climate impacts can be very useful for mitigation policy (and to some degree for compensation policy), adaptation actors typically require information that is more disaggregated spatially and temporally.

The conceptual model of vulnerability to climate change promoted by the Intergovernmental Panel on Climate Change (IPCC) (2007) and widely adopted for ecological vulnerability assessments (Bell, Johnson and Hobday, 2011) provides a basis for operationalizing and assessing the vulnerability of linked social and ecological systems. Assessments of vulnerability to environmental change typically examine three inter-related concepts:

1. exposure;
2. sensitivity; and
3. Adaptive capacity.

The Intergovernmental Panel on Climate Change (IPCC), in its Second Assessment Report, defines vulnerability as “the extent to which climate change may damage or harm a system.” It adds that vulnerability “depends not only on a system’s sensitivity, but also on its ability to adapt to new climatic conditions” (Watson *et al*. 1996: 23). In a presentation made at the Sixth Conference of the Parties to the UNFCCC (COP-6), Robert T. Watson, Chair of the IPCC, defines vulnerability as the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate and the ability to adapt the system to changes in climate. Hence, a highly vulnerable system is one that is highly sensitive to modest changes in climate and one for which the ability to adapt is severely constrained.

The elements of vulnerability are described in more detail below.

***Exposure***

Exposure represents the important climate events and patterns that affect the system, but it also includes other changes in linked systems that might be induced by climate effects. In a practical sense, exposure is the extent to which a region, resource or community experiences changes in climate (IPCC 2007).

It is characterized by the magnitude, frequency, duration, and/or spatial extent of a weather event or pattern. Some regions or sectors are more exposed to extreme climate events because of their location, range, type of resources they depend upon, or local oceanography (Stokes and Howden 2009).

***Sensitivity***

Sensitivity is the degree to which a system is affected by, or responsive to, climate changes. The sensitivity of ecological systems to climate change is normally described in terms of physiological tolerances to change and/or variability in physical and chemical conditions (i.e. temperature, pH, etc.).

For example, social systems are more likely to be sensitive to climate change if they are highly dependent on a climate vulnerable natural resource (Marshall et al. 2007). These factors can confound (or ameliorate) the economic effect of climate exposure. A climate adaptation plan should consider how sensitive the local community and resources are to changes in the climate.

***Adaptive capacity***

Adaptive capacity describes the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches. It requires amongst many other things, the flexibility to experiment and adopt novel solutions (Gunderson 2000; Levin et al. 1998). In ecosystems, adaptive capacity is related to genetic diversity, biological diversity, and heterogeneity within landscapes (Carpenter and Gunderson 2001; Peterson 2002). In social systems, adaptive capacity can be a conscious or inadvertent characteristic, enhanced by the existence of institutions and networks that learn and store knowledge and experience, create flexibility in problem solving, without compromising the ability to cope and adapt to future change (Armitage 2005; Holling and Meffe 1996; Nelson et al. 2007a; Scheffer et al. 2001). Adaptive capacity greatly influences the vulnerability of communities and regions to climate change effects and hazards (Adger 2006; Adger et al. 2005; Rapport et. al.1998).

**5.3. Vulnerability of developing countries**

There are different perceptions of what “vulnerability” means, which in turn affect how vulnerability can be measured.

Vulnerability is the risk of being harmed by exogenous shocks which, in the case of LDCs, can imply a marked reduction of long-term average growth rates and impact on development prospects.

Vulnerability is a function of the magnitude and frequency of shocks, the exposure to such shocks and the resilience (i.e., the capacity to react to shocks).

The vulnerability of least-developed countries (LDCs) to climate change has been noted both by researchers and the United Nations. Many LDCs are located in parts of the world that are expected to be badly affected by temperature and precipitation changes. Moreover, climate-sensitive economic sectors, such as agriculture, are more important for the generation of output and income in LDCs than in other countries. Due to their low level of development, LDCs are also less resilient to negative external events and have lower capacity to adapt than other developing countries. This increased vulnerability is seen as unfair, as LDCs have contribut­ed to climate change, by emitting greenhouse gases or by changing their land-use patterns.

Climate change is not an isolated phenomenon. Rather, it is its interaction with development process­es that determines whether climate change is a handicap to development. Climate change vulnerability is not easily separable from vulnerability to other events and could be characterized as a vulnerability amplifier.

Natural disasters; agriculture and food security; health; fresh water; coastal and marine zones; and terrestrial ecosystems and biodiversity. These areas are identified as main areas impacted by climate change in the IPCC.

***A. Natural disasters***

The impact of climate change on natural disaster is the most widely discussed consequence of climate change. In fact, it is often the only area addressed in several climate change vulnerability studies (e.g., Brooks, Adger and Kelly, 2005, Yusuf and Francisco 2009, Harmeling 2010). Typically, four main catego­ries of natural disaster are distinguished: geophysical (such as earthquakes and volcanoes), meteorological (storms), hydrological (such as floods) and climatological (such as drought, heat waves and cold waves). Climate change is expected to increase the frequency, the geographic distribution and the intensity of some weather events and extremes (IPCC, 2007, Summary for policymakers), and all weather-related disasters (i.e., meteorological, hydrological and climatological) are potentially impacted by climate change.

Natural disasters are a function of the hazard itself, exposure and resilience. Hence, if climate change increases the frequency and magnitude of certain natural hazards, it may lead to more frequent and more severe disasters, depending on direction and magnitude of changes in exposure and resilience. For in­stance, it has been argued that the increase in natural disaster occurrence and intensity observed over the past decades was driven primarily by an increase in exposure (UNISDR, 2009). Low and lower-middle income developing countries are among the countries facing the highest risk of human and economic losses due to disasters. Population growth and unplanned economic development in these countries are main drivers for the increase in exposure. Hence, further increases in exposure are very probable, even if policy instruments such as land zoning and planning can play a large role in reducing exposure.

It should be noted that destruction of economic assets does not only reduce the wealth of impacted countries, but can also lead to long lasting economic development consequences through the impact on human capital. Even if growth rates are able to rebound relatively quickly, development can be delayed for long periods.

Increased frequency in extreme precipitation and overall higher precipitation intensity are very likely consequences of climate change. This can lead to increased and more severe flooding, depending on timing of snow and rain fall, river basin conditions and flood prevention infrastructure (IPCC, 2007, Summary for policymakers). Floods are the most frequent natural disaster, leading to a loss of life, destruction of physi­cal capital, reduced agricultural production and other effects such as increase in water borne diseases and reduced water quality. Increased glacier melting can also lead to increased flooding, including through the outburst of glacial lakes. Moreover, intense and extreme precipitation is also the main cause for the high vulnerability of the transport sector found in some developing country studies, in particular if roads are unpaved (World Bank, 2009).

***B. Agriculture***

There are various channels through which climate change impacts agricultural production, in addition to natural disasters discussed above. Higher temperature generally increases growing seasons in colder regions, but decreases them in warmer zones. Precipitation increases soil moisture and freshwater availability, general­ly boosting production. Both level and distribution of precipitation play an important role. Increased rainfall variability and intensity can have negative impacts for both rain fed and, to a lesser extent, irrigated agri­culture. Moreover, a higher atmospheric concentration of carbon dioxide enhances plant growth and water use efficiency for various crops. However, such positive effect of carbon dioxide does not materialize in areas where nutrient availability, in particular nitrogen availability, is the dominant constraint to plant growth.

***C. Health***

There are various channels through which climate change is expected to affect human health. As discussed above, climate change could increase climatic hazards such as heat waves, droughts and floods. Reduced fresh water availability, and increased spread of bacterial contaminants caused by climate change could lead to increase in mortality and diseases due to unsafe water, sanitation and hygiene, which constitutes one of the biggest health risk factors in developing countries (World Health Organization (WHO), 2008). Climate change is also expected to increase the size of areas where vector-borne diseases such as malaria which again could lead to increased health burden in the absence of countervailing measures. Finally, rising high temperatures, even outside of heat waves, are expected to increase cardiovascular and respiratory diseases, whereas rising low temperatures would decrease the burden of disease

Overall, negative health impacts are expected to dominate, not only in developing countries but also in developed countries such as the United States (National Research Council, 2010). The magnitude of fu­ture negative effects, however, remains quite uncertain. Estimates for the current situation find only a modest role for global climate change as risk factor for mortality and morbidity. A recent report by the WHO on global health risks attributes 141,000 deaths (equivalent to 0.2 per cent of world deaths) to climate change in 2004. Predominantly in poor countries, however, not all possible health impacts are included in the report. Africa is found to be the most affected region in relative terms. Country level data, however, are not available. Because any mortality and morbidity increase leads to a decline of human capital, it exacerbates structural development handicaps of countries.

***D. Water availability***

Both current observations and climate projections indicate that freshwater resources are very strongly impacted by climate change, which would have important development implications. First, average water availability and its distribution over time critically affect agriculture. However, changes in water availability can have a wide range of further development impacts.

The supply of safe drinking water can be affected. Depending on water infrastructure and manage­ment techniques, both reduction in water availability and increase in water variability caused by changes in precipitation, runoff and river flows can have detrimental effects. Moreover, increases in temperature can have negative effects on water quality. Heavy precipitation events and flooding can also lead to increased water pollution, in particular if environmentally unsafe agricultural and mining practices are employed and waste water treatment facilities are insufficient. In particular for many small island developing states, saltwa­ter intrusion due to sea level rise and storm surges can further diminish already scarce water resources.

Changes in river flows and runoff can affect electricity production from hydropower plants. This has been identified as major impact of climate change in countries such as Mozambique or Ghana (World Bank, 2010). Impacts, however, could be very diverse at the regional level. For example, in Europe, it is expected that hydropower production in Scandinavia will increase, whereas it will be reduced in South and South-East Europe (Bates and others, 2008). Reduced hydropower production can lead to lower economic activity depending on the overall electricity production capacity, the mix in electricity sources and the availability of regional power pools.

**5.4*.* Gender and climate change**

***Why climate change is a gender issue?***

Women are particularly vulnerable to climate change because they are more prone to the adverse impacts from climate change. Their limited adaptive capacities arise from prevailing social inequalities and ascribed social and economic roles that manifest itself in differences in property rights, access to information, lack of employment and inequal access to resources.

Further, changes in the climate usually impact on sectors that are traditionally associated with

women, such as paddy cultivation, cotton and tea plantations, and fishing. This means increased hardship for women. For example, studies show that climate change has an adverse impact on fishing, as the sea level rises and saline water enters into freshwater systems, making fishing

difficult. Further, in extreme events more women deaths are observed for women’s inability to swim or run or lack of strength to withstand physically demanding situation such as stroms,

floods.

From a long term perspective, this will have serious implications for gender relations, as women may end up spending more time on tasks that reinforce stereotypical gender roles. Thus, women are faced by a situation where their ability to adapt is low (due to a number of pre‐existing factors), but the share of the adaptation burden falling disproportionately on them. This makes the consideration of the impact of climate change on gender most imperative.

**Women bear a disproportionate burden of climate change consequences**

* **Decreased food security**

With changes in climate, traditional food sources become more unpredictable and scarce. This exposes women to loss of harvests, often their sole sources of food and income.

* **Impact on livelihoods**

Women are more dependent for their livelihood on natural resources that are threatened by climate change. For instance, climate change causes a rise in the sea level, affecting the fishing community (both men and women) not only in terms of fish‐catch but also with regard to water scarcity, as seawater gets into fresh water. Besides, when the land is inundated, infrastructure (roads and houses) are damaged. Large scale migration from inundated areas is expected and much of the burden of migration falls on women.

* **Water resources ‐ shortage and access**

Climate change may exacerbate existing shortages of water. Women are largely responsible for water collection in their communities and are therefore are more affected when the quantity of water and/or its accessibility changes.

* **Increased burden of care giving**

As primary caregivers, women may see their responsibilities increase as family members suffer increased illness due to exposure to vector borne diseases such as malaria, water borne diseases such as cholera and increase in heart stress mortality.

**What are the gender dimensions of both adaptation and mitigation?**

**Adaptation**

The fundamental goal of adaptation strategies is the reduction of the vulnerabilities to climate induced change in order to protect and enhance the livelihoods of poor people. Experience shows that vulnerability is differentiated by gender. Adaptation to climate change or indeed climate variability is dependent on issues such as wealth, technological power, access to information, all of which are major problem areas for women. However, women can be key agents of adaptation and mitigation to climate change. Their responsibilities in households, communities and as stewards of natural resources position them well to develop strategies for adapting to changing environmental realties (WEDO, 2007).

**Mitigation**

Women also have a role deriving from their own strength. Women are engaged in a number of activities such as brick‐making, charcoal‐making waste management and agro‐processing where

energy efficiency can lead to CO2 mitigation and their role in mitigation in these areas can be

vital. The development of Clean Development Mechanisms (CDM), through carbon sequestration from afforestation and reforestation can also be done by poor rural women (Jyoti

Parikh, 2003). Women in urban areas can implement energy efficiency programmes at the household level ‐ lighting, the use of appliances etc, while women in rural areas may be encouraged to use biomass and biogas (for fuel generation), and switch to solar energy. Poor women, without access to modern energy fuels are faced with problems relating to indoor air

pollution and bear huge health burdens as a result‐ there is a high incidence of bronchitis, asthma

and other health problems. While women should not be denied the use of fossil fuels like Kerosene, yet at the same time appropriate technologies that take into account the specific socio‐economic realities of different rural areas, reduce women’s workload, free‐up time and enable them to pursue income generating or other activities need to be developed.

**What is the way forward?**

It is clear that gender differences mustbe taken into account to understand the impact of climate change. Gender differentiated strategies for responses and capacity‐ building are needed, due to differences in gender specific roles and responsibilities created by society. These findings should feed into the climate negotiations as well as national debates to enable decision‐makers to have a better understanding of how different groups of people are affected and what kind of capacity and support is needed.

More specifically the following actions are required:

* **Recognize that women are more vulnerable in climate change driven scenarios:**

Government should analyze and identify gender‐specific impacts and protection measures related to floods, droughts, diseases, and other environmental changes and disasters. An inter‐ministerial task force could be set up towards this end.

* **Understand and address gender‐specific natural resource use pattern :**

Government should develop strategies to enhance women’s access to and control over natural resources, in order to reduce poverty, protect environmental resources, and ensure that women and poor communities can better cope with climate change.

* **Identify women’s particular skills and capacities that lend themselves to mitigation and adaptation :**

Given that women’s knowledge and participation has been critical to the survival of entire communities in disaster situations, government should take cognizance of women’s specialized skills in different aspects of their livelihood and natural resource management strategies and utilize those that lend themselves to mitigation and adaptation.

* **Increase women’s participation in decision‐making at all levels in climate change**

**mitigation and adaptation :**

Women’s participation in climate change related debates and planning must be enhanced by tools and procedures that augment their capacity and sensitize decision‐makers to the advantages of equal participation.

**5.5. Adaptation option**

Adaptation refers to changes in “processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate” and involves adjustments to decrease the vulnerability of communities and regions to the impacts of climate change and variability (IPCC, 2001b).

Adaptation to climate is the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides (Burton 1992, quoted in Smit et al. 2000);

Adaptation involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer-term climate change (Smit 1993, quoted in Smit et al. 2000);

The term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change (Stakhiv 1993, quoted in Smit et al. 2000);

Adaptation to climate change includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system (Smith et al. 1996, quoted in Smit et al. 2000); and

Adaptability refers to the degree to which adjustments are possible in practices, processes or structures of systems to projected or actual changes of climate. Adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of change in conditions (Watson et al. 1996, quoted in Smit et al. 2000).

According to the IPCC Third Assessment Report, adaptation “has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages.” Furthermore, it is argued that human and natural systems will, to some extent, adapt autonomously and that planned adaptation can supplement autonomous adaptation. However, “options and incentives are greater for adaptation of human systems than for adaptation to protect natural systems” (IPCC 2001: 6-8).

Definitions of terms that describe system characteristics that are relevant for adaptation include the following:

**Sensitivity**: degree to which a system is affected by, or responsive to, climate stimuli

**Vulnerability**: degree to which a system is susceptible to injury, damage or harm

**Impact potential**: degree to which a system is susceptible to climate stimuli

**Resilience**: degree to which a system rebounds, recoups or recovers from a stimulus

**Responsiveness**: degree to which a system reacts to stimulus

**Adaptive capacity**: the potential or capability of a system to adapt to (to alter to better suit) climatic stimuli

**Adaptability**: the ability, competency or capacity of a system to adapt to (to alter to better suit) climatic stimuli

Building on some of this literature, and on its previous work, the most recent definitions adopted by the IPCC (2001) are the following:

Sensitivity: the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli.

Adaptive capacity: the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability: the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. [It] is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Adaptation is often the result of interactions between climatic and other factors.

**Adaptation Issues in the UNFCCC and the Climate Negotiations**

Successful adaptation depends upon technological advances, institutional arrangements, availability of financing, and information exchange (Watson et al. 1996: 24).

Within the United Nations Framework Convention on Climate Change (UNFCCC), there exists recognition of the need to adapt to climate change and to assist those countries that are least able to adapt. Acknowledging that the world is already committed to some climate change, UNFCCC Parties (in particular, developing countries) have been taking the issue of adaptation quite seriously. Thus, adaptation has been regarded as one of the key “developing country issues” in the context of the climate negotiations.

The following are concrete examples of UNFCCC efforts to address the issue of adaptation:

According to **Article 4.1** of the UNFCCC, Parties are committed to:

Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to facilitate adequate adaptation to climate change (Art. 4.1. (b)); and Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods (Art. 4.1 (e)).

**Article 4.4** states that:

The developed country Parties and other developed Parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting the costs of adaptation to those adverse effects.

Articles 4.8 and 4.9 of the Convention make specific reference to developing country Parties, in particular least developed countries. These articles explicitly mention funding and transfer of technology “to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change” (UNFCCC 1992). Special attention is given, in article 4.8, to those countries considered most vulnerable e.g., small-island countries, those countries with arid or semi-arid areas, etc.

Clearly, adaptation measures and options vary according to sector, and may be constrained or enhanced by national or local conditions. In agriculture, for example, adaptation options could include adjustments to planting dates or changes in fertilization rates, irrigation applications, cultivar traits and selections of animal species. In the water resources sector, integrated water resource management techniques can be applied to adapt to the hydrologic impacts of climate change and to minimize the harmful effects of climate change on human health, the strengthening of public health infrastructure could be seen as an obvious adaptation measure (IPCC, 2001).

**CHAPTER SIX**

**6. Politics and regulatory frameworks of climate change**

**6.1. Climate change convention**

**What are conventions and protocols?**

The world’s governments have adopted several multilateral treaties and conventions on the environment over the past 70 years. From protecting wild animals, to reducing toxic industrial emissions. These legally-binding agreements form the basis for international environmental law. They also play a vital role in setting international norms and strengthening cooperation amongst countries with differing national interests. This has also in a way helped in the development of national policies and legislation, environmental risk management and solutions.

**Convention** is a term generally used for formal multilateral treaties with a broad number of parties. Conventions are normally open for participation by the international community as a whole, or by a large number of states. The generic term convention is synonymous with the generic term treaty.

**Protocol** is used for agreements less formal than those entitled treaty or convention. The term could be used to cover the various kinds of instruments. A protocol deals with ancillary matters such as the interpretation of particular clauses of the treaty, those formal clauses not inserted in the treaty, or the regulation of technical matters.

**Basel Convention (1992)**

The Basel Convention on Transboundary Movements of Hazardous Wastes and their Disposal was adopted in response to concerns about toxic waste from industrialized countries being dumped in developing countries and countries with economies in transition.

Its objectives are

* To minimize the generation of hazardous wastes in terms of quantity and hazardousness;
* To dispose of them as close to the source of generation as possible;
* To reduce the movement of hazardous wastes.

**Stockholm Convention on POPs (2002)**

The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty adopted to protect human health and the environment from POPs. Chemicals that are highly toxic, persistent, bioaccumulate and move long distances in the environment. The Convention seeks the elimination or restriction of production and use of all intentionally produced POPs (i.e., industrial chemicals and pesticides). It also seeks the continuing minimization and, where feasible, ultimate elimination of the releases of unintentionally produced POPs such as dioxins and furans.

**UNCCD (1996)**

The United Nations Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa. The treaty acknowledges that the causes of desertification are many and complex, ranging from international trade patterns to the unsustainable land management practices of local communities.

**United Nations Framework Convention on Climate Change (UNFCCC)** **(1994)**

Also called the Climate Change Convention, the UNFCCC is the centre piece of global efforts to combat global warming. It was adopted in June 1992 at the Earth Summit in Rio de Janerio, and entered into force on 21 March 1998. The convention.s primary objective is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

**Ramsar Convention (1975)**

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It is known popularly as the .Ramsar Convention.

**Kyoto Protocol**

In December 1997, more than 160 nations met in Kyoto, Japan, to negotiate binding limitations on greenhouse gases for the developed nations, pursuant to the objectives of the Framework Convention on Climate Change of 1992. The outcome of the meeting was the Kyoto Protocol, in which the developed nations agreed to limit their greenhouse gas emissions, relative to the levels emitted in 1990.

**Cancun Agreements**

The Cancun Agreements constituted a significant achievement for the UN climate process. They form the pillars of the largest collective effort the world has ever seen to reduce emissions, in a mutually accountable way, with national plans captured formally at international level under the banner of the UNFCCC. The Cancun Agreements also included the most comprehensive package ever agreed by governments to help developing nations deal with climate change. It encompassed finance, technology and capacity-building support to help such countries meet urgent needs to adapt to climate change, and to speed up their plans to adopt sustainable paths to low emission economies that could also resist the negative impacts of climate change.

The Cancun Agreements were a set of significant decisions by the international community to address the long-term challenge of climate change collectively and comprehensively over time, and to take concrete action immediately to speed up the global response to it.

The agreements, reached on December 11 in Cancun, Mexico, at the 2010 United Nations Climate Change Conference, represented key steps forward in capturing plans to reduce greenhouse gas emissions, and to help developing nations protect themselves from climate impacts and build their own sustainable futures.

**Objectives Cancun agreement**

* Establish clear goals and a timely schedule for reducing human-generated greenhouse gas emissions over time to keep the global average temperature rise below two degrees;
* Encourage the participation of all countries in reducing these emissions, in accordance with each country's different responsibilities and capabilities to do so.
* Review progress made towards two-degree objective and a review by 2015 on whether the objective needs to be strengthened in future, including the consideration of a 1.5C goal, on the basis of the best scientific knowledge available.

**Convention on Biological Diversity (CBD)** **(1993)**

The three objectives of the CBD are:

* The conservation of biological diversity,
* The sustainable use of its components,
* The fair and equitable sharing of the benefits arising out of the utilization of genetic resources.

**CITES (1995)**

The Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES, aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Since the trade in wild animals and plants crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation.

**Montreal Protocol (1989)**

The Montreal Protocol on Substances that Deplete the Ozone Layer stipulates that the production and consumption of compounds that deplete ozone in the stratosphere, chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform be phased out.

The Vienna Convention for the Protection of the Ozone Layer (1985), which outlines states’ responsibilities for protecting human health and the environment against the adverse effects of ozone depletion, established the framework under which the Montreal Protocol was negotiated.

**6.2. History and policy mechanisms of Kyoto protocol**

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change, which **commits** its Parties by setting internationally binding emission reduction targets.

Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of "common but differentiated responsibilities."

The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh, Morocco, in 2001, and are referred to as the "Marrakesh Accords." Its first commitment period started in 2008 and ended in 2012.

The mechanisms help to stimulate green investment and help Parties meet their emission targets in a cost-effective way.

**Monitoring emission targets**

Under the Protocol, countries' actual emissions have to be monitored and precise records have to be kept of the trades carried out.

Countries with commitments under the Kyoto Protocol to limit or reduce greenhouse gas emissions must meet their targets primarily through national measures. As an additional means of meeting these targets, the Kyoto Protocol introduced three market-based mechanisms, thereby creating what is now known as the “carbon market.”

The Kyoto mechanisms are:

1. [Emissions Trading](http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php)
2. [The Clean Development Mechanism (CDM)](http://unfccc.int/kyoto_protocol/mechanisms/clean_development_mechanism/items/2718.php)
3. [Joint Implementation (JI)](http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php)
4. [**Emissions Trading**](http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php)

Parties with commitments under the Kyoto Protocol (Annex B Parties) have accepted targets for limiting or reducing emissions. These targets are expressed as levels of allowed emissions, or “assigned amounts,” over the 2008-2012 commitment periods. The allowed emissions are divided into “assigned amount units” **(AAUs).**

Emissions trading, as set out in Article 17 of the Kyoto Protocol, allows countries that have emission units to spare - emissions permitted them but not "used" - to sell this excess capacity to countries that are over their targets. Thus, a new commodity was created in the form of emission reductions or removals. Since carbon dioxide is the principal greenhouse gas, people speak simply of trading in carbon. Carbon is now tracked and traded like any other commodity. This is known as the "carbon market."

1. [**The Clean Development Mechanism (CDM)**](http://unfccc.int/kyoto_protocol/mechanisms/clean_development_mechanism/items/2718.php)

The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol, allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO2, which can be counted towards meeting Kyoto targets.

The mechanism is seen by many as a trailblazer. It is the first global, environmental investment and credit scheme of its kind, providing standardized emissions offset instrument, CERs.

A CDM project activity might involve, for example, a rural electrification project using solar panels or the installation of more energy-efficient boilers.

The *CDM* allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.

The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets.

The CDM is the main source of income for the UNFCCC [Adaptation Fund](http://unfccc.int/cooperation_and_support/financial_mechanism/adaptation_fund/items/3659.php), which was established to finance adaptation projects and programmes in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a 2% levy on CERs issued by the CDM

1. [**Joint Implementation (JI)**](http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php)

The mechanism known as “joint implementation,” defined in Article 6 of the Kyoto Protocol, allows a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO2, which can be counted towards meeting its Kyoto target.

Joint implementation offers Parties a flexible and cost-efficient means of fulfilling a part of their Kyoto commitments, while the host Party benefits from foreign investment and technology transfer.

**Time line of Kyoto protocol**

This time line detailing the international response to climate change provides a contextual entry point to the Essential Background.

2012 - The Doha Amendment to the Kyoto Protocol is adopted.

2011 — The Durban Platform for Enhanced Action drafted and accepted by the COP, at COP17.

2010 — Cancun Agreements drafted and largely accepted by the COP, at COP16.

2009 — Copenhagen Accord drafted at COP15 in Copenhagen. This was taken note of by the

COP. Countries later submitted emissions reductions pledges or mitigation action

pledges, all non-binding.

2007 — IPCC's Fourth Assessment Report released. Climate science entered into popular

consciousness. At COP13, Parties agreed on the Bali Road Map, which charted the way

towards a post-2012 outcome in two work streams.

2005 — Entry into force of the Kyoto Protocol. The first Meeting of the Parties to the Kyoto

Protocol takes place in Montreal.

2001 — Release of IPCC's Third Assessment Report. Bonn Agreements adopted, based on the

Buenos Aires Plan of Action of 1998. [Marrakesh Accords](http://unfccc.int/essential_background/library/items/3598.php?rec=j&priref=600001855&data=&volltext=FCCC%2FCP%2F2001%2F13%2FAdd.1&anf=0&sorted=date_sort&dirc=DESC&seite=) adopted at COP7, detailing

rules for implementation of Kyoto Protocol, setting up new funding and planning

instruments for adaptation, and establishing a technology transfer framework.

1997 — Kyoto Protocol formally adopted in December at COP3.

1996 — The UNFCCC Secretariat is set up to support action under the Convention.

1995 — The first Conference of the Parties (COP 1) takes place in Berlin.

1994 — UNFCCC enters into force.

1992 —At the Earth Summit in Rio, the UNFCCC is opened for signature along with its sister

Rio Conventions, UNCBD and UNCED.

1991 — First meeting of the Intergovernmental Negotiating Committee (INC) takes place.

1990 — IPCC's first assessment report released. IPCC and second World Climate Conference

call for a global treaty on climate change. United Nations General Assembly

negotiations on a framework convention begin.

1988 — The Intergovernmental Panel on Climate Change is set up.

1979 — The first World Climate Conference (WCC) takes place.

**6.3. Clean Development Mechanism (CDM)**

The Clean Development Mechanism is one of the key components of the Kyoto Protocol. An offshoot of the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol is a legally binding global agreement to combat climate change through a reduction of greenhouse gas (GHG) emissions. The Kyoto Protocol follows the fundamental UNFCCC principle of "common but differentiated responsibility" which recognizes that the burden of responsibility should fall heaviest on the countries which have historically emitted the greatest quantity of GHGs. So the Protocol legally requires the highly industrialized and developed countries (known as Annex 1 Parties) to achieve quantified reductions in manmade GHG emissions. The less developed countries (non-Annex 1 Parties) the smallest emitters, yet the most vulnerable to climate risks have no binding reduction targets. The stated purpose of the Clean Development Mechanism is to help developing (non-Annex 1) countries to achieve sustainable development, and assist industrialized (Annex I) countries in complying with their emission reduction commitments. Under CDM Annex I countries can take credits for projects that reduce emissions in non Annex I countries. The first aim of the CDM is to account the carbon credit (both positive and negative) through emission reduction and removal. So, the emission reduction projects primarily deal with energy efficiency and fuel substation. Moreover, the emission removal projects also have afforestation, reforestation and deforestation activities (Mandal *et al*., 2005). The second aim of CDM is to assist the host countries to achieving their sustainable development (Gundimedia, 2004).

Institutional capacity building and technology transfer are the means of encouraging sustainable development in the developing countries where as abatement projects in the developing countries are the means of enabling developed countries to meet part of their commitment in cost effective way for emission limitation and reduction commitments (Sijm *et al*., 2000). Thus, the CDM intrinsically helps in achieving the Kyoto Protocol goal as well as helping developing nations.

**6.4. Post Kyoto International Efforts Negotiation**

Post-Kyoto negotiations refer to high level talks attempting to address [global warming](http://en.wikipedia.org/wiki/Global_warming) by limiting [greenhouse gas](http://en.wikipedia.org/wiki/Greenhouse_gas) emissions. Generally part of the [United Nations Framework Convention on Climate Change](http://en.wikipedia.org/wiki/United_Nations_Framework_Convention_on_Climate_Change) (UNFCCC), these talks concern the period after the first "commitment period" of the [Kyoto Protocol](http://en.wikipedia.org/wiki/Kyoto_Protocol), which expired at the end of 2012. Negotiations have been mandated by the adoption of the [Bali Road Map](http://en.wikipedia.org/wiki/Bali_Road_Map) and Decision 1/CP.13 ("The Bali Action Plan").

Earlier, the Kyoto Protocol was signed in 1997 and aimed to address climate change. More precisely, the Kyoto Protocol aimed to reduce GHG emissions by 5% over the period 2008-2012 for industrialized countries included in Annex I.

**Strengths of the Kyoto Protocol**

Among the Kyoto Protocol strengths is its inclusion of provisions for market-based approaches intended to lower the cost of the global climate regime:

(a) Emissions trading among Annex I countries that commit to targets under the Protocol,

(b) ‘‘joint implementation,’’ which allows for project-level trades among the Annex I countries, and

(c) The Clean Development Mechanism (CDM), which provides for the use of project-level emissions offsets created in non-Annex I (developing) countries to help meet the compliance obligations of firms in Annex I countries.

The Kyoto Protocol also recognizes domestic sovereignty and provides flexibility at the national level for countries to meet their emissions targets their commitments in whatever manner they choose. Furthermore, the Protocol has at least the appearance of fairness in that it focuses on the wealthiest countries and those responsible for the majority of the current stock of anthropogenic GHGs in the atmosphere. This is consistent with the principle enunciated in the UNFCCC of ‘‘common but differentiated responsibilities and respective capabilities’’ (United Nations 1992).

Finally, the fact that the Kyoto Protocol was signed by more than 180 countries and subsequently ratified by a sufficient number of Annex I countries for it to come into force speaks to the political viability of the agreement in terms of participation, if not compliance.

**Weaknesses of the Kyoto Protocol**

The Kyoto Protocol also has some weaknesses. First, some of the world’s leading emitters either have not ratified the treaty or have not committed to specific targets that would restrict emissions. To date, the United States—until recently the country with the largest share of global emissions, about 19 percent (Gregg, Andres, and Marland, 2008) has not ratified and is unlikely to ratify the agreement. Also, some of the world’s largest, most rapidly growing economies, including China, India, Brazil, South Africa, Indonesia, South Korea, and Mexico, do not take on targets. Even if all of the Annex I countries, including the United States, were to reduce their CO2 emissions to zero by 2030, unless there are also significant reductions by China and India, it will be physically impossible for the world to achieve the frequently discussed climate target of stabilizing atmospheric CO2 concentrations at or below 450 ppm.

The relatively small number of countries that have agreed to take action under the Protocol highlights a second weakness.

A third weakness centers on the nature of the Kyoto Protocol\_s emissions trading elements. The provision in Article 17 concerning international emissions trading is unlikely to be effective because the trading would be among national governments rather than among private sector firms.

Fourth, with its five-year time horizon (2008–12), the Kyoto Protocol represents a relatively short-term approach to what is fundamentally a long-term problem because GHGs reside in the atmosphere for a very long time—from decades to centuries. Moreover, to encourage the magnitude of technological change that will be required to address the threat of climate change meaningfully, long-term price signals must be sent to the private market to stimulate the necessary sustained investment and technological innovation (Newell 2010).

Finally, the Kyoto Protocol provides insufficient incentives for compliance (Barrett 2010). In particular, the Protocol’s enforcement mechanism, a requirement that countries make up any deficit in subsequent compliance periods, is unlikely to induce policy responses that are consistent with the emissions targets.

**CHAPTER SEVEN**

**7. An overview of climate change adaptation strategy of Ethiopia**

**7.1. The need for NAPA**

National adaptation programmes of action (NAPAs) provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs to adapt to climate change. Those for which further delay would increase vulnerability and/or costs at a later stage.

**7.2. NAPA and its relationship to Ethiopia’s development goals**

## Hotspot areas

In 2010 two hotspot area’s in Ethiopia were selected – the Central rift valley and the south eastern part of the country – to further elaborate the prioritized adaptation actions as described in Ethiopia’s NAPA. Each hotspot area had this thematic focus: re-greening, adaptation of coffee farming and nature conservation in the Central rift valley, and land degradation and pastoralism in the south eastern part of the country.

The following summarizes the NAPA for Ethiopia.

**Climate Related Hazards**

* Drought
* Floods
* Heavy rains
* Strong winds
* Heat waves (high temperatures)

**Main Human Vulnerabilities and Livelihood Impacts**

* Land degradation
* Soil erosion
* Deforestation
* Loss of biodiversity
* Desertification
* Recurrent drought
* Flood
* Water and air pollution

**7.3. Objectives of NAPA**

The main goal of the NAPA exercise is the identification of the urgent and immediate needs and concerns of the least developed countries (LDCs), relating to adaptation to the adverse effects of climate change".

More specifically, the objectives of the NAPA project were:

1. To understand the main characteristics of climate hazards (notably floods,

droughts and so on);

(2) To understand coping mechanisms to climate hazards and climate change at the grassroots

level;

(3)To understand existing programmes and institutional arrangements for addressing climate

hazards and climate change;

(4) To identify and prioritize adaptation activities to climate hazards and climate change.

**7.4. Potential barriers for implementing the NAPA**

## The challenges of climate change

Sustainable land use, food supply and water management are critical concerns for countries in East Africa. In regions that are very vulnerable to climate change, the specific circumstances and needs have to be mapped before an adaptation strategy to climate change can be developed. Ethiopia has prepared a National Adaptation Programme of Action (NAPA) in which adaptation strategies in the agricultural sector play an important role.

The barriers for the implementation of the NAPA can be categorized as follows:

* Limitations in available human resources. Limited technical capacity to develop and implement specific measures may be a barrier to effective implementation of the NAPA;
* Institutional limitations. For example, in the water sector, the water tariff regime and the approach to resolve water conflicts remain incomplete. In addition, there are many aspects to implementing legislation that remain difficult, namely:
* The proliferation of institutions operating in the sector without an efficient coordination mechanism
* A deficiency in the functioning of the regulatory entity
* Overlapping of attributions among State institutions
* Insufficiency of regulatory texts for the protection of water resources
* Deficient knowledge of the law by the institutions intervening in the sector
* Poor participation of the population in the resolution of the problems of the sector;
* Financial limitations. This may significantly change the countries’ situation in relation to development financing mechanisms, namely through the reduction of budgetary support. This may also discourage the Government from investing in so-called “non-productive” projects and programmes. On the other hand, the increased efficiency in resources management, the achievement of results in the field, and increasing regularity and transparency in the management of funds, will all facilitate financial support from donors;
* Enhanced climatic data and monitoring capacity. Data models and ability to collect and use these is a limit to designing the optimal investments, and;
* Low awareness of the public.

**7.5. Identification of key Adaptation Needs for Ethiopia**

**Priority Adaptation Projects**

1. Promoting drought/crop insurance program in Ethiopia

2. Realizing food security through multi-purpose large-scale water development project

3. Community Based Development and Commercialization of Non-timber Forest Products (Gum Arabic, Myrrah and Frank Incense)

4. Community Based Rehabilitation of Degraded Eco-Systems in Selected Parts of Ethiopia

5. Propagation and Commercial Scale Cultivation of Wild Essential Oil Crops

6. Establishment of Centre for Propagation and Commercialization of Traditional Herbal Medicinal Plants

7. Establishment of Acacia Woodland Nature Reserve in the Ethiopian Rift Valley System

8. Community Based Carbon Sequestration Project in the Rift Valley System of Ethiopia

9. Range Shift Cultivation of Selected Cash Crops in Drought Prone Areas

10. Establishment of National Center for Climate Change

11. Development of an Incentive Scheme for Farmers (Hill-farming communities) to Reforest Hill Areas in the Northern Parts of Ethiopia

12. Participatory Approach to Rehabilitate Degraded Hills/Ecosystem in Northern Ethiopia

13. Institutional Re enforcement for Biodiversity Conservation

14. Establishment of National Environmental Education Program

15. Reforestation for Fuel in the Highlands of Ethiopia

16. Regional Capacity Building for Monitoring and Inventorying of Biodiversity

17. Establishment of Potato-centered Small-sized Cottages

18. Reclamation of Bush Encroached Rangelands

19. Promotion of Legume-based Agroforestry Systems and Home-garden Agriculture

20. Development of New and Rehabilitation (upgrading) of the existing watering sites in Pastoral Areas

21. Aquaculture Development for Efficient Harvest of Commercial Spirulina Species in the Lakes of the Ethiopian Rift Valley System

22. Reorganization of drought Affected Communities

23. Stall feeding promotion and free range grazing restriction in selected regional states of Ethiopia

24. Promotion of on farm and homestead forestry and agroforestry practices in arid, semi-arid and dry-sub humid parts of Ethiopia

25. Undertake soil and water conservation practices for improved land husbandry in Afar, Somali and Gambella regional states and Diredawa city administration

26. Develop community seed bank and food storage facilities in Amhara, SNNPRS, Tigray, Oromia.

27. Capacity building for small scale irrigation planning and development in Afar, Gambella, Somali and SNNPRS.

28. Community based sustainable utilization and management of wet lands in selected wet lands in Ethiopia

29. Strengthening/enhancing drought and flood early warning systems in Ethiopia

30. Capacity building for climate change adaptation in Ethiopia at federal as well as regional levels

31. Public awareness program on climate change in Ethiopia at national as well as regional levels

32. Enhancing the use of water for agricultural purpose on small farms in arid and semi arid parts of Ethiopia

33. Community capacity building to initiate and implement environmental health program and or projects in the national regional states

34. Commercial level uses of some indigenous, wild edible fruits in selected arid and semi arid areas of Ethiopia

35. Malaria containment program (MCP) in selected areas of Ethiopia

36. Institutional development; enhancement of research and development capacity of the national dry land research centers in Somali, Gambella, Benishangul-gumuz, low lands of Oromia, Amhara, Tigray, Afar and SNNPR.

37. Improving/enhancing the range land resources management practices in the pastoral areas of Ethiopia

**Project Components:**

* Establish institutional structure;
* Assemble a multidisciplinary integrated assessment team;
* Synthesize available information on adverse effects of climate change;
* Conduct a participatory assessment of vulnerability to current climate variability;
* Identify key climate change adaptation measures;
* Develop country-driven criteria for prioritizing adaptation activities;
* Develop priority adaptation projects, including stakeholder consultations;
* Distribute draft NAPA document for public review;
* Distribute the final NAPA document to government and civil society representatives; and
* Disseminate NAPA document to public

## Climate change adaptation in policy making

A consortium of Wageningen UR partners, in which the Wageningen UR Centre for Development Innovation (CDI) takes part, wants to contribute to the mainstreaming of climate change adaptation into the sustainable development agenda of Ethiopia. We focus on the capacities and knowledge that needed to better integrate climate change adaptation responses into policy processes of agriculture, rural development and natural resources management.

**7.5.3. Criteria for selecting priority activities**

Following on from the analyses of the major socio-economic sectors, in relation to different climatic scenarios, and to the expected negative impacts of climate change, the first step was to propose a set of adaptation measures to these negative impacts.

Next, the proposed measures were analyzed in greater depth in order to determine whether they responded effectively to the most urgent and immediate adaptation necessities. As a result of this analysis, some measures were taken. Next, the five following criteria were used to determine priority actions:

**CRITERIA**

1. Contribution to the resolution of the immediate and urgent problems related to climate change. This is considered the most fundamental criteria, in line with the least developed countries expert group (LEG) recommendations;

2. Capacity to contribute to poverty reduction. Again, in line with LEG guidelines, this is a most

fundamental criteria;

3. The number of beneficiaries. The Ethiopia NAPA stakeholders felt it important that the adaptation activities respond to the needs of a sizeable group of the community;

4. The synergies among the different instruments of environmental policy. In line with the LEG

criteria, it was felt important that the proposed activities build synergies with other environmental actions, including actions to implement global environmental agreements in Ethiopia

5. The overall cost of the action, and the anticipated benefit, in monetary terms if possible. In the process to select priorities, the first two criteria were given additional weight, since they reflect, respectively, the extent to which the measure will address the immediate and urgent problems of climate change, and, the extent to which the measure will contribute to improving the lives of the poorer and more vulnerable target populations.

**Priority measures**

**Priority Measures**

* Construct infrastructures for collection, supply and storage of water and recharge of aquifers
* Reinforce actions to protect watersheds in order to improve food security
* Diversify income-generating activities in rural areas
* Modernize and diffuse localized irrigation technologies
* Invest strongly in environmentally sustainable production techniques
* Use varieties and species that are adaptable to changing climatic conditions
* Diversify activities and measures to support the populations that live off the exploitation of coastal resources
* Support diversification of alternative activities to artisanal fishing (e.g. training, equipment, micro-credit)
* Continue the actions of preservation and management of protected areas
* Rehabilitate and/or construct infrastructures for protection of coastal zones
* Strengthen equipment and modernization of artisanal fishing;
* Support implementation of initiatives to use renewable energies (solar and wind) in particular at the level of rural communities
* Modernize the network of climate and maritime monitoring stations
* Stimulate production and establishment of endemic plants
* Conserve and sustainably use medicinal species
* Promote research on species that are threatened and vulnerable to the climate change