African Forest Forum

A platform for stakeholders in African forestry

Basic Science of Climate Change

A COMPENDIUM FOR SHORT COURSES IN AFRICAN FORESTRY

03

Basic Science of Climate Change

A COMPENDIUM FOR SHORT COURSES IN AFRICAN FORESTRY

Correct citation: African Forum Forest. 2019. Basic science of climate change: A compendium for short courses in African forestry. 88 pp

African Forest Forum
United Nations Avenue, Gigiri
P.O. Box 30677-00100
Nairobi, Kenya

Tel: +254 20 722 4203
Fax: +254 20 722 4001

Website: www.afforum.org

ISBN 978-9966-7465-3-5

9 789966 746535

Front cover photos: An affluent of the river Zio in Northen Togo (left), Land clearing for agriculture in Benin (middle), private plantation of Gmelina arborea in Benin (right). Credit: Sognigbé N'Danikou and Dèdéou A. Tchokponhoué

Back cover photo: A Zio riverbed at Alokoegbé-kpota in Southern Togo.
Credit: Dèdéou A. Tchokponhoué

Design & Layout: Conrad Mudibo, Ecomedia

Table of Contents

Abbreviations and Acronyms

AFF	African Forest Forum
BOD	Biochemical oxygen demand
CC	Climate Change
CFCs	Chlorofluorocarbons
CH4	Methane
CO2	Carbon dioxide
COD	Chemical oxygen demand
DRR	Disaster risk reduction
GHGs	Greenhouses gases
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
N2O	Nitrous oxide
SFM	Sustainable Forest Management
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organisation

Acknowledgements

This compendium has been developed through an organic process that initially led to the development of “Training modules on forest-based climate change adaptation, mitigation, carbon trading, and payment for other environmental services”. These were developed for professional and technical training, and for short courses in sub-Saharan African countries. The compendium provides the text required for effective delivery of the training envisaged in the training modules; in other words, it is structured based on the training modules. In this context many people and institutions, including those from government, civil society, academia, research, business, private sector, and other communities, have contributed in various ways in the process that culminated in the development of the compendium. We wish to collectively thank all these individuals and institutions for their invaluable contributions, given that it is difficult in such a short text to mention them individually.

We also appreciate the kind financial support received from the Government of Switzerland through the Swiss Agency for Development and Cooperation (SDC) to implement an AFF project on “African forests, people and climate change” that generated much of the information that formed the basis for writing this compendium. AFF is also indebted to the Swedish International Development Cooperation Agency (Sida) for its support of another AFF project on “Strengthening sustainable forest management in Africa” that also provided inputs into the compendium, in addition to helping facilitate various contributors to this compendium. The issues addressed by the two projects demonstrate the interest of the people of Switzerland and Sweden in African forestry and climate change.

We are also grateful to the lead authors, the contributors mentioned in this compendium and the pedagogical expert, as well as reviewers of various drafts of the compendium.

We hope that the compendium will contribute to a more organized and systematic way of delivering training in this area, and eventually towards better management of African forests and trees outside forests.

Preface

African forests and trees support the key sectors of the economies of many African countries, including crop and livestock agriculture, energy, wildlife and tourism, water resources and livelihoods. They are central to maintaining the quality of the environment throughout the continent, while providing international public goods and services. Forests and trees provide the bulk of the energy used in Africa. Forests and trees are therefore at the centre of socio-economic development and environmental protection of the continent.

Forests and trees outside forests in Africa are in many ways impacted by climate change, and they in turn influence climate. Hence, African forests and trees are increasingly becoming very strategic in addressing climate change. The great diversity of forest types and conditions in Africa is at the same time the strength and the weakness of the continent in devising optimal forest-based responses to climate change. In this regard, given the role of forests and trees to socio-economic development and environmental protection, actions employed to address climate change in Africa must simultaneously enhance livelihoods of forest dependent populations and improve the quality of the environment. It is therefore necessary for Africa to understand how climate change affect the inter-relationships between food, agriculture, energy use and sources, natural resources (including forests and woodlands) and people in Africa, and in the context of the macro-economic policies and political systems that define the environment in which they all operate. Much as this is extremely complex, the understanding of how climate change affect these inter-relationships is paramount in influencing the process, pace, magnitude and direction of development necessary for enhancing people's welfare and the environment in which they live.

At the forestry sector level, climate affects forests but forests also affect climate. For example, carbon sequestration increases in growing forests, a process that positively influences the level of greenhouse gases in the atmosphere, which, in turn, may reduce global warming. In other words, the forests, by regulating the carbon cycle, play vital roles in climatic change and variability. For example, the Intergovernmental Panel on Climate Change (IPCC) special report of 2018 on the impacts of global warming of 1.5 ^{o}C above pre-industrial levels underscores the significance of afforestation and reforestation, land restoration and soil carbon sequestration in carbon dioxide removal. Specifically, in pathways limiting global warming to 1.5 ^{o}C, agriculture, forestry and land-use (AFOLU) are projected with medium confidence to remove 0-5, 1-11 and 1-5 $GtCO_2\ yr^{-1}$ in 2030, 2050 and 2100, respectively. There are also co-benefits associated with AFOLU-related carbon dioxide removal measures such as improved biodiversity, soil quality and local food security. Climate, on the other hand, affects the function and structure of forests. It is important to understand adequately the dynamics of this interaction to be able to design and implement appropriate mitigation and adaptation strategies for the forest sector.

In the period between 2009 and 2011, the African Forest Forum sought to understand these relationships by putting together the scientific information it could gather in the form of a book that addressed climate change in the context of African forests, trees, and wildlife resources. This work, which was financed by the Swedish International Development Cooperation Agency (Sida), unearthed considerable gaps on Africa's understanding of climate change in forestry, how to handle the challenges and opportunities presented by it and the capacity to do so.

The most glaring constraint for Africa to respond to climate change was identified as the lack of capacity to do so. AFF recognizes that establishment and operationalization of human capacities are essential for an effective approach to various issues related to climate change, as well as to improve the quality of knowledge transfer. For example, civil society organisations, extension agents and local communities are stakeholders in implementing adaptation and mitigation activities implicit in many climate change strategies. In addition, civil society organisations and extension agents are more likely to widely disseminate relevant research results to local communities, who are and will be affected by the adverse effects of climate change. It is therefore crucial that all levels of society are aware of mechanisms to reduce poverty through their contribution to solving environmental problems. Training and updating knowledge of civil society organisations, extension service agents and local communities is one of the logical approaches to this. Also professional and technical staff in forestry and related areas would require knowledge and skills in these relatively new areas of work.

It was on this basis that AFF organized a workshop on capacity building and skills development in forest-based climate change adaptation and mitigation in Nairobi, Kenya, in November 2012 that drew participants from selected academic, research and civil society institutions, as well as from the private sector. The workshop identified the training needs on climate change for forestry related educational and research institutions at professional and technical levels, as well as the training needs for civil society groups and extension agents that interact with local communities and also private sector on these issues. The training needs identified through the workshop focused on four main areas, namely: Science of Climate Change, Forests and Climate Change Adaptation, Forests and Climate Change Mitigation, and Carbon Markets and Trade. This formed the basis for the workshop participants to develop training modules for professional and technical training, and for short courses for extension agents and civil society groups. The development of the training modules involved 115 scientists from across Africa. The training modules provide guidance on how training could be organized but do not include the text for training; a need that was presented to AFF by the training institutions and relevant agents.

Between 2015 and 2018, AFF brought together 50 African scientists to develop the required text, in the form of compendiums, and in a pedagogical manner. This work was largely financed by the Swiss Agency for Development and Cooperation (SDC) and with some contribution from the Swedish International Development Cooperation Agency (Sida). In this period eight compendiums were developed, namely:

1. Basic science of climate change: a compendium for professional training in African forestry
2. Basic science of climate change: a compendium for technical training in African forestry
3. Basic science of climate change: a compendium for short courses in African forestry
4. Carbon markets and trade: a compendium for technical training in African forestry
5. Carbon markets and trade: a compendium for professional training in African forestry
6. Carbon markets and trade: a compendium for short courses in African forestry

7. International dialogues, processes and mechanisms on climate change: compendium for professional and technical training in African forestry
8. Climate modelling and scenario development: a compendium for professional training in African forestry

Another notable contribution during the period 2011-2018 was the use of the training module on "Carbon markets and trade" in building the capacity of 574 trainers from 16 African countries on rapid forest carbon assessment (RaCSA), development of a Project Idea Note (PIN) and a Project Design Document (PDD), exposure to trade and markets for forest carbon, and carbon financing, among others. The countries that benefited from the training are: Ethiopia (35), Zambia (21), Niger (34), Tanzania (29), Sudan (34), Zimbabwe (30), Kenya (54), Burkina Faso (35), Togo (33), Nigeria (52), Madagascar (42), Swaziland (30), Guinea Conakry (40), Côte d'Ivoire (31), Sierra Leone (35) and Liberia (39). In addition, the same module has been used to equip African forest-based small-medium enterprises (SMEs) with skills and knowledge on how to develop and engage on forest carbon business. In this regard, 63 trainers of trainers were trained on RaCSA from the following African countries: South Africa, Lesotho, Swaziland, Malawi, Angola, Zambia, Zimbabwe, Mozambique, Tanzania, Uganda, Kenya, Ethiopia, Sudan, Ghana, Liberia, Niger, Nigeria, Gambia, Madagascar, Democratic Republic of Congo, Cameroon, Côte d'Ivoire, Burkina Faso, Gabon, Republic of Congo, Tchad, Guinea Conakry, Senegal, Mali, Mauritania, Togo and Benin .

An evaluation undertaken by AFF has confirmed that many trainees on RaCSA are already making good use of the knowledge and skills gained in various ways, including in developing bankable forest carbon projects. Also many stakeholders have already made use of the training modules and the compendiums to improve the curricula at their institutions and the way climate change education and training is delivered.

The development of the compendiums is therefore an evolutionary process that has seen the gradual building of the capacity of many African scientists in developing teaching and training materials for their institutions and the public at large. In a way this has cultivated interest within the African forestry fraternity to gradually build the capacity to develop such texts and eventually books in areas of interest to the continent, as a way of supplementing information otherwise available from various sources, with the ultimate objective of improving the understanding of such issues as well as to better prepare present and future generations in addressing the same.

We therefore encourage the wide use of these compendiums, not only for educational and training purposes but also to increase the understanding of climate change aspects in African forestry by the general public.

Macarthy Oyebo
Chair, Governing Council of AFF

Godwin Kowero
Executive Secretary-AFF

Executive summary

Overview

The science of climate change looks at how the Earth's climate has changed over the years and the causes as well as the possible future changes which could result from human interference with the climate system. Understanding how climate influences society and how humans influence climate has become more urgent now than ever before. Information and knowledge generated and provided by climate change science forms the basis in shaping policies and agreements. The cross-cutting nature of the problems requires the engagement of everyone at all levels. It is therefore important to have some basic understanding of the science of climate change in order to appreciate the seriousness of the problem posed by it and find lasting solutions by undertaking appropriate climate preventive actions.

Chapter one of the this module explores the science of climate change. This involves a description of the concepts of weather and climate by clearly defining and differentiating between them. The elements of weather and climate are also well analyzed. The difference between the concept of climate variability and climate change is also discussed in detail. In addition, the types, sources and effects of of GHGs are discussed.

Chapter two discusses the causes of climate change. Both natural and human-indiuced drivers of climate change are decribed in detail. Under natural drivers, aspects of volcanic eruptions and wildfire are discussed. Under antropogenic drivers, land use changes, use of fossils fuels and also the urbanization are discussed.

Chapter three examines climate change and ecosystem. The disturbances of ecosystems under climate change are addressed. Various indicators of ecosystem disturbances are explained and also the challenges and opportunities of climate change on ecosystem.

Chapter four focuses on vulnerability to and impact of climate change. Various approaches of vulnerability assessments are discussed and from this chapter it is clear to determine the extent of vulnerability,using socioeconomic or ecological assessments.

Chapter five, finally, discusses the different UN conventions on the envrioment. It is important to note that these conventions play an important role in ensuring that environment is well maintained and protected from human induced actions. They are normally open for participation by the international community as a whole, or by a large number of States.

This module covers five chapters as follows:

- Basics of Climate Change
- Causes of Climate Change
- Climate Change and Ecosystems
- Vulnerability to and Impact of Climate Change
- United Nations Conventions on the Environment

The five chapters are presented below. A sample implementation matrix is found in Annex 1 (Tables 3 and 4).

Aim

The aim of this module is to enable learners acquire knowledge of the basic science of climate, its implications to society and the environment including conventions to address some of the challenges on development.

Expected learning outcomes

At the end of this module, learners should be able to:

- understand basic terminologies used in climate change
- understand causes and impacts of climate change
- appreciate the role of climate on ecosystems
- explain the role of various international conventions on climate and environment
- contribute to design and implementation of national development policies and strategies
- integrate climate change into local development plans

Chapter 1: Basics of climate change

1.0 Chapter overview

This chapter introduces the basic concepts of climate, climate change and climate variability. It explores the science, causes and impacts of climate change. It examines linkages between GHG emissions and climate change, analyzes opportunities and challenges associated with climate change, and gives details on the concept of ecosystem, its definition and functioning, and disturbance under climate change. The chapter also addresses the aspects of pollution of the atmosphere, soil and water, and disturbance indicators. Before then, some fundamental definitions that you need to know are introduced.

Expected Learning outcomes

By the end of this chapter learners should be able to:

- state the basic concepts of climate change;
- distinguish between climate change and climate variability;
- identify the causes of climate change;
- explore the challenges and opportunities due to climate change; and
- provide basic tools on ecosystems disturbance in the context of climate change.

1.1 Weather and climate

Objectives

At the end of this topic the learner should be able to:

- explain the difference between weather and climate
- collect and and interpret local weather data, and,
- explain the reason why daily weather measurements are highly variable compared to long-term climate data

1.1.1 Definition of weather and climate

We often confuse weather and climate. In general, time can be used to identify the difference between them. *Weather* is the state of the atmosphere of a given place at a specific time with respect to weather variables over a short term which could be in minutes to weeks. Such variables include temperature, atmospheric pressure, wind, solar energy, humidity, precipitation, cloudiness and wind. It can also be described as the day-to-day temperature and precipitation. *Climate* on the other hand is the term for the average of atmospheric conditions over longer periods of time. According to WMO climate is the long-term average weather conditions of a region (usually taken over a period of more than 30 years). As they say, climate is what you expect, but weather is what you get. Table 1 highlights this difference.

Table 1: Differences between weather and climate

Weather	Climate
It is an instantaneous atmospheric condition	It is an average atmospheric condition
It can change rapidly, within even less than an hour	It sustains over a period of 30 years, as defined by WMO
It prevails over a small area	It prevails over a large region
It has limited predictability	It is almost constant
It depends primarily on temperature, vegetation; temperature and moisture differences	It depends on latitude, altitude, distance to water bodies; influences/influenced by vegetation cover and other geographic factors (valleys, mountains and hills).

Weather is controlled by the instability in the atmosphere as a result of differences in solar heating caused by Earth's rotation and the different heat absorption capabilities of the earth-atmosphere system. This causes air to be in motion and this is what transports energy between the polar regions and the tropics. Dust and pollen in the atmosphere can combine with water vapor to form precipitation if conditions are right. Climate on the other hand is dependent on both latitude and altitude. This is primarily due to the amount of solar heating received, which varies with latitude. However, locations with the same latitude may have different climates depending on multiple factors such as proximity to the ocean or a large water body, vegetation and altitude.

Important to note

1. It is not the climate that makes the weather, but the weather that makes the climate.
2. Weather changes rapidly but climate changes gradually

1.1.2 Elements of weather/climate

There are many components of weather, including sunshine, rain, cloud cover, wind, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves, etc.

When scientists analyze climate, they're looking at averages of precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather that occur over a long period in a particular place. Some of these elements include temperature, humidity, precipitation, atmospheric pressure, wind, solar radiation and are briefly highlighted below.

- **Temperature** is how hot or cold the atmosphere is, i.e. how many degrees Celsius it is above or below freezing (zero degrees). We use thermometers for measuring temperature. Thermometers use various physical properties such as thermal expansion of gases, liquids or solids to determine the current temperature. The two important parts of a thermometer are: the sensor in which some physical change occurs with temperature, plus some means of converting this physical change into a numerical value (e.g. the visible scale in glass thermometer).
- **Humidity** is the amount of water vapour in the atmosphere. Hygrometers are used for detecting and measuring humidity. There are several types of hygrometers (coil, hair tension, capacitive, resistive, etc.), whose operation is based on different principles.
- **Precipitation** refers to water (in either gas, liquid or solid form) that falls from the air to the ground. Forms of precipitation include snow, hail, sleet, drizzle, fog, mist and rain. In the case of rain, we can use a rain gauge for measuring precipitation that has fallen in a given time interval. Usually, a rain gauge is part of every weather station. It is used in meteorology as an additional tool of the weather forecast and in climatology for the purpose of long-term statistics of precipitation. The amounts of rain accumulated in the gauge are read either manually or by automatic weather station (AWS). In the case of snow or ice, we can use a snow gauge.
- **Atmospheric pressure** is the weight of air exerted on the earth's surface. We can use a barometer to measure it. Atmospheric pressure changes are often due to the rise of warm air and the descent of cold air
- **Wind** refers to the movement of air from areas of high pressure to those of low pressure. It is characterized by both speed and direction. We can use anemometers to determine the speed of wind. They can also be used for measuring the speed and direction of wind. In most cases a wind vane is associated with the measurement of wind direction. We can also use more advanced devices like the wind profiler that uses radar or sound waves (SODAR) to determine the wind speed and direction at various elevations above the ground.
- **Solar radiation** is the radiant energy emitted by the sun, particularly electromagnetic energy. About half of the radiation is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum. There are a number of devices called solarimeters that can be used to measure solar radiation in different regions of the electromagnetic spectrum. We also have Sunshine Duration Sensors called Radiometers for the measurement of sunshine duration. This is defined by WMO as the time during which the direct solar radiation exceeds the level of 120 W/m2.

In order to help people prepare for and face the negative impacts of weather and climate, countries have put in place agencies to monitor both weather and climate - National Meteorological Agencies or National Weather Services. They issue alerts, warnings and forecasts from time to time. Weather and climate forecasting is also done by international monitoring agencies like NOAA (National Oceanic and Atmospheric Administration) and NASA (National Space Agency) among others.

1.2 Basic concepts of climate change

Objectives

At the end of this topic the learners should be able to:

- explain the difference between climate change and climate variability;
- explain the concepts of global warming and greenhouse effect; and,
- describe some of the greenhouse gases

In this section, we examine some of the basic concepts used in climate change that are often confusing.

1.2.1 Changes in weather and climate

Important to note

As already pointed out above, climate is the averaging of atmospheric/weather conditions over longer periods of time. Climate is therefore a product of average weather. It means the relationship between climate and weather is quite close. Climate change is a statistical shift in the mean state of weather. Climate is sometimes commonly used to describe the conditions of the atmo-sphere, hydrosphere, cryosphere and even biosphere that interact to determine what weather may occur.

We can tell the future state of weather and climate through Weather Forecasting and Climate Prediction. Weather forecasting is the application of science and technology to tell the anticipated state of the atmosphere for a future time and a given location. The outputs of a forecast have some level of confidence attached to them. Climate prediction or climate forecast is an attempt to produce a most likely estimate of the actual evolution of the climate, i.e. average or expected atmospheric and earth-surface conditions, in the future.

Important to note

Climate projection is the simulated response of the climate system to a scenario of future emission or concentration of GHGs and aerosols, generally derived using climate models (IPCC, 2013; Alfieri et al. 2017; Engelbrecht and Engelbrecht 2016; Déqué et al. 2017; Abiodun et al. 2017). Climate projections are different from climate predictions because they rely on the emission/concentration/ radiative forcing scenario used; which also depends on assumptions of future socioeconomic and technological developments that may be realized.

1.2.2 Climate variability and climate change

Climate variability refers to the variations in the mean state and other statistics (e.g. standard deviations) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural external processes outside the earth system, or to natural or anthropogenic internal influences.

As noted earlier, climate is defined in terms of the average state of the atmosphere over at least 30 years. This assumes that mean state remain more or less stable. In reality, climate varies on both longer and shorter time scales. The variations in the mean state and other statistics (e.g. standard deviations, probability of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events is what we refer to as climate variability (IPCC, 2018; IPCC, 2013). It is considered natural because it is a result of internal interactions between the atmosphere, ocean, land surface and sea ice (the climate system). Variability may be due to anthropogenic external factors (i.e. human influences) or natural internal processes affecting the climate system (solar cycle, volcanic eruptions, earth's rotation etc.). Climate change on the other hand refers to a change in the state of the climate identifiable (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2013). Figure 1 and figure 2 below are some examples of what constitute climate change.

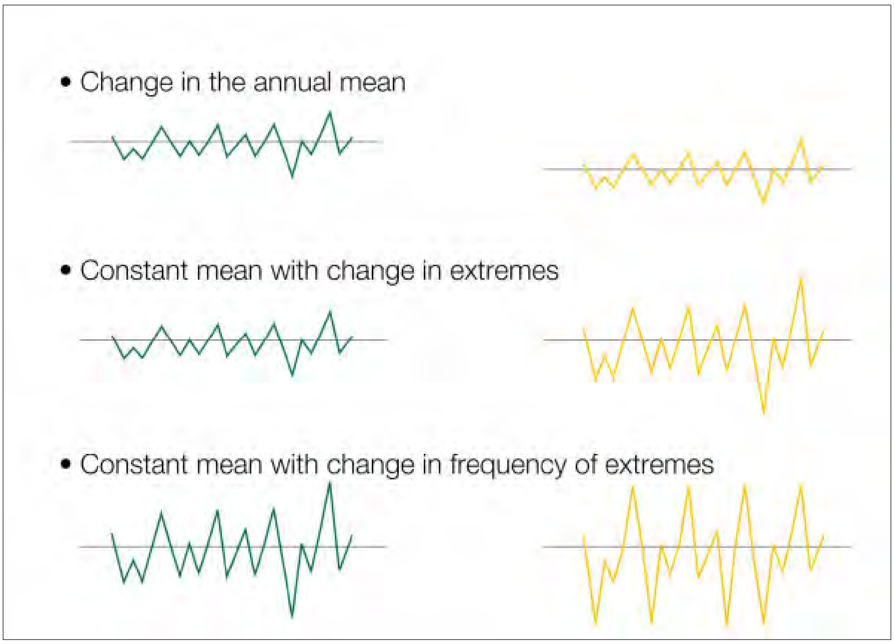

Figure 1: Examples of climate change
Source: IPCC, 2001

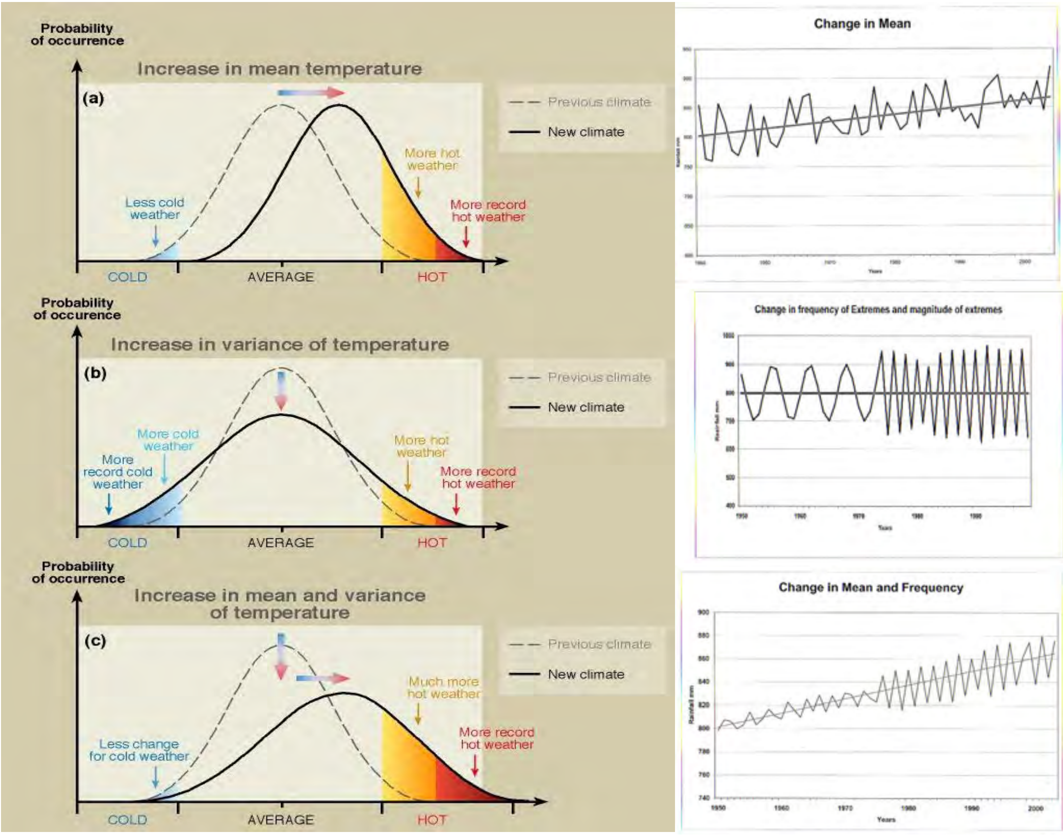

Figure 2: Changes in frequency distribution e.g. mean variance, skewness and kurtosis.
Source: IPCC, 2001

Box 1

Climate Change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability (Figure 2) of its properties, and that persists for an extended period, typically decades or longer.

Activity 1 Group discussion

1) Discuss among yourselves the differences between the following:
   - weather and climate;
   - climate change and climate variability
2) With the guidance provided by the instructor; visit a weather station to learn about some of the weather instruments
   - In groups: Use a simple thermometer or raingauge to oberve surface air temperature or rainfall (this could be daily at the same time) - the instructor could arrange to get some instruments
   - Repeat this for a period of interest then plot a graph of the weather element with time

1.3 Global warming and its effects

In this section, we explain the concepts of global warming, greenhouse gases, greenhouse effect and also explore the sources and sinks of greenhouse gas emissions.

1.3.1 Global warming and Greenhouse gasses

Global warming is the rise in global temperature. The warming happens when GHGs trap heat and light from the sun in the earth's atmosphere, which increases the temperature. The effect of global warming is that it makes the sea rise which causes the water to cover many low land islands. Global warming is the net effect of GHGs that result into the gradual heating of Earth's atmosphere and surface. While some say that global warming is a natural process and that there have always been GHGs, the amount of gasses in the atmosphere has skyrocketed in recent history. The Industrial Revolution had a big part to play in the amount of atmospheric CO_2 being released. Before, CO_2 fluctuated between about 180 ppm during ice ages and 280 ppm during interglacial warm periods. Since the Industrial Revolution, the amount of CO_2 has dramatically increased compared to when the last ice age ended. Chlorofluorocarbons (CFCs), once used as refrigerants and aerosol propellants until they were phased out by international agreement, are also GHGs.

CO_2 has a significant impact on global warming, partly because of its abundance in the atmosphere. In addition, CO_2 stays in the atmosphere for thousands of years. However, methane is about 21 times more efficient at absorbing radiation than CO_2, giving it a high GWP rating, even though it stays in the atmosphere only about 10 years.

Because the Earth is much colder than the Sun, it radiates at much longer wavelengths, primarily in the infrared part of the spectrum. Much of this thermal radiation emitted by the land and oceans is absorbed by the atmosphere, including clouds, and reradiated back to Earth. This is called the greenhouse effect (Figure 3). However, we must distinguish natural greenhouse effect from enhanced greenhouse effect. Box 2 gives this distinction.

Box 2

Natural Greenhouse effect occurs when naturally occurring GHGs allow incoming short-wave solar radiation to pass through the atmosphere, but trap this energy when it is radiated back to space as long-wave radiation. As a result, the temperature tends to rise.

Enhanced Greenhouse effect is the increase in the natural process of the greenhouse effect, as a result of human activities like burning fossil fuels through which GHGs are released into the atmosphere at a far greater rate than would occur through natural processes thus enhancing greenhouse effect.

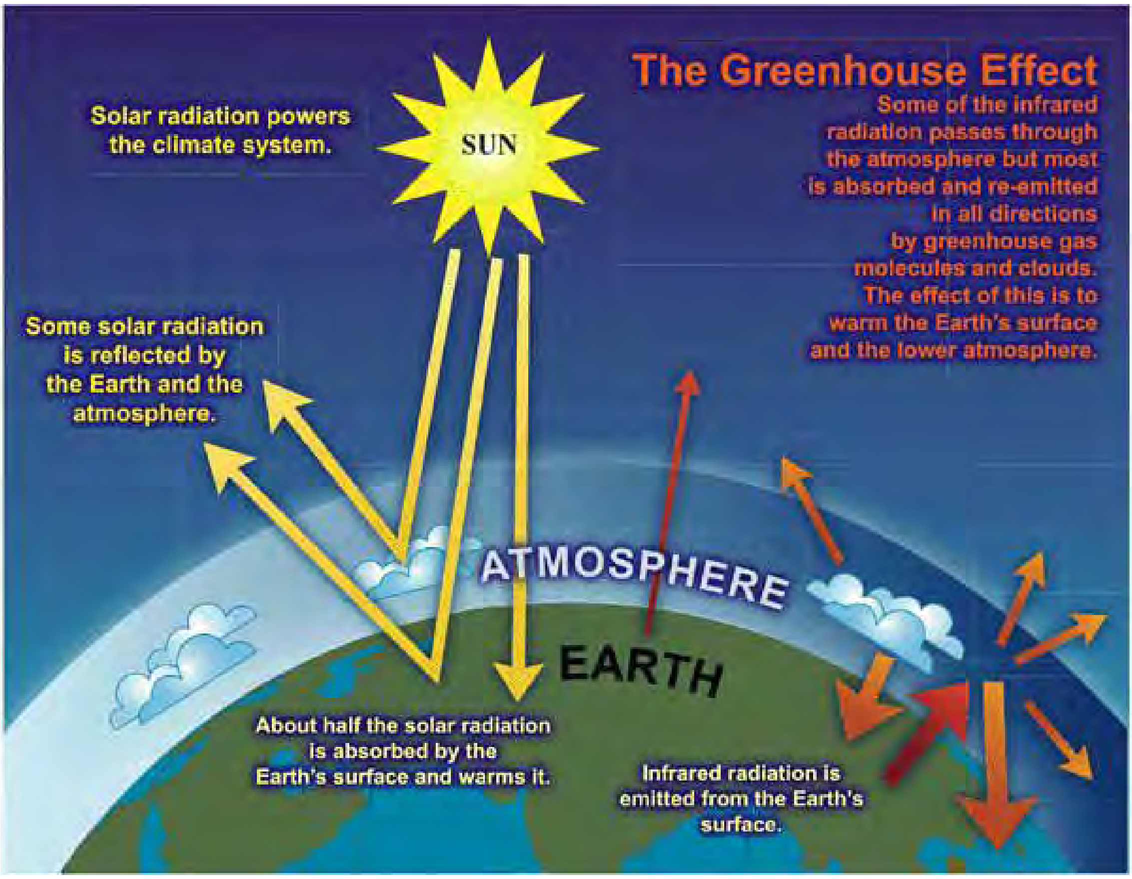

Figure 3: A simplified diagram illustrating the greenhouse effect.
Source: Le Treut et al., 2007

The greenhouse effect, combined with increasing levels of GHGs and the resulting global warming, is expected to have profound implications, according to the near-universal consensus of scientists. If global warming continues unchecked, it will lead to significant climate change, accompanied by a rise in sea levels, increasing ocean acidification, extreme weather events and other severe natural and societal impacts. Planting of trees has been found to significantly help to reduce the build up of CO_2 in the atmosphere as growing trees sequester CO_2 through photosynthesis. Atmospheric CO_2 is converted and stored in the vegetation and soils of the forest. However, forests cannot sequester all of the CO_2 we are emitting to the atmosphere through the burning of fossil fuels and a reduction in fossil fuel emissions is still necessary to avoid build up in the atmosphere.

Activity 1 Group discussion

1) Discuss among yourselves the differences between the following:
   - weather and climate;
   - climate change and climate variability
2) With the guidance provided by the instructor; visit a weather station to learn about some of the weather instruments
   - In groups: Use a simple thermometer or raingauge to oberve surface air temperature or rainfall (this could be daily at the same time) - the instructor could arrange to get some instruments
   - Repeat this for a period of interest then plot a graph of the weather element with time

Greenhouse gasses (GHGs) are gasses that trap heat in the atmosphere. They are therefore responsible for much of the warming that is observed. The most significant GHGs are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Many of these gases occur naturally in the atmosphere, such as CO_2, methane, water vapor, and nitrous oxide, while others are synthetic. Man-made gases include the chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), as well as sulfur hexa-fluoride (SF_6). These are highlighted below for ease of reference.

- **Water vapor** is the most abundant and important greenhouse gas in the atmosphere. However, human activities have only a small direct influence on the amount of atmospheric water vapor. Indirectly, humans have the potential to substantially affect it by changing climate. For example, a warmer atmosphere contains more water vapor.
- **Carbon dioxide** enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g. manufacture of cement). CO_2 is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane** is emitted during the production and transport of coal, natural gas and oil. Emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous oxide** is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- **Hydrofluorocarbon, perfluorocarbon, sulfur hexafluoride and nitrogen trifluoride** are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone depleting substances (e.g., chlorofluorocarbons, hydro chlorofluorocarbons and halons). These gases are typically emitted in smaller quantities, but because they are potent GHGs, they are sometimes referred to as High Global Warming Potential (GWP) gases.

- **Ozone** is a greenhouse gas that is continually produced and destroyed in the atmo-sphere by chemical reactions. In the troposphere, human activities have increased ozone through the release of gases such as carbon monoxide, hydrocarbons and nitrogen oxide, which chemically react to produce ozone. The halocarbons released by human activities destroy ozone in the stratosphere and have caused the ozone hole over Antarctica.
- **Aerosols** are small particles present in the atmosphere with widely varying size, concentration and chemical composition. Some aerosols are emitted directly into the atmosphere while others are formed from emitted compounds. Aerosols contain both naturally occurring compounds and those emitted as a result of human activities. Fossil fuel and biomass burning have increased aerosols containing sulphur and organic compounds and black carbon (soot).

The level of effect of a gas on climate depends on three factors:

- **amount of gas in the atmosphere,** i.e. its concentration; GHG concentrations are measured in parts per million, parts per billion, and even parts per trillion; one part per million is equivalent to one drop of water diluted into about 13 gallons of liquid;
- **how long the gas stays in the atmosphere** (lifetime); each of these gases can remain in the atmosphere for different lengths of time, ranging from a few years to thousands of years; all gases remain in the atmosphere long enough to become well mixed, meaning that the amount measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions;
- **how strong an impact they have on temperature**; some gases are more effective than others at making the planet warmer.

1.3.2 Sources of greenhouse gases

Atmospheric concentrations of both natural and man-made gases have been rising over the last few centuries due to the industrial revolution. As the global population has increased and our reliance on fossil fuels (such as coal, oil and natural gas) has been firmly solidified, so emissions of these gases have risen. While gases such as CO_2 occur naturally in the atmosphere, through our interference with the carbon cycle (through burning forest lands, or mining and burning coal), we artificially move carbon from solid storage to its gaseous state, thereby increasing atmospheric concentrations. Some GHGs, like methane, are produced through agricultural practices including livestock manure management. Others, like CO_2, largely result from natural processes like respiration and from the burning of fossil fuels like coal, oil and gas. Figure 4 shows 87 % of all human-produced CO_2 emissions come from the burning of fossil fuels like coal, natural gas and oil. The largest human source of CO_2 emissions is the combustion of fossil fuels.

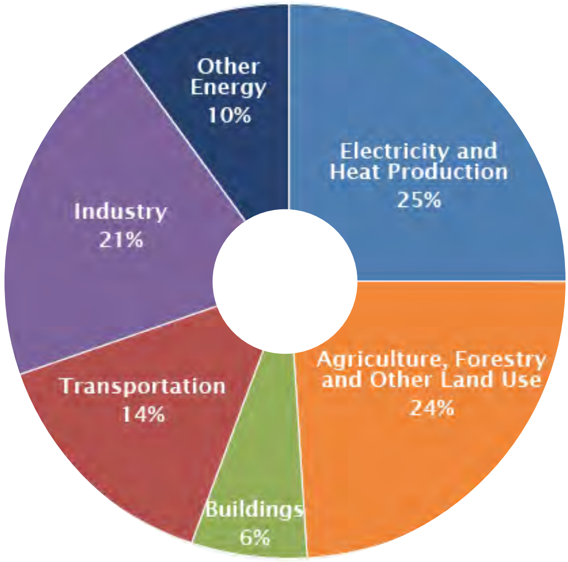

Figure 4: Global GHG emissions by economic sector
Source: IPCC 2014; based on global emissions from 2010.

Human activities cause the release of large amounts of CO_2. These activities include:

- deforestation - cutting down trees for fuel, farms, buildings and roads; when trees are felled to produce goods or heat, they release the carbon that is normally stored by photosynthesis; this process releases nearly a billion tons of carbon into the atmosphere per year; and,
- increased use of energy (and so an increased use of fossil fuels).

As the percentage of CO_2 in the atmosphere has increased, so in general has the Earth's mean temperature.

The amount of man-made water vapour is insignificant compared to the amount of water vapour from natural sources. However, emissions of methane and CO_2 are contributing to increase global warming. Table 2 gives some examples of natural and man-made GHGs and their possible sources.

Table 2: Some examples of GHGs and their sources

Greenhouse gas	Natural source	Man-made source
Methane	Decomposing plant material	Rice paddy fields, cattle, coal mines
Water vapour	Evaporation from oceans, lakes and rivers	Burning hydrocarbon fuels
Carbon dioxide	Respiration by plants/animals, forest fires, volcanoes	Making cement and burning fossil fuels

Increases in the concentration of GHGs have the potential to change the space-time patterns of global climate, with associated impacts, including sea-level rise. The concentra-tions of the main GHGs, viz.CO_2, methane (CH_4) and nitrous oxide (N_2O) in the atmosphere are increasing exponentially. IPCC (2007) indicates that global atmospheric concentration of CO_2, CH_4, and N_2O increased by 35%, 148% and 18% respectively in 2005 compared to their pre-industrial levels.

It is scientifically proven that the concentrations of GHGs in the atmosphere are on increase and that this increase is causing global climate change. Human-driven emissions of CO_2 and other GHGs and land-use change processes are primarily responsible for the increase.

The GHGs that are naturally present in the atmosphere is a natural component of the climate system; they help in the maintenance of the Earth temperatures. The gases are relatively transparent to incoming solar radiation and retain outgoing long wave radiation. Concentrations of GHGs especially CO_2 has risen over the past 250 years, owing to the combustion of fossil fuels for energy production.

Land use change also has contributed to the changing climate; vegetation destruction adds the concentration of carbon in the atmosphere. Generally, deforestation has been due to creation of agricultural land and urban growth, and timber and fuel production.

Summary

Chapter one introduced the knowledge of climate change. It has explored the science of climate change. This chapter has described the concepts of weather and climate by clearly defining and differentiating weather and climate. The elements of weather and climate are also well described. Climate variability and climate change was also well defined and an illustration showing the difference between climate variability and climate change through the use of diagram is included.

The chapter also has described the concept of global warming. This includes looking at the sources and the effects of GHGs. The different types of GHGs were also explained into details. The sources of GHGs are both natural and anthropogenic and these were clearly described.

References

Abiodun, B. J., Adegoke, J., Abatan, A. A., Ibe, C. A., Egbebiyi, T. S., Engelbrecht, F., & Pinto, I. 2017. Potential impacts of climate change on extreme precipitation over four African coastal cities. Climatic Change, 143(3–4), 399–413. https://doi.org/10.1007/s10584-017-2001-5

Alfieri, L., Bisselink, B., Dottori, F., Naumann, G., de Roo, A., Salamon, P., et al. 2017. Global projections of river flood risk in a warmer world. Earths Future, 5(2), 171–182. https://doi.org/10.1002/eft2.183

Barry, R.G. & R.J. Chorley, 2009. Atmosphere, weather and climate. Routledge.

Cotton, W.R., & R.A. Pielke Sr, 2007. Human impacts on weather and climate. Cambridge University Press.

Déqué, M., Calmanti, S., Christensen, O. B., Dell Aquila, A., Maule, C. F., Haensler, A., et al. 2017. A multi-model climate response over tropical Africa at +2°C. Climate Services, 7, 87–95. https://doi.org/10.1016/j.cliser.2016.06.002

Engelbrecht, C. J., & Engelbrecht, F. A. 2016. Shifts in Köppen-Geiger climate zones over southern Africa in relation to key global temperature goals. Theoretical and Applied Climatology, 123, 247–261. https://doi.org/10.1007/s00704-014-1354-1

GIEC, (2012). Gestion des risques de catastrophes et de phénomènes extrêmes pour les besoins de l'adaptation au changement climatique, 32p. Available at : http://max2.ese.upsud.fr/epc/conservation/BEMA/Indices_biodiversite_070305.pdf

Herzog, H., B. Eliasson & O. Kaarstad 2000. Capturing greenhouse gases. Scientific American 282(2):72-79.

Le, T.H., R. Somerville, U. Cubash, Y. Ding, C. Mauritzen, A. Mokssit & M. Prather, 2007. Historical overview of climate change science.

Metz, B., O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer 2007. Climate Change 2007: Mitigation. Contribution of Working Group III to the 4th Assessment Report of IPCC.

OECD, 2005. OECD factbook 2005: economic, environmental and social statistics. Paris.

IPCC. 2018. Annex I: Glossary [R. Matthews (ed.)]. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty[V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.

IPCC, 2014: climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the 5th Assessment Report of IPCC. Geneva, Switzerland, 151 p

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the 5th Assessment Report of IPCC. 1535 p.

IPCC, 2001. Climate change 2001: the scientific basis. Contribution of Working Group 1 to the 3rd Assessment Report of IPCC. Edited by JT Houghton et al. Cambridge University Press, Cambridge, UK, and New York, USA, 2001. 881 p.

Watson, R.T., H. Rodhe, H. Oeschger & U. Siegenthaler, 1990. Greenhouse gases and aerosols. Climate change: the IPCC scientific assessment 1, 17.

World Bank, 2002. Market-based Mechanisms for Conservation and Development, Annual Review, July 2001 – June 2002.

Chapter 2: Causes of climate change

2.0 Chapter overview

In the previous chapter, we introduced the basic science of climate change, where we learned the difference between weather and climate and how they relate to climate variability and change. In this chapter, we will look at some of the causes of climate change, an integral part of the basic science of climate.

Causes of climate change include natural and anthropogenic factors. Natural factors are driven by the interaction between the earth and the solar system. Anthropogenic causes are human-induced. We will learn about anthropogenic causes of climate change due to GHG emissions, e.g. land use changes including deforestation, transportation, use of fossil fuels, burning of forests and grasslands, industrial activities, unplanned settlements and urbaniza-tion, among others. The chapter also reviews observed trends in climate change. Focus will be given to anthropogenic causes of climate change, the subject of section 2.3.

Expected Learning outcomes

By the end of this Chapter the learner should be able to:

- Explain the main causes of climate change;
- Describe “anthropogenic” cause of climate change;
- Describe the five main anthropogenic causes of climate change

2.1 External drivers of natural causes of climate change

2.1.1 Introduction

The drivers of climate change are classified into natural and human-induced. Natural causes can be internal or external. This topic describes the natural drivers of climate change and their impact on the environment.

Objectives

By the end of this session, the learner should be able to:

- describe how climate is influenced by regular variations in the earth's orbit around the sun;
- examine changes in solar thermal output;
- explain how fluctuating levels of solar magnetic activity influences climate; and
- evaluate the impacts by extra-terrestrial objects on climate.

Activity 1 (brainstorming)

Describe the causes of global warming that are not caused by man.

2.1.2 Regular variations in the Earth's orbit around the Sun

The earth revolves around the sun along its orbit. Also, it rotates about its own axis. Earth axis of rotation is tilted away from the perpendicular to the plane of its orbit around the sun. At present, the tilt away from the perpendicular is about 23.5Â°.

2.1.3 Changes in solar thermal output

The sun is the source of most of the energy that drives the biological and physical processes in the world around us. In oceans and on land it fuels plant growth that forms the base of the food chain, and in the atmosphere it warms air which drives our weather. The rate of energy coming from the sun changes slightly day to day. Over many millennia in the Earth-Sun orbital relationship the geographical distribution of the sun's energy over the Earth's surface can change. It has been suggested that changes in solar output might affect our climate - both directly, by changing the rate of solar heating of the Earth and atmo-sphere, and indirectly, by changing cloud forming processes.

The rate at which energy from the sun reaches the top of Earth's atmosphere is denoted by the term "total solar irradiance" (or TSI). TSI fluctuates slightly from day to day and week to week. Superimposed on these rapid short-term fluctuations is a cycle related to sunspots in the outer layers of the Sun that lasts approximately 11 years.

The current TSI varies with season, time of day, and latitude. Yet it is thought that small changes in this relatively small amount of absorbed solar energy can make a difference to our climate.

Case study 2.1 Could changes in the rate of solar absorption, called radiative forcing (RF), be influencing our climate today?

1. Direct changes in climate due to solar output

The average increase in solar radiative forcing since 1750 is much smaller (~ 0.12 W m^{-2}) than the increase in RF due to heat-trapping gases (~2.6 W m^{-2}) over that same time period. The slight increase in solar absorption is, moreover, more than offset by natural cooling. The twentieth century witnessed the eruption of major volcanoes — the most recent, Pinatubo, in 1991 — that spewed tiny reflective particles into the atmosphere. Incoming energy from the sun that encountered these particles was reflected back into space. In other words, natural processes alone would have brought about slight late twentieth century cooling, not the warming we have experienced.

2. Indirect changes in climate due to solar output

The variations of the rate of emission of solar radiation on the 11 year time scale, as well as the small long-term increase in TSI over the past few centuries, appear in some studies to be correlated with variations in cloud patterns. These changes in absorbed solar energy appear to be far too small to explain the major changes in our climate.

Two different hypotheses have been proposed to test whether solar radiation can explain climate change. The first relies on the fact that in both the 11 year cycle and, in the longer term, the changes in solar energy are highest at ultraviolet (short) wavelengths. The short wavelength radiation is particularly effective in modifying ozone concentrations in the level of the atmosphere above where typical weather occurs. According to this hypothesis, modifications in the ozone layer could in turn filter down to that level of the atmosphere where our weather is formed, potentially modifying clouds and temperatures there.

The second hypothesis relies on the fact that changes in solar activity also change the flow of small, charged, highly energetic particles (known as galactic cosmic rays) that travel through the atmosphere toward Earth. These particles in turn create more ions (charged atoms or molecules) from air molecules in the atmosphere, and it has been suggested that these ions might modify cloud formation, causing large changes in weather and temperatures below.

So far, there is no convincing evidence that either of these ideas adequately demonstrate a causal links between small changes in solar irradiance and the relatively large, measurable changes in Earth's surface temperature over the past century.

Source: Hansen et al. (2005)

2.1.4 Fluctuating levels of solar magnetic activity

The current position of bodies like the IPCC is that climate change in the industrial age is predominantly caused by anthropogenic GHGs, CO_2, with relatively small natural contribu-tions due to solar irradiance and volcanoes.

However, in the last decade a new theory, developed by Henrik Svensmark, a physics professor at the Danish National Space Centre in Copenhagen, about how variations in the Sun's magnetic activity may have a very profound impact on climate on earth has attracted growing interest in the scientific community. The theory proposes a link between fluctuations in the sun's magnetic activity and resulting changes in the solar wind around the earth affecting how many cosmic rays hit the earth, particularly the lower atmosphere, which in turn affect the rate of low level cloud formation which in turn drives climate variability.

It has long been acknowledged that there seemed to be a very good fit between solar magnetic activity, as evidenced by sun spot levels and the waxing and waning of solar cycles, and climate changes. The British Astronomer Royal, William Herschel, noticed a correlation between sunspots and the price of wheat in England. This marked the first observation that Earth's climate may be affected by variations of the Sun. The well-known Little Ice Age around the 17th and 18th centuries – when sunspots all but disappeared for 70 years during the Maunder Minimum, the cosmic ray flux increased and the climate cooled – seems to be merely the latest of around a dozen similar events over the last ten thousand years. However there was no proposed mechanism which could explain how changes in the solar cycle could affect the climate to the degree suggested by the historical record as the overall level of energy emitted by the sun, and thus the solar energy hitting the earth, did not seem to vary that much with the solar cycles.

2.1.5 Role of extra-terrestrial objects

An impact event is a collision between celestial objects causing measurable effects. Impact events have physical consequences and have been found to regularly occur in planetary systems, though the most frequent involve asteroids, comets or meteoroids and have minimal impact. When large objects impact terrestrial planets like the Earth, there can be significant physical and biospheric consequences, though atmospheres mitigate many surface impacts through atmospheric entry. Impact craters and structures are dominant landforms on many of the Solar System's solid objects and present the strongest empirical evidence for their frequency and scale (Crowley, 2000).

Impact events appear to have played a significant role in the evolution of the Solar System since its formation. Major events have significantly shaped Earth's history, have been implicated in the formation of the Earth–Moon system, the evolutionary history of life, the origin of water on Earth and several mass extinctions. Notable impact events include the Chicxulub impact, 66 million years ago, believed to be the cause of the Cretaceous–Paleogene extinction event.

An international team of researchers that includes James Kennett, professor of earth science at UC Santa Barbara, has discovered melt-glass material in a thin layer of sedimentary rock in Pennsylvania, South Carolina and Syria. According to the researchers, the material — which dates back nearly 13,000 years — was formed at temperatures of 1,700 to 2,200º C, and is the result of a cosmic body impacting Earth.

These new data are the latest to strongly support the controversial Younger Dryas Boundary (YDB) hypothesis, which proposes that a cosmic impact occurred 12,900 years ago at the onset of an unusual cold climatic period called the Younger Dryas. This episode occurred at or close to the time of major extinction of the North American megafauna, including mammoths and giant ground sloths, and the disappearance of the prehistoric and widely distributed Clovis culture. The researchers’ findings appear today in the Proceedings of the National Academy of Sciences.

“These scientists have identified three contemporaneous levels more than 12,000 years ago, on two continents yielding siliceous scoria-like objects (SLO’s),” said H. Richard Lane, program director of National Science Foundation’s Division of Earth Sciences, which funded the research. *“SLO’s are indicative of high-energy cosmic airbursts/impacts, bolstering the contention that these events induced the beginning of the Younger Dryas. That time was a major departure in biotic, human and climate history.”*

Morphological and geochemical evidence of the melt-glass confirms that the material is not cosmic, volcanic or of human-made origin. *“The very high temperature melt-glass appears identical to that produced in known cosmic impact events such as Meteor Crater in Arizona, and the Australasian tektite field,”* said Kennett.

“The melt material also matches melt-glass produced by the Trinity nuclear airburst of 1945 in Socorro, New Mexico,” he continued. *“The extreme temperatures required are equal to those of an atomic bomb blast, high enough to make sand melt and boil”*.

In Text Questions

- How does the orbiting of the earth influence climate change?
- How does solar thermal output influence climate?

2.2 Internal drivers of natural causes of climate change

2.2.1 Introduction

This section introduces the natural but internal drivers of climate change, such as volcanic eruptions, earth albedos and wildfires and their impacts on climate change.

Objectives

By the end of this session, the learner should be able to:

- describe how volcanic eruptions, earth albedos and wildfires cause climate change; and,
- distinguish the natural from man-made causes of wildfires.

Activity 1 (brainstorming) (20 minutes)

Analyse the internal drivers of climate change.

2.2.2 Volcanic eruptions, tremors, plate tectonics

An earthquake (also known as a quake, tremor or temblor) is the perceptible shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's crust that creates seismic waves. Earthquakes can be violent enough to destroy whole cities. The seismicity, seismism or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. There are still debates on whether climate change can cause earthquakes among scientists.

2.2.3 Earth's albedo

Albedo is a measure of the reflectivity of a surface. The albedo effect when applied to the Earth is a measure of how much of the Sun's energy is reflected back into space. Overall, the Earth's albedo has a cooling effect.

The most significant projected impact on albedo is through future global warming. With the exception of Antarctic sea-ice, recently increasing by 1% a year, nearly all the ice on the planet is melting. As the white surfaces decrease in area, less energy is reflected into space, and the Earth will warm up even more.

The loss of Arctic ice is of particular concern. The ice is disappearing quite fast; not only is albedo decreasing, but the loss triggers a positive feedback. By exposing the ocean surface to sunlight, the water warms up. This melts the ice from underneath, while man-made CO_2 in the atmosphere warms the surface. Humidity also increases and water vapour is a powerful GHG. More ice therefore melts, which exposes more water, which melts more ice from underneath. This loop fuels itself, the effect getting more and more pronounced. This is a good example of a positive feedback. Increased water vapour also has another effect, which is to increase the amount of cloud. As mentioned already, clouds can increase albedo (a negative feedback), but also warming (a positive feedback).

2.2.4 Wildfires

Wildfires are unplanned, unwanted wild land fires, including unauthorised human-induced fires. Wildfires are a common occurrence in some parts of the world. They occur on every continent except Antarctica, most frequently in hot areas where there are extended periods of drought. The cost of wildfires, in terms of risks to human life and health, property damage and public funds, are devastating, and they are only likely to increase unless we better address the risks of wildfires and reduce our activities that lead to further climate change.

Natural causes of wildfires include lightning, spontaneous heating and volcanic eruptions.

- **Lightning** is the single biggest natural cause of wildfires. Most fires started by lightning are small and burn out quickly but if the conditions are right they can spread very rapidly. About 8 million lightning strikes hit the earth every day!
- **Spontaneous heating** is where material becomes heated to the point at which it catches fire without a spark. This is common where lots of leaves and branches have fallen to the ground and not been cleared away - the flow of air is restricted and often leads to fire.
- **Volcanic eruptions** give out red hot lava and ash which can start wildfires.

Activity 2 (Group Discussion)

Discuss any three natural causes of wildfires

In Text Question(s)

Describe how albedo and wildfires cause climate change?

2.3 Anthropogenic causes of climate change

As stated earlier, climate change has two causes, one of them being anthropogenic, meaning 'human induced'. In general, humans have over the past centuries been engaging in activities that release GHGs into the atmosphere. Some of these activities include land use and land cover changes, deforestation and forest degradation and urban settlement. This sub-topic looks at the different anthropogenic activities that increase the amounts of atmospheric GHG concentrations.

2.3.1 Land use, Land use change and Forestry (LULUCF)

There are two types of land use change: direct anthropogenic (human-caused) changes and indirect changes. Examples of anthropogenic changes include deforestation, reforestation and afforestation, agriculture, and urbanization. Indirect changes include those changes in climate or in CO_2 concentrations that force changes in vegetation. The land-cover changes have resulted in a number of alterations in the regional and global climate system, primarily by:

a) changing the reflectivity of the earth's surface, since the type of land cover determines the amount of energy from the sun that is reflected back into space;

b) changing the amount of water lost from the surface via plants, i.e evapotranspiration;

c) modifying winds, heat wave resilience, vulnerability to floods and other such factors in the proximity of human settlements; and,

d) modifying atmospheric CO_2 uptake.

In a nutshell, Land-use changes (e.g. cutting down forests to create farmland) have led to changes in the amount of sunlight reflected from the ground back into space (the surface albedo). The scale of these changes is estimated to be about 20% of the total contribution to GHGs. About half of the land use changes are estimated to have occurred during the industrial era, much of it due to replacement of forests by agricultural cropping and grazing lands. The largest effect of deforestation is estimated to be at high latitudes where the albedo of snow-covered land, previously forested, has increased. This is because snow on trees reflects only about half of the sunlight falling on it, whereas snow-covered open ground reflects about two-thirds.

Other significant changes in the land surface resulting from human activities include tropical deforestation which changes evapotranspiration rates (the amount of water vapour put into the atmosphere through evaporation and transpiration from trees), desertification, which increases surface albedo, and the general effects of agriculture on soil moisture characteristics.

Except for climate change studies there are few reliable records of past changes in land use. One way to build up a better picture of the effects of past changes is to combine surface records of changing land use with satellite measurements of the properties of vegetation cover. Such analyses show that forest clearing for agriculture and irrigated farming in arid and semi-arid lands are two major sources of climatically important land cover changes. The two effects tend, however, to cancel out, because irrigated agriculture increases solar energy absorption and the amount of moisture evaporated into the atmosphere, whereas forest clearing decreases these two processes.

2.3.2 Deforestation and forest degradation

Important to note

Deforestation is clearing Earth's forests on a massive scale, often resulting in damage to the quality of the land. Forests cover about 30% of the world's land area, but patches are lost every year due to deforestation. Forests serve many purposes; 70% of Earth's animals and plants live in forests, trees serve a crucial role in the water cycle by returning water vapor back into the atmosphere, trees keep forest soils moist by blocking the sun, and most importantly, trees absorb the GHGs that fuel global warming.

Deforestation and land use change contribute approximately 20 to 25 % of the carbon emissions that cause climate change. In addition, more than 1 billion people living in extreme poverty depend on these forests for water, fuel and livelihoods. Deforestation devastates the lives of people who are poor.

Forests are cut down for many reasons, but most of them are related to money or to people's need to provide for their families (Rondeux, 2012). The biggest driver of deforestation is agriculture. Farmers cut forests to provide more room for planting crops or grazing livestock. Often, many small farmers will clear a few acres to feed their families by cutting down trees and burning them in a process known as "slash and burn" agriculture. Logging operations, which provide the world's wood and paper products, also cut countless trees each year. Loggers, some of them acting illegally, also build roads to access more and more remote forests, which lead to further deforestation. Forests are also cut as a result of growing urban sprawl. Not all deforestation is intentional. Some is caused by a combination of human and natural factors like wildfires and subsequent overgrazing, which may prevent the growth of young trees.

Deforestation has many negative effects on the environment. The most dramatic impact is loss of habitat for millions of species. 70 % of Earth's land animals and plants live in forests, and many cannot survive the deforestation that destroys their habitats. Deforestation also drives climate change. Forest soils are moist, but without protection from sun-blocking tree cover they quickly dry out. Trees also help perpetuate the water cycle by returning water vapor back into the atmosphere. Without trees to fill these roles, many former forest lands can quickly become barren deserts.

Removing trees deprives the forest of portions of its canopy, which blocks the sun's rays during the day and holds in heat at night. This disruption leads to more extreme tempera-ture swings that can be harmful to plants and animals. Trees also play a critical role in absorbing GHGs that fuel global warming. Fewer forests mean larger amounts of GHGs entering the atmosphere and hence increased speed and severity of global warming.

2.3.3 Urbanization and settlement

The rate of growth of urban areas is quite high, especially in developing countries, including Kenya, Nigeria, South Africa, Ethiopia, among others in Africa. Urban areas have been known to have very high consumption rates, poor traffic management systems and poor waste disposal. 75 % of commercial energy is consumed in urban and peri-urban areas. It is basically in the form of fossil fuels, e.g. coal and petroleum based products. In addition, 80% of all waste is generated from cities and up to 60% of GHG emissions which cause climate change emanate from cities. Satellite photographs show that most waste and pollu-tion is spewed out by cities. The combination makes urban areas a major GHGs contributor.

2.3.4 Use of fossil fuels

Many power stations across the world burn fossil fuels (including coal, oil and gas) to generate energy. Coal is the remains of ancient plants and trees that grew over 200 million years ago. Oil and gas is made up of the remains of microscopic plankton. Over millions of years, these remains become the carbon-rich coal, oil and gas we can use as fuel. When fossil fuels are burnt they release CO_2 into the atmosphere which contributes to global warming. Using fossil fuels to generate energy also releases pollutants into the atmosphere such as sulphur dioxide.

Fossil fuels provide the main source of energy for our modern global economy. However, stocks of fossil fuels are limited and alternatives need to be found. A very big portion of world leaders agree that there is urgent need to act on the impact of fossil fuels on the global climate. Efforts to do this have included banning use of fossil fuels and introduction of use of alternative renewable energy.

2.3.5 Agriculture

Agriculture is generally defined as the cultivation of crops and animal husbandry. This activity is responsible for an estimated one third of climate change. It is generally agreed that about 25% of CO_2 emissions are produced by agriculture, mainly deforestation, the use of fossil fuel-based fertilizers, and the burning of biomass. Most of the methane in the atmosphere comes from domestic ruminants, forest fires, wetland rice cultivation and waste products, while conventional tillage and fertilizer use account for 70% of the nitrous oxides. According to IPCC, the three main causes of the increase in GHGs observed over the past 250 years have been fossil fuels, land use and agriculture.

Over the past centuries, human ingenuity has led to technological advances in agriculture that have allowed substantial increase in crop yields, in part stimulated to meet population growth. Intensive agricultural methods are reported to have detrimental effects on the environment. The agricultural sector has become one of the main driving forces in gas emissions and land use effects. Together, these agricultural processes comprise 54% of methane emissions, roughly 80% of nitrous oxide emissions, and virtually all CO_2 emissions tied to land use. Deforestation for land cleaning purposes also affects regional carbon reuptake, which can result in increased concentrations of CO_2, the dominant GHG. World-wide, livestock production occupies 70% of all land used for agriculture, or 30% of the land surface of the Earth.

Summary of agricultural activities´ contribution to climate change

The cultivation of crops and livestock for food contribute to emissions in a variety of ways.

- various management practices for agricultural soils can lead to production and emission of nitrous oxide (N_2O); activities that can contribute to N_2O emissions from agricultural lands range from fertilizer application to methods of irrigation and tillage; management of agricultural soils accounts for over half of the emissions from the agriculture sector;
- livestock, especially cattle, produce methane (CH_4) as part of their digestion; this process is called enteric fermentation, and it represents almost one third of the emissions from agriculture;
- the way in which manure from livestock is managed also contributes to CH_4 and N_2O emissions; manure storage methods and the amount of exposure to oxygen and moisture can affect how these GHGs are produced; manure management accounts for about 12% of the total GHG emissions from agriculture in the US; and,
- smaller sources of emissions include rice cultivation, which produces CH_4, and burning crop residues, which produce CH_4 and N_2O.

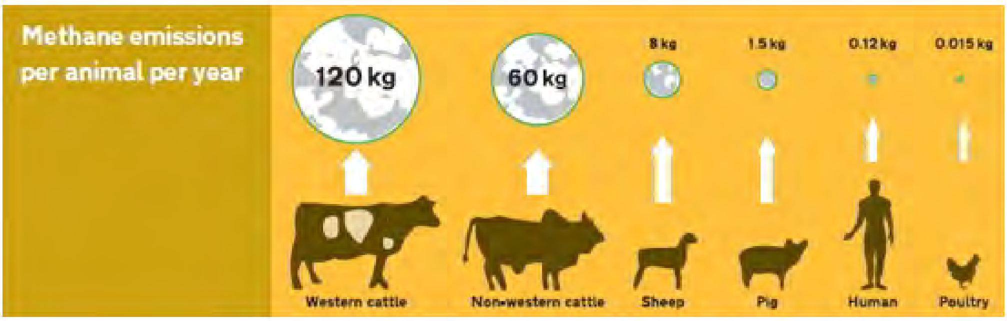

Figure 5. Methane emissions per animal per year in kg.
Source-http://www.worldfuturecouncil.org/2326.html

Activity 1

Explain how the following practices can contribute to climate change:

- agriculture;
- Land use, Land use change and Forestry;
- use of fossil fuels;
- urbanization and settlement; and,
- deforestation and forest degradation.

Activity 2

- Describe the causes of climate change in your locality

Self-assessment/Revision question

Diferentiate between natural and anthropogenic factors that cause climate changes?

Summary

The first section of this chapter has presented how regular variations in the earth's orbit around the sun; changes in solar thermal output; fluctuating levels of solar magnetic activity; and impacts by extra-terrestrial objects affect climate change. The next topic looks at how some factors termed internal drivers also contribute to climate change.

The second section of the chapter has described how internal drivers – volcanic eruptions, tremors, plate tectonics; Earth's albedo (radiation balance at the earth's surface); and wildfires caused by natural factors such as lightning contribute to climate change. The next topic presents the anthro-pological drivers of climate change.

Other than natural causes, climate change drivers are also anthropogenic, meaning that they are human-induced. Humans have over many centuries been engaging in activities that increase the amount of GHGs in the atmo-sphere. Types of anthropogenic causes include land cover and land use changes, deforestation and forest degradation, urbanization, use of fossil fuels and agriculture. Each of these has their unique impact to the climate system, and the degree of impact also varies from place to place.

References

Crowley, T.J., 2000. Causes of climate change over the past 1000 years. Science 289(5477):270-277.

Goodess, C.M., J.P. Palutikof & T.D. Davies, 1992. The nature and causes of climate change: assessing the long-term future. Belhaven Press.

Hansen, J., L. Nazarenko, R. Ruedy, M. Sato, J. Willis, A. del Genio, D. Koch, A. Lacis, K. Lo, S. Menon, T. Novakov, J. Perlwitz, G. Russell, G.A. Schmidt & N. Tausnev, 2005. Earth's energy imbalance: Confirmation and implications. Science 308:1431-1435.

IPCC, 2014. Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability.Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IPCC, 2012. Managing the risk of extreme events and disasters to advance climate change adaptation. A special report of working group 1 and 2 of IPCC. Cambridge University Press, Cambridge, UK, and New York, USA, 582pp.

IPCC, 2007. Fourth Assessment Report: The Physical Science of Climate Change 2007 – Working Group 1. Cambridge Press, UK.

Qin, Dahe, et al., 2014. Climate change 2013: The physical science basis. Ed. Thomas Stocker. Cambridge, UK, and New York: Cambridge University Press.

Shell, K.M. (n.d.). The albedo effect and global warming. Available at: https://www.skepticalscience.com/earth-albedo-effect.htm

UK National ecosystem assessment (UK NEA), 2011. Synthesis of the Key Findings. Information Press, Oxford, Available at: http://uknea.unepwcmc.org/Resources/tabid/82/Default.aspx

UNEP, 2008. Africa: Atlas of Our Changing Environment. Division of Early Warning and Assessment (DEWA). United Nations Environment Programme, Nairobi.

Chapter Three: Climate Change and Ecosystems

3.0 Chapter overview

This chapter provides defintitions of concepts on climate change and ecosystems, functioning of an ecosystem, disturbance of ecosystems under climate change, air, soil and water pollution, indicators of ecosystem disturbance and challenges and opportunities of climate change on ecosystems.

Expected Learning Outcomes

At the end of this chapter, the learners will be able to;

- Explain the effects of climate change on forest and aquatic ecosystems
- Describe the indicators of ecosystems disturbance
- Assess challenges and opportunities of climate change on ecosystems

Objectives

At the end of this session learners will be able to:

- define the concept of ecosystem;
- explain the difference between biocenosis and biotope; and
- explain the functioning and importance of an ecosystem.

3.1 Definition of concepts

Biocenosis. This refers to specific associations of microorganisms, plants and animals that are dependent ona given area (phytocenosis, zoocenosis, microcenosis).

Biotope. This is an area of homogeneous or similar environmental conditions that provide a habitat for a group of plants and animals (e.g. Congo rain forest). The environmental factors could be physical or chemical in nature. Physical factors (climatic, topography and soil), and chemical factors (oxygen, mineral salts, pH); others are abiotic factors in water and soil.

Ecosystem. An ecosystem is a functional system that includes a community of living things and their environment. It is a relatively stable and integrated unit that relies on photo-synthetic organisms. An ecosystem is considered as a kind of collective entity, made up of transient individuals, some of which can live up to several thousand years (large trees, for example), while some micro-organisms can live only a few hours, or even a few minutes.

An ***ecological unit*** is formed by a biotope and a biocenosis and the relationships between living beings (biotic interaction), the relationships between living beings and their biotope, and the relationship between the ecosystem and its environment.

3.1.1 Functioning

Interaction

The soil is an essential element in all life on earth. Living beings draw much of their needs from the soil (water and mineral salts for plants, food source for many animals) in addition to emit most of their waste into the soil. The soil is also the most extraordinary recycling plant where organic waste (cadavers, animal and vegetable waste) is split and transformed into mineral elements that will be used by plants.

Trophic chains

An ecosystem is an integrated unit (with its various abiotic and biotic components) that works, despite the competition of a large number of organisms for resources. Every living being, even the smallest ones (bacteria, fungi, etc.) constitutes a source of food for another living organism. This is called the trophic chain or food chain and consists of a transfer of matter and energy from one trophic level to another.

Producers is the set of green plants that fix the energy of the sunlight (photosynthesis). There is on average 1 to 5% of the solar energy that is captured by plants.

Consumers. All plants and animals consume organic matter from producers to obtain the energy needed for their metabolism. This energy production takes place essentially from the oxidative degradation (respiration) of the organic matter (catabolism). Then, there will be edification of the own (organic) matter of these consumers (anabolism).

Decomposers are mainly bacteria and fungi. They feed on dead organic matter (dead bodies, bedding, etc.). Their role is to decompose organic matter or mineralize it (into CO_2, NH_3, H_2S, etc.). These mineral elements will be taken up by other bacteria, e.g. nitrifying bacteria → nitrates, sulfurizing bacteria → sulfates, etc.

Ecosystem dynamics

The dynamics of forest ecosystems is characterized by cycles that can be apprehended at very different temporal and spatial scales. Thus, an interglacial cycle spreads over several tens of thousands of years and concerns a continent; we observe the slow resettlement of the forest and then its disappearance in favor of a steppe, a tundra or glaciers. Changes in temperature and, more generally, in climate are the driving force behind these processes.

Structure and evolution of the stand (floristic composition, density, basal area); structure and evolution of populations; climatic disturbances or natural disasters leading to regressive phenomena which reactivate new progressive processes; anthropogenic actions leading to the diversification of the observed dynamic trajectories.

3.2 Disturbance of ecosystems under climate change

Studies on the effects of climate on forest ecosystems have focused on the ability of species to tolerate temperature and moisture changes and to disperse but have ignored the effect of disturbances caused by climate change (Ojima et. al., 1991).

Disturbances, both natural and human-induced, shape forest ecosystems by influencing their composition, structure and functional processes. Natural disturbances include fire, drought, introduced species, insect and pathogen outbreaks, affecting forests differently. Forest disturbances also influence how much carbon is stored in trees or dead wood. All these natural disturbances interact with human-induced effects, e.g. pollution and land use change. Climate change can affect forests by altering the frequency, intensity, duration and timing of fire, drought, introduced species, insect and pathogen outbreaks etc.

Objectives

At the end of this session learners should be able to:

- describe the effects of climate change on forest ecosystems; and
- describe the effects of climate change on aquatic ecosystems

3.2.1 Effects of climate change on forest and aquatic ecosystems

Global climate change is the most important source of impact on forest ecosystems. The climate has a decisive influence on the rhythms of forest respiration and production and on other processes, working through temperature, atmospheric radiative forcing and water regimes over medium and long terms. Also, climate and weather conditions influence short-term processes such as fires, herbivory and species migration. Climate change will have an adverse effect on forest ecosystems because it may cause the physiological tolerance of certain species to be exceeded and many biophysical forest processes altered. Most scientific studies show that many tropical forests will not be resilient to climate change over the long term if the current and predicted trend of rainfall decreases and drought increases continues (Betts et al., Sanderson; Woodward, 2008; Malhi et al., 2008). Climate change also has a significant impact on aquatic ecosystems.

3.3 Air, soil and water pollution

Objectives

At the end of this session participants will be able to:

- identify sources of pollution of receiving environments;
- explain the fate of pollutants; and,
- describe the effects of pollution on the three receiving areas.

3.3.1 Atmospheric pollution

Industrial development and vehicle traffic are accompanied by the release of increasing quantities of smoke, toxic gases and other polluting substances into the atmosphere. The increase in energy production, the metallurgical industry, cement works, road traffic, the incineration of large quantities of refuse, and the fermentation of organic matter play significant roles in atmospheric pollution (Choi et al., 2009; Ramade, 1995).

3.3.2 Soil pollution by modern agriculture, industrial and mining activities

The constant intensification of agriculture, the use of ever increasing quantities of artificial substances (chemical fertilizers, pesticides, etc.), lead to irreversible contamination of cultivated soils. Chemical pollution, accompanied by their local overload of surplus ferment-able organic products, inevitably jeopardizes long-term soil fertility.

Current practices of over-fertilization with mineral fertilizers combined with the cessation of the recycling of organic matter in cultivated soils represent a long-term threat to the fertility of the latter.

3.3.3 Pollution of continental and oceanic waters

Biological pollution of the water results in a high bacteriological contamination. The use of streams as a means of diluting urban effluents has serious implications for public hygiene. Pollution by organic matter allows many species of pathogenic germs to multiply. Mineral pollution of water results from the release into the latter of various compounds such as nitrates, phosphates and other salts used in agriculture, various residues rejected by industries.

Water can also be polluted by synthetic organic substances. The production and use of agricultural chemicals is a serious threat to the hydrosphere (Gu et al., 2015; Ramade, 1995). Plastics are very common contaminants in rivers and in the marine environment in Africa.

3.4 Indicators of ecosystems disturbance

Objectives

At the end of this session learners should be able to:

- explain climate-related disturbance indicators;
- discuss disturbance indicators related to vegetation cover;
- explain disturbance indicators related to air quality;
- describe soil-related disturbance indicators;
- explain disturbance indicators related to water quality;
- assess the disturbance indicators related to agricultural yields; and,
- explain bio-indicators

3.4.1 Climate-related indicators

The main climate indicators for ecosystem disturbance include maximum and minimum temperatures, daily precipitation, solar radiation, soil water reserve, frequency and intensity of floods and droughts.

3.4.2 Indicators related to vegetation cover and air quality

Normalized vegetation index, i.e. biomass measurement and seasonal vegetation change, are the main indicators of the vegetation cover. Regarding the air, its quality is often appreciated based on main industrial GHGs including CO_2 and CH_4, emission sources due to human activities including use of fossil fuels (coal, petroleum products, natural gas), deforestation, agriculture, livestock, urbanization, refrigeration, and waste disposal and treatment.

3.4.3 Soil-related indicators

Key determinants include rainfall, inappropriate farming practices, population growth, land tenure, poverty rates, and institutional measures.

3.4.4 Indicators related to water quality

Physicochemical parameters. Temperature of water plays an important role for the example, with regard to the solubility of salts and gases, including, inter alia, the oxygen ary balance of aquatic life. Furthermore, the temperature increases the rates of chemical and biochemical reactions by a factor of 2 to 3 for a temperature increase of 10 °C .

Electrical conductivity (EC) is a numerical expression of the ability of a solution to conduct electric current. Most mineral salts in solution are good conductors. Measurement of con-ductivity makes it possible to determine the overall quantity of dissolved salts in the waters.

The pH is the measure of the acidity of water. The pH scale extends in practice from 0 (very acid) to 14 (very alkaline); the median value 7 corresponds to a neutral solution at 25 °C.

Suspended materials include all mineral or organic materials that do not dissolve in water. They include clay, sand, silt, small organic and mineral material, plankton and other insolvent microorganisms in water.

Chemical and organic parameters. Chemical oxygen demands (COD) and biochemical oxygen demand (BOD) are parameters for assessing water quality. The measurement of these two parameters is based on the difference between the initial dissolved oxygen content and the final dissolved oxygen content after oxidation of the organic matter present in a water sample. The ratio of BOD to COD is an indicative measure of the biochemical "*degradability*" of the compounds present in the water.

Dissolved oxygen concentrations are, along with pH values, one of the most important water quality parameters for aquatic life. Oxygen dissolved in surface waters comes mainly from the atmosphere and photosynthetic activity of algae and aquatic plants.

Mineral chemical parameters. Concentrations of nitrites (NO_2^-), nitrates (NO_3^-), ammonia (NH_3), ammonium (NH_4^+), phosphates (PO_3^-), nitrogen (N) and phosphorus (P) are important parameters for monitoring the quality of surface water.

3.4.5 Indicators related to agricultural yields

Main determinants of agricultural yields are temperature; precipitation; soil moisture; evolution of agricultural water demand; availability of water in the soil; stress index; evolution of biomass and vegetation cover; and projection of agricultural yields in different regions of Africa.

3.5 Challenges and opportunities of climate change on ecosystems

3.5.1 Challenges

Objectives

By the end of this session the learner should be able to;

Analyse the challenges and opportunities associated with ecosystems response to climate change

Challenges are manifested through a number of indicators e.g. loss of biodiversity, tempera-ture rise, increase in extreme events among others commented on below.

Loss of biodiversity

As human activities, particularly agriculture but also settlement and industrial development, have expanded over the last few centuries, natural vegetation such as forests, grasslands and heath lands, has been increasingly cleared; thus, once extensive plant communities have been reduced in size and broken into smaller patches. This habitat reduction and fragmentation limits the ability of many species to migrate to areas with favorable conditions. Species on mountain-tops, islands and peninsulas will have a similar problem.

The decline in biodiversity (the number of different species of organisms on Earth) that has occurred in the last few decades, however, is a rapid decline. Biodiversity loss threatens human security and well-being. Food chains on which we depend will be disrupted, water sources may disappear, and medicines and other resources obtained from lost organisms or the organisms that depend on them could be lost to us. Climate change is a major driver of the loss of biodiversity, and it is predicted to have an even greater impact in the decades to come. Melting Arctic sea ice, ocean acidification, warming temperatures, extreme weather events, and rising sea levels will have a devastating effect on some species (Boyd and Banzhaf, 2006). Climate change is affecting the habitats of several species, which must either adapt or migrate to areas with more favourable conditions.

Deforestation is a human activity that has huge impact on biodiversity. It also contributes to climate change, which further affects habitats. Even small changes in average temperatures can have a significant effect upon ecosystems. The inter-connected nature of ecosystems means that the loss of species can have knock-on effects upon a range of ecosystem functions. In general, those species with restricted climatic envelopes, small populations and limited ability to migrate are most likely to suffer in the face of rapid climate change.

Temperature rise and coral bleaching

A number of species will be affected physiologically by climate change. There is evidence that some species are physiologically vulnerable to temperature rises.

Warmer sea surface temperatures are blamed for an increase in a phenomenon called coral bleaching. This is a whitening of coral caused when the coral expels their zooxanthellae, a symbiotic photosynthesizing algae that lives within the coral tissues and provides it with essential nutrients. The zooxanthellae also give corals their spectacular range of colors. Zooxanthellae are expelled when the coral is under stress from environmental factors such as abnormally high water temperatures and/or pollution. Since the zooxanthellae help corals in nutrient production, their loss can affect coral growth and make corals more vulnerable to disease. Ocean acidification poses yet another challenge for corals because it makes it harder for corals to build their skeletons.

Increases in extreme events

Predicted changes in the intensity, frequency and extent of disturbances such as fire, cyclone, drought and flood will place existing vegetation under stress and favor species able to rapidly colonize denuded areas. In many cases this will mean the spread of alien 'weed' species and major changes in the distribution and abundance of many indigenous species. Heat waves may affect the biodiversity of marine ecosystems, as seen in 2010-2011 in south western West Australia. Extended periods of warmer sea temperatures resulted in the shut-down of the abalone industry, and the migration of whale sharks and manta rays further south and east than usual.

The type, frequency and intensity of extreme events are expected to change as Earth's climate changes, and these changes could occur even with relatively small mean climate changes. Changes in some types of extreme events have already been observed, e.g. increases in the frequency and intensity of heat waves and heavy precipitation events. In a warmer future climate, there will be an increased risk of more intense, more frequent and longer-lasting heat waves. A related aspect of temperature extremes is that there is likely to be a decrease in the daily (diurnal) temperature range in most regions. It is also likely that a warmer future climate would have fewer frost days Growing season length is related to number of frost days, and has been projected to increase as climate warms. There is likely to be a decline in the frequency of cold air outbreaks (i.e. periods of extreme cold lasting from several days to over a week) in Northern Hemisphere winters.

Rainfall patterns

The marginal nature of the environment in dry lands means that even minor changes in rainfall patterns could have major impacts on plants and animals.

Increased carbon dioxide and plant growth

The basic ingredients for photosynthesis include CO_2 and water. Increased CO_2 in the atmosphere causes increased growth rates in many plant species. However, the effect of CO_2 on plant growth must be supported by adequate soil moisture and nutrients. It has been observed that increased concentrations of CO_2 could diminish the nutritional value of foliage and affect the herbivores animals. Most CO_2 emitted into the atmosphere is absorbed by the oceans. This has resulted in a decrease in the ocean's pH, which in turn affects the rate at which many marine organisms build skeletons, meaning that reefs damaged by bleaching or other agents would recover more slowly.

Sea level rise

According to an IPCC report, sea level is predicted to rise by 26–98 centimeters by 2100, due to the thermal expansion of the oceans and the melting of polar ice-caps and ice sheets. Coupled with the effects of storm surges, which are expected to be of a greater magnitude in a warmer world, this increase in sea level could threaten many coastal ecosystems. Also at risk are mangrove forests and low-lying freshwater wetlands.

Reduced crop yield

While research has shown that a rise in CO_2 tends to promote pasture growth, this could be counteracted by reduced rainfall; a 10% reduction in average rainfall is predicted to counter the effect of a doubling of CO_2 concentration in the atmosphere. If rainfall declines by more than 10%, the likely impact will be reduced pasture growth, which is not only important for animal production, but could also lead to potential environmental degradation of some grazing lands. In conjunction with the likelihood of reduced pasture growth, there is potential for increased variability of pasture production.

Plants may differ in their ability to acclimatize to gradual increases in temperature, and the incidence of extreme temperatures outside the coping range may result in changes to the botanical composition of pastures. In addition to these impacts on pasture yield and quality, increased temperature and humidity will impact directly on the productive capacity of grazing animals, particularly cattle. Adaptation to increased heat stress could involve cross-breeding. Other intensive animal industries, such as poultry and pigs, are also vulnerable to increases in temperature and the resultant heat stress on animals. Structures may have to be redesigned to accommodate the conditions likely to be encountered in a changed climate. An alternative strategy is to relocate to a more favorable climatic regions. Either option will be expensive, with the latter having flow-on effects to local communities, such as changed employment options.

Increased incidence of pest and diseases

Pests and pathogens are weather-dependent, and many thrive in hotter, wetter climates — i.e. the sort of change that global warming is predicted to create over the coming decades.

Increased drought and floods

Droughts. Below average precipitation is usually the major cause of droughts. This is especially true if this continues for an extended period of time. There are seasons or years when the precipitation received over a given region is within the normal range of variability. Similarly, there are periods when the precipitation received over a region is either above or below the normal range of variability. Compounding the problem of drought is adverse societal factors such as poor land-use practices, conflicts, poverty, poor communication infrastructure and lack of (or poorly imple-mented) traditional coping mechanisms are major catalysts for drought disasters areas.

Floods are an excessive flow that overtops the normal water channels. Often, floods result from heavy showers or precipitation. Compounding the problem of flooding is deforestation and land degradation which effectively decrease channel capacities to carry water due to sediment loads.

Activity 2 (Group work)

- Name some opportunities brought about by climate change in your area ?
- Analyse the challenges brought about by climate change in your area ?
- Propose how you can deal with each these challenges that you have mentioned.

Along with the risk of drying, there is an increased chance of intense precipitation and flooding due to the greater water-holding capacity of a warmer atmosphere. This has already been observed and is projected to continue because in a warmer world, precipita-tion tends to be concentrated into more intense events, with longer periods of little precipita-tion in between. Therefore, intense and heavy downpours would be interspersed with longer relatively dry periods. Another aspect of these projected changes is that wet extremes are projected to become more severe in many areas where mean precipitation is expected to increase, and dry extremes are projected to become more severe in areas where mean precipitation is projected to decrease.

Self-assessment/ Revision questions

- How does climate change threaten biodiversity?
- Describe climate change bring about floods and droughts?

3.5.2 Opportunities

Climate change does not always lead to challenges, there are also a number of oppor-tunities that can be associated with it, e.g. diversification of livelihood sources and carbon incentives among others. We now explore and try to understand some of these opportunities.

Carbon incentives

Carbon incentives offered for GHG mitigation are an opportunity for countries to invest in these projects and earn revenue, thus providing them with multiple benefits towards environmental management and conservation as well as revenue collection. The carbon market has grown to over 70 billion Euros, with a huge proportion of it invested in developing countries. The benefits associated with this include new technology in energy and production and lower costs for energy.

Diversification of livelihood sources

Shifting climate patterns offers communities with opportunities to diversify their livelihoods into more adaptive and productive streams. Supported by improved technology and capacity, these communities can therefore diversify into better yielding seed types or crops that fetch better value in the market, while at the same time ensuring that these livelihoods are best adapted to the changing climate conditions of the places in which they are located.

Increased investment in environmental improvement

The accelerating nature of climate change and the growing frequency of extreme climate events ensure that adaptation is going to be one of the fastest growing topics for govern-ments and the private sector, adding that now is the time for companies to understand the advantages of being early movers in responding to the challenges and opportunities of climate change. Once adaptation moves into the design, engineering and construction phases, markets in strong economies will see higher growth driven by major projects like desalination plants, levees, sea walls, port reinforcements and similar projects. Long term, climate change adaptation projects will represent tens of billions of dollars annually, including design and construction. Most of these will be geared towards environmental improvement.

Improved primary forest production

Water, sunlight and CO_2 are needed by plants for survival. Forests, just like any other plant, solely depend on CO_2 for their biological activity. They use this to manufacture their own food, which is either stored or used for growth. What would happen if there were a lot of CO_2 in the atmosphere. They would obviously benefit since they can grow faster due to the availability of one of the components that they require for activity.

Therefore, the current increases in GHG emissions is definitely expected to have positive impacts on forests, as they now have a better chance to flourish This is especially true for primary forests, i.e. those that regenerate on their own without any help from man. They are the best type of forest because, as we have noticed, they are natural. This means that they can survive through the climate conditions of that place and also host a wide range of biodiversity, thus increasing the benefits that can be obtained from them.

Capacity building

Countries adversely affected by climate change have seen an increase in the need for capacity to power adaptation and mitigation activities. Organizations and firms have there-fore taken this opportunity to provide communities and countries with training and capacity building in different aspects, e.g.: renewable energy generation, business development, livelihood diversification etc. This means that new capacities and skills are slowly being introduced into countries and communities, enabling them to develop faster than before.

Improved globalization and networking

Climate change provides a global agenda that has in the past brought together countries and organizations to discuss and come to an understanding regarding different issues related to climate change and environmental degradation. For example, the Conference of Parties congregation is a global event that brings together actors from different back-grounds to discuss future plans with regard to climate change adaptation and mitigation. Some firms take this as an opportunity to network and expand their business reach while at the same time encouraging climate sensitive development.

Technology transfer

To promote both mitigation and adaptation to climate change, developed countries have over the past years been transferring technology to developing countries to help them achieve both mitigation and adaptation targets.

Technological solutions are imperative in meeting the challenges of climate change. A critical factor in GHG emissions, technology is also fundamental to enhancing existing abilities and lowering the costs of reducing these emissions (Becker, 2002). Broad diffusion of current technologies and transition to new ones, for example, has improved efficiency in energy use, introduced less carbon-intensive sources of energy, and further developed renewable energy sources. The transition to a low-carbon economy has been driven by cycles of technological discontinuities and innovations. Countries are encouraged to promote and cooperate in the development and diffusion, including transfer, of technologies that control, reduce or prevent GHG emissions.

Most transfer of technology occurs in the private sector. Such transfer can be market-based (e.g. trade, foreign investment and technology licensing) or informal (e.g. imitation and the mobility of technical and managerial personnel). The role of the public sector, however, is no less critical. Given that transfer of technology is not an automatic or costless process, legal and policy incentives are often required to achieve effective rates and approaches of technology transfer in relation to national and international needs and objectives.

Self-assessment/ revision questions

Explain how climate change can provide opportunity for the following:

- diversification of livelihood sources;
- capacity building;
- improved primary forest production;
- improved globalization and networking;
- increased investment in environmental improvement; and
- technology transfer.

Summary

This chapter has explained about the concept of climate change and ecosystems. An ecosystem is a functional system that includes a community of living things and their environment. The disturbances of ecosystems under climate change are addressed and these disturbances are both natural and human induced. Natural disturbances on forest include fire, drought, and introduced species insect and pathogen outbreaks. On the other hand, human-induced effects on the environment are, for example, pollution and land use change.

Various indicators of ecosystem disturbance are explained. There are various indicators such as Climate-related indicators, Soil-related indicators, Indicators related to water quality and Indicators related to agricultural yields. Finally, the challenges and opportunities of climate change on ecosystem were well discussed. Challenges include loss of biodiversity, coral bleaching and temperature rise. Opportunities include carbon incentives and diversification of livelihood sources.

References

Becker, L., 2002. Repeated Blows. Scientific American 286:76–83.

Boyd, J. & S. Banzhaf, 2006. What Are Ecosystem Services. The Need for Standardized Environmental Accounting Units. Discussion Paper, Resources for the Future, 29 p.

Bradley, B.A., M. Oppenheimer & D.S. Wilcove, 2009. Climate change and plant invasions: restoration opportunities ahead? Global Change Biology 15(6):1511-1521.

Choi, S.N. Kim, H. Cha, and R. Ha. Micro sensor node forair pollutant monitoring: Hardware and software issues. InSensors MEMS, 2009.

Doney, S.C., M. Ruckelshaus, J.E. Duffy, J.P. Barry, F. Chan, C.A. English, H.M. Galindo, J.M. Grebmeier, A.B. Hollowed, N. Knowlton & J. Polovina, 2011. Climate change impacts on marine ecosystems.

Ducks Unlimited Canada, 2004. Natural Values. In Wetland values. Available at: http://www.ducks.ca/conserve/wetland_values/pdf/nvalue.p

Gameren, V. van, 2013. Adaptation to climate change: a case study on private forest owners in Wallonia. What transition for our societies? , 151.

Gu, Baojing., Ju, Xiaotang., Jie Chang, Ge Ying., and Vitousek, Peter M, 2015. Integrated reactive nitrogen budgets and future trends in China. PNAS, 112 (28): 8792-8797

Hoegh-Guldberg, O. & J.F. Bruno, 2010. The impact of climate change on the world's marine ecosystems. Science 328(5985):1523-1528.

Lindner, M., M. Maroschek, S. Netherer, A. Kremer, A. Barbati, J. Garcia-Gonzalo, R. Seidl, S. Delzon, P. Corona, M. Kolström & M.J. Lexer, 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest ecology and management 259(4):698-709.

Massicotte, E., 2012. Evaluation of the economic value of ecological goods and services: Brompton Lake approach, methods and examples (Doctoral dissertation, University of Sherbrooke).

Mayrand, K., M. Paquin & C.L. Carpentier, 2004. Payment for environmental services: Study and evaluation of current systems. Montreal, Commission for Environmental Cooperation of North America, 59 .

Scholze, M., W. Knorr, N.W. Arnell & I.C. Prentice, 2006. A climate-change risk analysis for world ecosystems. Proceedings of the National Academy of Sciences 103(35):13116-13120.

Soto, M.A.C., O.S. Bonilla, V.R. Gatjens & M.M. Quirós, 2002. Local management and participation around payment for environmental services: Case studies in Costa Rica. International Center for Economic Policy, CINPE, San Jose, Costa Rica.

Stewart, S. & S. Springs, 2016. 5. United States of America. UNESCO Science Report: circa 2030. 129 pp.

Wallace, K.J., 2007. Classification of ecosystem services: Problems and solutions. Biologi-cal Conservation 139:235-246.

http://galileo.cyberscol.qc.ca/InterMet/climat/climat_du_monde.htm

http://www.uvt.rnu.tn/resources-uvt/cours/zoologie/chapitre1/chap1/Chapitre-3/index.html

http://www.fao.org/docrep/003/s8500f/s8500f0e.htm

http://canadianbiodiversity.mcgill.ca/francais/patterns/surveys.htm

http://www.bf.refer.org/toure/pageweb/erohydry.htm#formes

Water cycle. http://water.usgs.gov/edu/watercyclefrench.html#global

Chapter Four: Vulnerability to and Impact of Climate Change

4.0 Chapter overview

In the previous chapter, we learned about the meaning of anthropogenic causes of climate change and different types of such causes. We also identified some examples of these drivers in our vicinity. In this chapter, we will be introduced to the concepts of vulnerability to and impacts of climate change.

Vulnerability to climate change comprises a set of conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards, or to get hurt by an external stress (Downing et al., 2003).

The impacts of climate change demonstrate the effect of climate change on different sectors in both natural and human systems. These impacts have serious implications for societies by aggravating vulnerabilities (Hellmuth et al., 2009). To contain them will require the development of adaptation mechanisms for the changing climate. This chapter introduces trainees to concepts of vulnerability, biophysical vulnerability and impacts, socio-economic vulnerability, and impacts and reduction of risks associated with climate change. The key issues are highlighted in the subsections that follow.

Expected learning outcomes

By the end of this chapter learners should be able to:

- Explain the meaning of vulnerability to climate change; and
- Assess the impacts of climate change globally and in your vicinity

4.1 The concept of vulnerability

Definition of vulnerability

Vulnerability of a system refers to its physical, social and economic aspects. According to IPCC (2007), vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and adaptive capacity. Mathemati-cally, this can be denoted as:

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

Exposure, sensitivity and adaptive capacity are known as the factors that determine vulnerability. These are briefly discussed below.

Exposure is defined as the degree of climate stress upon a particular unit of analysis; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (McCarthy, 2001). Exposure depends upon things that can be affected by climate change (populations, resources, property etc) and the change in climate itself (sea level rise, precipitation, temperature changes, etc).

Sensitivity is the degree to which a system will be affected by, or responsive to, climate stimuli. Sensitivity is basically the biophysical effect of climate change. It can be altered by socio-economic changes (Patt et al., 2005). For example, new crop varieties could be either more or less sensitive to climate change.

Adaptive capacity refers to the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Pilifosova, 2001). As the name suggests, adaptive capacity is the capability of a system to adapt to impacts of climate change. Factors that determine adaptive capacity include: Wealth; Technology; Education; Institutions; Information; Infrastructure; and Social capital.

Important to note

In other words, the greater the exposure or sensitivity, the greater is the vulnerability. However, adaptive capacity is inversely related to vulnerability. So, the greater the adaptive capacity, the lesser is the vulnerability. Therefore, reducing vulnerability would involve reducing exposure through specific measures like building a dyke in case of sea level rise, or increasing adaptive capacity through activities that are closely aligned with development priorities.

Vulnerability is not just general. There are specific types of vulnerabilities, namely: Socio-economic, livelihood and biophysical vulnerability.

Socio-economic and livelihood vulnerability

This relates to the social and economic factors that face systems/people. Examples of socio-economic factors are: sources of livelihoods (e.g forestry, agriculture, fisheries, etc); human health; food insecurity; water scarcity, floods and droughts; human migration and conflicts; damage to infrastructure and settlements; loss of income; and disease incidences. Social vulnerability is the exposure of groups or individuals to stress as a result of social and environmental change, where stress refers to unexpected changes and disruption to livelihoods. Stress encompasses disruption to groups or individuals' livelihoods and forced adaptation to the changing physical environment. Vulnerability can therefore be explained by a combination of social factors and environmental risk, where risk are those physical aspects of climate related hazards external to the social system.This definition emphasises the social dimensions of vulnerability, in contrast to the predominant views on vulnerability to the impacts of climate change which concentrate on the physical dimensions of the issue.

Biophysical vulnerability

This relates to ecosystems, biodiversity, topography and edaphic factors. Many poor people are directly dependent on ecosystems for their livelihoods. Indeed, biodiversity is the foundation and mainstay of agriculture, forests and fisheries. Natural forests, freshwater and marine ecosystems maintain a wide range of ecosystem goods and services, including the provisioning and regulation of water flows and quality, timber and fisheries. The "poorest of the poor" are, often, especially dependent on these goods and services (Muoghalu, 2014).

Activity 1

- Explain what we mean by vulnerability assessment
- Define the terms exposure, sensitivity and adaptive capacity.
- Describe the different types of vulnerabilities?

4.2 Approaches to vulnerability assessment

Assessing the vulnerability to climate change and subsequently working out adaptation needs requires good quality information. This includes climate data, such as temperature, rainfall and the frequency of extreme events, and non-climatic data, such as the current situation on the ground for different sectors including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity, and coastal zones (Glick et al., 2011).

Vulnerability assessments are conducted in various disciplines and for a variety of reasons, including enhancing understanding of vulnerability contexts and drivers of vulnerability, in order to improve planning and design, and identify appropriate policy interventions. In the context of climate change and development, a strong focus would be on the delivery of relevant knowledge to improve adaptation planning and action.

4.2.1 Socioeconomic assessment

This is an assessment carried out to determine the vulnerability of household's socio-economic systems to particular climate hazards (Smith et al., 2009). Socio-economic indicators are used to determine the vulnerability, e.g. livelihoods, access to education, health service provision, quality of nutrition, demographical indications, etc.

Socio-economic vulnerability assessment is considered as a way to reduce damage asso-ciated with hazards related to socio-economic conditions. Generally, vulnerability is seen as the outcome of a mixture of environmental, social, cultural, institutional and economic structures, and processes related to exposure to hazards, shocks and external stresses, and the ability to cope with or adapt to these risks. It involves the analysis of five dimensions of vulnerability, comprising a range of economic, social, environmental (biodiversity) and climate change indicators that can be quantified through a combination of primary data (field surveys) and secondary data (official statistics and reports).

Besides, we can use the sustainable livelihoods approach to determine the relative vulnera-bility of rural livelihoods across a study area to various sources of stress, including popula-tion pressure, poverty, food security and livelihoods as perceived by survey participants, so as to understand people's resilience and adaptive capacity (Smith et al., 2001). The term 'livelihood' includes capabilities, assets (including both material and social resources) and activities utilized by a household for a means of living. A household livelihood is considered to be vulnerable when it cannot cope with or recover from stresses and shocks to its capabilities and productive asset base.

4.2.2 Ecological assessment

Ecological vulnerability is used to describe a property of a specific system that is exposed to the external or internal disturbances, and whose structure and functions easily change due to its sensitivity to the disturbances and lack of adaptive capability. The interaction between the environment and the social driver decides the exposure and sensitivity of the system (Mach and Mastrandrea, 2014; Muoghalu, 2014).

Ecological assessment consists of monitoring the current and changing conditions of ecological resources from which success or failure of the ecosystem can be judged without bias; understanding more fully the structure and function of ecosystems in order to develop improved management options; developing models to predict the response of ecosystems to changes resulting from human-induced stress from which possible ecosystem manage-ment strategies can be assessed and assessing the ecological consequences of manage-ment actions so that decisionmakers can best understand the outcomes of choosing a particular management strategy. This assessment uses ecological indicators to find out whether a system is vulnerable or not.

Activity 2

Describe the approaches to vulnerability assessments?

4.3 Climate change risk management

4.3.1 Disaster risk reduction

Disaster risk reduction (DRR) is the concept and practice of reducing disaster risks through systematic efforts to analyse and reduce causal factors. Reducing exposure to hazards, lessening vulnerability of people and property, wise management of land and environment, and improving preparedness and early warning for adverse events are all examples of disaster risk reduction (Davies et. al., 2009).

DRR includes disciplines like disaster management, mitigation and preparedness, but DRR is also part of sustainable development. In order for development activities to be sustainable they must also reduce disaster risk. On the other hand, unsound development policies will increase disaster risk and losses. Thus, DRR involves every part of society, every part of government, and every part of the professional and private sectors.

Early warning systems

If you reside in the lower parts of a flood plain, the possibility of flooding in your area increases when the long rains begin. Now imagine two scenarios: 1) You get information that there will be flooding over a certain period, and 2) You do not get information. In scenario 1, with the information you get, you can make decisions to move away in higher grounds so as to avoid the flooding, or you can opt to construct flood control structures. In scenario 2, without knowledge of the impending floods, you will not be able to do anything, until it gets closer or when you are hit by the floods themselves.

The information you get in advance of a climate event is what we call early warning information. To ensure that the information reaches the target population, systems/ mechanisms are put in place to create the information, package it and convey it to the people. Early warning systems enable communities that are at risk from the impacts of climate change to take adaptation measures so as to reduce their vulnerability to these hazards (Manzoor, 2013).

Climate change insurance

We all know about motor vehicle and medical insurances. They are a form of protection from future hazards that you may face. In the case of motor insurance, one protects oneself from a possible accident, with the premise that should it occur, the insurance agency will reimburse the individual a certain amount of money to cover the costs incurred during the accident. This is similar for medical insurance, where the agreement is that if the insured person falls sick, the insurance agency will cover medical expenses incurred.

There is a growing body of evidence that changing patterns of extreme events are one of the contributing factors to recent global economic losses. The economic bearings caused by climate change differ from one region to another, not only because of geographical differences, but because of regional differences in adaptive capacity and response to hazards (Allison et al., 2009). Therefore, insurance can be seen as an important tool for addressing climate change and disaster risk management, in addition to other prevention and security measures, such as development of a disaster modeling system beyond risk sharing and incorporation of risk management cycle into government budget planning (Lindner et al., 2010).

The same concept is used in climate risk management. Insurance is provided for commodities in the form of crop and livestock insurance. These, just like motor and health insurance, cover against loss from climate related hazards, e.g. droughts which may lead to crop failure or low availability of pasture for livestock. When individuals experience losses in their crop or livestock, then the insurance agency reimburses the losses incurred, thus enabling them to pick up from where they were before the climate hazard hit.

Infrastructure

Sometimes, in order to protect life and property from extreme climate events like floods and storms, infrastructure is built. Examples include: flood walls, dykes, storage facilities, raised roads, etc. These structures are informed by indepth knowledge of the occurrence and maginitude of climate events, and are built in such a way as to ensure that such events hit, the structure will remain strong and protect life or property around it (Ferguson and Gleeson, 2012).

4.3.2 Adaptation mechanisms

There exist other adaptation mechanisms that haven't been discussed above. These are both forest and non-forest based. Forest based ones are those that involve use of forests to protect communities and households against the impacts of climate change (Koetse and Rietveld, 2009). Examples of these include afforestation and re-afforestation, to ensure that land cover is maintained or introduced into an area, and growth of crop trees (like mango and orange trees) in a large area, which serves to forest the region but also provide fruits for communities. Other adaptation mechanisms involve tree value addition, where different parts of trees are used to create other useful products which, when sold, can earn good returns. From this communities gain the benefits of a forested environment as well as the economic benefits of market participation. An example of a tree commonly used for this is the Bamboo tree, which can be used to make a wide range of items.

4.3.3 Coping strategies

Everyone faces stresses at some point. In such cases, it has been shown that individuals will employ *coping strategies* in order to overcome these stresses. They are normally specific short term efforts, both behavioral and psychological, that people employ to master, tolerate, reduce or minimize stressful events. Such events can also be climate related, e.g. a drought or a storm. When people use coping strategies, they put in place measures that are short lived just to ensure that they get through the event. Examples of coping strategies include: taking children out of school in reaction to food shortages from a drought; or taking out a high interest loan to replace a car that has been washed away by floods. Coping strategies can both be positive and negative.

Activity 3

- Give examples of risk management activities (both past and ongoing) that you have come across in your region/country.
- Explain how the following are used in climate risk management:
  - early warning;
  - climate risk insurance;
  - infrastructure;
  - coping strategies.

Self-assessment/revision questions

- What is vulnerability?
- Describe the following types of vulnerability assessments:
  - socioeconomic vulnerability assessment; and,
  - ecological vulnerability assessment.

Summary

Vulnerability of a system to climate change impacts depends on its exposure to the hazard, sensitivity and adaptive capacity. To determine the extent of vulnerability, a socioeconomic or ecological assessment can be used. Once this is known different climate risk management measures can be used, e.g. coping mechanisms, forest and non-forest based adaptation mechanisms and other approaches like early warning and climate risk insurance.

References

Allison, E.H., A.L. Perry, M.C. Badjeck, W.N. Adger, K. Brown, D. Conway & N.K. Dulvy, 2009. Vulnerability of national economies to the impacts of climate change on fisheries. Fish and fisheries 10(2):173-196.

Davies, M., B. Guenther, J. Leavy, T. Mitchell, & T. Tanner, 2009. Climate change adaptation, disaster risk reduction and social protection: complementary roles in agriculture and rural growth?. IDS Working Papers 320:1-37.

Downing, T.E., A. Patwardhan, E. Mukhala, L. Stephen, M. Winograd & G. Ziervogel, 2003. Vulnerability assessment for climate adaptation. Adaptation Policy Framework: A Guide for Policies to Facilitate Adaptation to Climate Change. UNDP.

Ferguson, G. & T. Gleeson, 2012. Vulnerability of coastal aquifers to groundwater use and climate change. Nature Climate Change 2(5):342.

Glick, P., B.A. Stein & N.A. Edelson, 2011. Scanning the conservation horizon: a guide to climate change vulnerability assessment. National Wildlife Federation. Washington, D.C. 168 p.

Hellmuth, M.E., D.E. Osgood, U. Hess, A. Moorhead, H. Bhojwani, F. Tubiello & L.R. Brown, 2009. Index insurance and climate risk: prospects for development and disaster management (No. P01-275). CONSEA.

International Research Institute for Climate and Society, 2007. Climate risk management in Africa: Learning from practice. No. P01-261. Earth Institute at Columbia University.

IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of IPCC, Annex I. M.L. Parry et al. (eds.). Cambridge University Press, Cambridge, UK, 976pp.

Koetse, M.J. & P. Rietveld, 2009. The impact of climate change and weather on transport: An overview of empirical findings. Transportation Research Part D: Transport and Environment 14(3):205-221.

Lindner, M., M. Maroschek, S. Netherer, A. Kremer, A. Barbati, J. Garcia-Gonzalo & M.J. Lexer, 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest ecology and management 259(4):698-709.

Mach, K. & M. Mastrandrea, 2014. Climate change 2014: impacts, adaptation, and vulnera-bility (Vol. 1). C.B. Field & V.R. Barros (Eds.). Cambridge University Press. Cambridge and New York.

Manzoor, A., 2013. Toward resilience: a guide to disaster risk reduction and climate change adaptation.

McCarthy, J.J., 2001. Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of IPCC. Cambridge University Press.

Muoghalu, I.J. 2014. Vulnerability of biosphysical and socioeconomic systems in savannahs and woodlands of West and Central Africa to climate change. African Forest Forum, Working Paper Series, Vol. 2(14), 31 pp.

Patt, A., R.J. Klein & A. de la Vega-Leinert, 2005. Taking the uncertainty in climate-change vulnerability assessment seriously. Comptes Rendus Geoscience 337(4):411-424.

Smith, D.R., A. Gordon, K. Meadows & K. Zwick, 2001. Livelihood diversification in Uganda: patterns and determinants of change across two rural districts. Food Policy 26(4):421-435.

Smith, J.B., S.H. Schneider, M. Oppenheimer, G.W. Yohe, W. Hare, M.D. Mastrandrea & H.M. Füssel, 2009. Assessing dangerous climate change through an update of the IPCC “reasons for concern”. Proc. of the National Academy of Sciences 106(11):4133-4137.

Chapter Five: United Nations Conventions on the Environment

5.0 Chapter overview

This chapter presents the United Nations (UN) conventions, and principles, commitments, implementation mechanisms of the conventions. Furthermore, it contains definitions of concepts related to climate change and sustainable development, climate change related negotations, mitigation and adaptation, with specific focus on the UN Framework Conven-tion of Biological Biodiversity and UN Framework Convention to Combat Desertification.

Expected learning outcomes

By the end of this chapter leaners should be able to:

- Describe the different UN conventions on the environment.
- Analyse the objectives of the UN conventions

Convention is a formal agreement between States. The generic term 'convention' is thus synonymous with the term 'treaty'. Conventions are normally open for participation by the international community as a whole, or by a large number of States. Usually, instruments negotiated under the auspices of an international organization are entitled conventions

5.1 UN Framework Convention on Climate Change (UNFCCC)

Objectives

At the end of this topic participants will be able to:

- Describe the UNFCCC;
- State the objectives of the UNFCCC;
- list the principles of the UNFCCC;
- describe UNFCCC commitments, explain the mechanisms for implementing it; and,
- list at least 3 examples of good practice in combating climate change.

5.1.1 Background

UNFCCC is an international environmental treaty adopted on 9 May 1992 and opened for signature at the Earth Summit in Rio de Janeiro in June 1992. It then entered into force on 21 March 1994, after a sufficient number of countries had ratified it. 154 nations signed the UNFCCC, which, upon ratification, committed signatories' governments to reduce atmo-spheric concentrations of GHGs with the goal of "preventing dangerous anthropogenic interference with Earth's climate system". The commitment would require substantial reductions in GHG emissions. The ultimate objective of this Convention, and any related legal instruments that the Conference of the Parties may adopt, is to achieve, in accordance with the relevant provisions of the Convention, stabilization of GHG 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.

5.1.2 Definitions of concepts

Adverse effects of climate change are changes in the physical environment or biota due to climate change that have significant adverse effects on the composition, resistance or productivity of natural and managed ecosystems, on the functioning of socio-economic system or human health and well-being.

Emissions are the release of GHGs or precursors of such gases into the atmosphere over an area and over a given period of time.

Greenhouse gases (GHGs) are the gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit infrared radiation.

The regional economic integration organization is an organization constituted by sovereign

States of a given region which has competence in matters governed by this Convention or its protocols and has been duly authorized according to its internal procedures to sign, ratify, accept, approve or accede to such instruments.

The reservoir is one or more constituents of the climate system that retain a GHG or a precursor of GHGs.

Sinks are any process, activity or mechanism, natural or artificial that removes a GHG, an aerosol or a precursor of GHGs from the atmosphere.

The source is any process or activity that releases a GHG, an aerosol or a precursor of GHGs into the atmosphere.

5.1.3 The convention objectives

Main objectives of the convention are to:

- stabilize in accordance with the relevant provisions of the Convention, concentrations of GHGs in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate system (UN, 1992); and,
- achieve this level in sufficient time so as ecosystems can adapt naturally to climate change and in such a way that food production is not threatened and guarantee that economic development proceed in a sustainable manner (IPCC, 2007).

5.1.4 Principles

The convention principles include:

- preserving the climate system for the benefit of present and future generations on the basis of equity and common but differentiated accountability, and their respective capacities;
- taking full account of specific needs and special circumstances of developing countries particularly those that are highly vulnerable to the adverse effects of climate change;
- taking precautionary measures to predict, prevent or mitigate the causes of climate change and limit their adverse effects;
- incorporating climate change concerns into development policies; and,
- reconciling economic development and preservation of the environment with the per-spective of sustainable development.

5.1.5 Commitments

All parties, taking into account their common but differentiated responsibilities and the specificity of their national and regional development priorities, objectives and circum-stances:

- establish, regularly update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by their sources and the absorption by their sinks of all GHGs not regulated by the Montreal Protocol, using comparable methods to be approved by the Conference of the Parties (UNFCCC, 2006);

- establish, implement, publish and regularly update national and, where appropriate, regional programs containing measures to mitigate climate change while taking into account anthropogenic emissions by their sources, and absorption by their sinks of all GHGs not controlled by the Montreal Protocol, as well as measures to facilitate appropriate adaptation to climate change;
- encourage and cooperate on the design, implementation and dissemination - in particular through technologies transfer – on practices and processes to control, reduce or prevent anthropogenic GHGs not regulated by the Montreal Protocol in all relevant sectors, including energy, transport, industry, agriculture, forestry and waste manage-ment;
- promote sound management and cooperatively promote and support the conservation and, where appropriate, the strengthening of sinks and reservoirs of all GHGs not controlled by the Montreal Protocol, including biomass, forests and oceans and other terrestrial, coastal and marine ecosystems;
- prepare in cooperation, the adaptation to the impact of climate change and design and develop appropriate and integrated plans for coastal zones management, for water resources and agriculture, and for protection and the rehabilitation of areas affected by drought, desertification, and floods (particularly) in Africa.

5.1.6 Implementation mechanisms

The implementation mechanisms include:

- a national inventory by each country of anthropogenic emissions by sources, and absorption by sinks, of all GHGs not controlled by the Montreal Protocol, to the extent that its means permit, using comparable methods on which the Conference of the Parties will concur and encourage the use;
- a general description of measures taken or planned for implementing the Convention and any other information that the Party considers useful for achieving the objective of the Convention and suitable for inclusion in its communication, including where appro-priate data relevant to the determination of global emission trends;
- Each developed country and each of the other Parties included in Annex I shall include in its submission the following information:
    - the detailed description of policies and measures they have adopted to comply with the commitment under Article 4, paragraphs 2 (a) and 2 (b);
    - the accurate estimate of the effects of the policies and measures referred to in the above subparagraph (a) on anthropogenic GHG emissions by sources and absorption by sinks during the period referred to in Article 4, paragraph 2 (a);
    - in addition, each developed country and each other developed parties listed in Annex II, shall detail the measures taken in accordance with Article 4 (3) to (5);
    - developing country Parties may, on a voluntary basis, propose projects to be financed, including technologies, materials, equipment, techniques or specific practices that would

be required to implement them and, where possible, estimates of all incremental costs of these projects, anticipated progress in reducing emissions and increasing GHG absorption, and an estimate of the benefits expected.

5.1.7 Good practices in combating climate change

Good measures for combating climate change include:

- the promotion of agroecology (agroforestry, combination of different species, carbon, storage technique in the soil, use of resistant varieties);
- energy transition (promotion of new and renewable energies);
- forest ecosystems preservation; and,
- integrated water and soil management.

5.2 Climate change and sustainable development

Objectives

At the end of this session, the learners should be able to:

- Explain the link between climate change and sustainable development;
- describe the issues related to climate negotiations;
- explain mitigation and adaptation measures at different scales;
- explain the flexibility mechanisms at different scales; and
- describe Carbon Market opportunities at different scales.

Definition of Concepts

Climate change is the change in climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is in addition to the natural climate variability observed in comparable periods.

Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Bruntland, 1987).

The objective of sustainable development include to harmonize the environmental, social and economic dimensions of development.

- the environmental dimension refers to the maintenance of the ecological integrity: to integrate in all actions of human communities, the concern to maintain vitality and diversity of genes, species and of the set of natural terrestrial and aquatic ecosystems, through measures to protect the quality of the environment by restoring, developing and maintaining habitats that are essential to species;
- the social dimension refers to the concept of social equity between people, nations and generations: to meet the basic needs of present and future human communities and to improve the quality of life; and,

- the economic dimension relates to maintaining or improving economic efficiency: promoting optimum management of human, natural or financial resources.

The various socio-economic sectors in developing countries are expected to face multiple upheavals related to effects of climate change. Climate change, largely linked to GHGs emitted by industrialized countries, will lead to major climate, physical and ecological changes, which will disrupt agricultural systems, particularly in developing countries. Adaptation and mitigation will be needed to minimize the effects of climate change on human development.

5.2.1 Climate related negotiations

The various negotiation on the climate include:

- the Conference of the Parties (COP);
- the understanding of issues; and,
- the international climate agreements.

5.2.2 Mitigation at various scales

The most concerned actors with mitigation are the developed countries. They are the largest emitters of GHGs and have a historical responsibility in this phenomenon. Measures must be taken at spatial, temporal institutional and political scales to mitigate GHG emissions. The financing of measures must be carried out by developed countries.

The many mitigation strategies include retrofitting buildings to make them more energy efficient; adopting renewable energy sources like solar, wind and small hydro; helping cities develop more sustainable transport such as bus rapid transit, electric vehicles and biofuels; and promoting more sustainable uses of land and forests. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behavior. It can be as complex as a plan for a new city, or as a simple as improvements to a cook stove design. Efforts underway around the world range from high-tech subway systems to bicycling paths and walkways.

There are various mitigation approaches i.e.;

- A broad range of sectoral mitigation options is available that can reduce GHG emission intensity, improve energy intensity through enhancements of technology, behaviour, production and resource efficiency and enable structural changes or changes in activity. In addition, direct options in agriculture, forestry and other land use (AFOLU) involve reducing CO_2 emissions by reducing deforestation, forest degradation and forest fires; storing carbon in terrestrial systems (e.g. through afforestation); and providing bio-energy feedstocks. Options to reduce non- CO_2 emissions exist across all sectors but most notably in agriculture, energy supply and industry.
- Decarbonizing, i.e. reducing the carbon intensity of electricity generation, is a key component of cost-effective mitigation strategies in achieving low stabilization levels (of 450 to 500 ppm CO_2-eq, at least about as likely as not to limit warming to 2°C above pre-industrial levels) (medium evidence, high agreement).

- Efficiency enhancements and behavioural changes, in order to reduce energy demand compared to baseline scenarios without compromising development, are a key mitigation strategy in scenarios reaching atmospheric CO_2-eq concentrations of 450 to 500 ppm by 2100 (robust evidence, high agreement).
- The most cost-effective mitigation options in forestry are afforestation, SFM and reducing deforestation, with large differences in their relative importance across regions. In agriculture, the most cost-effective mitigation options are cropland management, grazing land management and restoration of organic soils (medium evidence, high agreement).

5.2.3 Adaptation at various scales

Adaptation involves adjusting practices, procedures or structures to current and projected climate change. The most concerned actors with adaptation are developing countries. Ability to adapt refers to the means available for a society to cope with stress. These also depend on the socio-economic, political, institutional and cultural characteristics of the society affected by climate hazards. Adaptation measures should be taken at spatial, temporal institutional/political scales with consistent financing approaches. There should be a synergy between adaptation and mitigation.

5.2.4 Flexibility mechanisms at various scales

Under the Kyoto Protocol, there is a provision for international mechanisms that allow for flexibility in achieving GHG emission reductions. The Principle of flexibility mechanisms include:

- The Joint Application; this is based on the 1992 UNFCCC. The Joint Implementation concept has evolved based on discrete emission reduction units which could be credited to an investor country for reduction projects realised in a host country. Reduction credits are based on actual, project-related avoidance, reduction or sequestration of GHGs. In this way the reduction of global GHGs could be reduced in a cost-effective manner.
- The Clean Development Mechanism (CDM); The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. CERs can be traded, sold and used by industrialized countries to 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, 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.
- The Emissions trading rely not on the transfer of reduction “credits” but on the trading of emission “rights” or allowances. In such a scenario, transfers between countries would be based on a “purchase” of emission rights from those countries whose emissions are below there national quotas. 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.

5.3 United Nations Framework Convention on the Conservation of Biological Diversity (CBD)

Learning objectives

At the end of this session, learner should be able to:

- explain the UNCBD;
- explain the objectives of the UNCBD;
- describe the principles of the UNCBD;
- describe the commitments of the UNCBD;
- analyse the mechanisms for the implementation of the UNCBD, and,
- list at least 3 examples of good practices for biodiversity conservation.

5.3.1 Definition of concepts

- **Biotechnology** refers to any technological application that uses biological systems, living organisms or their products, to make or modify products in the processes for specific use.
- **In situ conditions** refer to conditions characterized by the existence of genetic resources within ecosystems and natural habitats and, in the case of domesticated and cultivated species, in the environment where their distinctive characteristics have developed.
- **Ex situ conservation** refers the conservation of components of biological diversity outside their natural environment.
- **In situ conservation** refers to the conservation of ecosystems and natural habitats and the maintenance and reconstitution of viable populations of species in their natural environment and, in the case of domesticated and cultivated species, in the environ-ment in which their distinctive characteristics have developed.
- **Biological diversity** refers to the variability of living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within and between species and ecosystems.
- **Ecosystem** refers to the dynamic complex of plants, animals and micro-organisms communities and their non-living environment, which, through their interaction, form a functional unit.
- **Domesticated or cultivated species** refers to any species whose evolutionary process has been influenced by humans to meet their needs.
- **Habitat** refers to the place or type of site in which an organism or population exists in its natural state.
- **Genetic material** refers to the plant, animal, microbial material or other origin con-taining functional units of heredity.
- **Regional Economic Integration Organization** refers to any organization constituted by sovereign States of a given region, to which these Member States have transferred com-

petence with respect to the matters governed by this Convention and which has been duly authorized, in accordance with its internal procedures, to sign, ratify, accept, approve or accede to the said Convention.

5.3.2 Objectives

The Convention on Biological Diversity (CBD) was signed in 1992 in Rio de Janeiro and has been ratified or acceded to by more than 180 parties. The Convention has three main goals:

- the conservation of biodiversity;
- sustainable use of the components of biodiversity; and,
- sharing the benefits arising from commercial and other utilisation of genetic resources in a fair and equitable way.

In addition to its substantive provisions, the CBD establishes institutional arrangements to provide a mechanism to monitor its progress and facilitate further developments. Three institutions are established by the CBD: the Conference of the Parties (COP), the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and the Secretariat. In addition, the CBD establishes a financial mechanism for the provision of financial resources to developing country Parties.

5.3.3 Principles

In accordance with the Charter of the UN and the principles of international law, States have the sovereign right to exploit their own resources in accordance with their environmental policy and have a duty to ensure that activities within their Jurisdiction or control do not cause damage to the environment in other States or regions beyond national jurisdiction.

5.3.4 Implementation mechanisms

The implementation mechanisms include:

- the development of National Strategies, Plans or Programs for the the Conservation of Biological Diversity;
- the adjustment of existing policies, plans and programs to the measures of this Convention;
- the carrying out of impact studies of development initiatives and the reduction of negative impacts on biodiversity; and,
- the funding for actions to conserve biological diversity.

5.3.5 Good practices for biodiversity conservation

As good practices for biodiversity conservation, each country:

- identifies the components of biodiversity that are important for its conservation and sustainable use;
- identifies processes and categories of activities that have or are likely to have a significant adverse effect on the conservation and sustainable use of biological diversity and monitors their effects through sampling and other techniques;

- establishes a system of protected areas where special measures need to be taken to conserve biological diversity;
- adopts measures to conserve ex-situ components of biological diversity, preferably in the country of origin of those components; and,
- integrates considerations for the conservation and sustainable use of biological resources into the national decision-making process.

Developed countries set up and pursue scientific/technical education and training programs to identify and conserve biological diversity based on needs of developing countries.

5.4 United Nations Framework Convention to Combat Desertification (UNCCD)

Learning Objectives

At the end of this session, learnersshould be able to:

- State the objectives of the UNCCD;
- Analyse the principles of the UNCCD;
- describe the commitments of the UNCCD;
- explain the mechanisms for the implementation of the UNCCD; and,
- list at least 3 examples of good practice in combating desertification

5.4.1 Definition of concepts

- **Desertification** refers to land degradation in arid, semi-arid and dry sub-humid areas as a result of various factors, including climatic variations and human activities.
- **Combating desertification** refers to activities related to integrated land develop-ment in arid, semi-arid and dry sub-humid areas with a view to achieving sustainable development and aiming at: (i) preventing and/or reducing land degradation, (ii) rehabilitating partially degraded lands, and (iii) restoring desertified land.
- **Drought** refers to the natural phenomenon that occurs when precipitation has been significantly below normal levels and causes severe hydrological imbalances that are detrimental to production systems of land resource.
- **Drought mitigation** refers to activities related to drought prediction and aimed at reducing the vulnerability of society and natural systems to drought in the context of combating desertification.
- **Land** indicates the terrestrial bioproductive system incluiding soil, plants, other living things, and the ecological and hydrological phenomena occurring in the system.
- **Land degradation** refers to the decrease or disappearance of biological or economic productivity and the complexity of rainfed cultivated land, irrigated cropland, pastures, forests or woodland in arid, semi-arid and dry sub-humid areas as a result of land use or one or more phenomena, including those caused by human activity and its patterns of settlement, such as:
  - i. soil erosion caused by wind and/or water;
  - ii. deterioration of the physical, chemical and biological or economic properties of soils; and,
  - iii. the long-term disappearance of natural vegetation.

5.4.2 Objectives

The objective of UNCCD is;

- to combat desertification and mitigate the effects of drought in countries severely affected by drought and/or desertification, particularly in Africa, through effective measures at all levels, supported by international cooperation and partnership arrange-ments, within an integrated approach consistent with Agenda 21, with a view to contri-buting to the achievement of sustainable development in the affected areas.

5.4.3 Principles

To achieve the objectives of UNCCD and to implement its provisions, the Parties shall be guided, inter alia, by the following principles:

- parties should ensure that decisions concerning the design and implementation of programs to combat desertification and/or mitigate the effects of drought are undertaken with the participation of local communities, and that an enabling environment is created at the higher levels to facilitate action at the national and local levels;
- parties should, in a spirit of international solidarity and partnership, improve cooperation and coordination at the sub-regional, regional and international levels and better concen-trate financial, human, organizational and technical resources where they are needed;
- parties should, in a spirit of partnership, institute cooperation between public authorities at all levels, communities, NGOs and land-holders in order to increase understanding in the affected areas of the nature and the value of land and scarce water resources, and to promote sustainable use of these resources; and,
- parties should give full consideration to the special circumstances and needs of affected developing country Parties, especially the least developed among them.

5.4.4 Commitments

In the framework of UNCCD, the Parties shall:

- fulfill their obligations under UNCCD, individually or jointly, through existing or future bilateral and multilateral agreements or through the combination of these various types of agreements, as appropriate, with emphasis on coordinating efforts and develop-ing a coherent long-term strategy at all levels;
- adopt an integrated approach addressing the physical, biological and socio-economic aspects of desertification and drought;
- integrate poverty eradication strategies into action to combat desertification and mitigate the effects of drought;
- encourage cooperation among affected countries in areas of environmental protecttion and conservation of land and water resources relevant to desertification and drought;
- strengthen sub-regional, regional and international cooperation and cooperate within relevant intergovernmental organizations;

- undertake to actively support, as agreed, individually or jointly, the efforts of affected developing country Parties, particularly those in Africa, and the least developed countries, to combat desertification and mitigate the effects of drought; and,
- commit to provide substantial financial resources and other forms of support to assist affected developing country Parties, particularly those in Africa, in the development and effective implementation of their own plans and strategies to combat desertification and mitigate the effects of drought.

5.4.5 Implementation mechanisms

In the context of the implementation of UNCCD, Parties shall give priority to affected countries of Africa, taking into account the special situation prevailing in that region, without, however, neglecting the affected developing country in other regions. This implementation mechanism will focus on the participatory development of national and regional action programs, research and development, capacity building, public education and awareness, and the mobilization of financial resources.

5.4.6 Good practices for Sustainable Land Management (SLM)

SLM is the collection of strategies and practices that allow us to use land based resources (forests, soils etc) today in ways that ensure that future generations can also fully use them. Examples are conservation agriculture, agro-forestry and community forestry, etc.

Increasing Soil Organic Carbon (SOC) stocks is key to most SLM practices, and provides synergies for addressing DLDD (Desertification, Land Degradation and Drought), climate change adaptation and mitigation. Besides contributing to climate change mitigation by removing CO_2 from the atmosphere, enhancing organic carbon in soils improves soil health and fertility, water and nutrient retention capacity, food production potential and resilience to drought (Holt-Giménez, 2002). The potential and magnitude of each of these benefits will depend on the baseline conditions, and local environmental, socio-economic and cultural conditions.

SLM practices have a strong potential to enhance SOC sequestration, although estimates of this potential should consider the full GHG balance, including possible interactions between the carbon and nitrogen cycles that could affect the net climate change mitigation potential of applied practices.

Good practices for sustainable land management include:

- inventory and promotion of endogenous good land management practices;
- transfer, acquisition, adaptation and technology development; and
- integrated soil and water management.

Case Study 1: Strip mine rehabilitation (South Africa)

Description: Rehabilitation of areas degraded by strip mining, through returning stockpiled topsoil and transplanting of indigenous species, to promote revegetation.

Case Study 2: Area closure and reforestation with Acacia (Tunisia)

Description: Protection and reforestation of degraded arid lands in pre-Saharan Tunisia. Protection and reforestation of degraded arid lands in central and southern Tunisia (Bled Talah region) with tree species Acacia tortilis subsp. Raddiana, which is a native trees species able to tolerate extreme droughts and to persist on the edge of the Sahara desert. Acacia plantations are set up following a 3m x 3m grid. Seedlings are planted in the bottom of ininfiltration pits which are constructed for rainwater harvesting. Protection of the plantation area is established by means of a fence.

Case Study 3:Assisted cork oak regeneration (Morocco) Takhlif Madoum Elghaba
Description: Assisted cork oak regeneration in the Sehoul forest, by acorn seeding and seedling plantation (derived from a plant nursery), involving careful husbandry and protection from grazing.

Summary

UN conventions on the environment play an important role in ensuring that environment is well maintained and protected from human induced actions. A 'convention' is a formal agreement between States. Conventions are normally open for participation by the international community as a whole, or by a large number of States.

UNFCCC focuses on reducing atmospheric concentrations of GHGs with the goal of "preventing dangerous anthropogenic interference with Earth's climate system". UNFCCC has well stipulated objectives, principles and commitments towards reducing the concentration of GHGs. The UN Framework Convention on the Conservation of Biological Diversity (UNCBD) aims at ensuring that there is conservation of biodiversity and also there is sustainable use of the components of biodiversity. The UN Framework Convention to Combat Desertification (UNCCD) aims at combating desertification and mitigate the effects of drought in countries severely affected by drought and/or desertification, particularly in Africa.

Bibliography

Balmford, A., L. Bennun, B. ten Brink, D. Cooper, I.M. Côté, P. Crane & R.D. Gregory, 2005. The convention on biological diversity's 2010 target. Science 307(5707):212-213.

Bodansky, D., 1993. The United Nations framework convention on climate change: a commentary. Yale J. Int'l l., 18:451.

Boden, T.A., G. Marland, & R.J. Andres, 2009. Global, Regional and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, U.S.A.

Chardonnet, F., 2009. Typology of agro-pastoral farms of the rural community of Téssékré, in order to show the diversity, in the importance of the role of livestock breeding to the reduction of vulnerability.

Hansen, M.C., S.V. Stehman & P.V. Potapov, 2010. Quantification of global gross forest cover loss. Proceedings of the National Academy of Sciences 107(19):8650-8655.

Holt-Giménez, E., 2002. Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: a case study in participatory, sustainable land management impact monitoring. Agriculture, Ecosystems & Environment 93(1-3):87-105.

IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the IPCC Fourth Assessment Report. Cambridge University Press, New York, USA.

Langner, A., F. Achard & G. Grassi, 2014. Can recent pan-tropical biomass maps be used to derive alternative Tier 1 values for reporting REDD+ activities under UNFCCC? Environmental Research Letters 9(12).

Morgan, J. & D. Waskow, 2014. A new look at climate equity in the UNFCCC. Climate Policy 14(1):

Protocol, K., 1997. United Nations framework convention on climate change. Kyoto Protocol, Kyoto, 19.

Stirling, A., 2001. On science and precaution in the management of technological risk.

UNCCD and UNFCCC, 2004. In Final Report on the Workshop on forest and forest ecosystems: Promoting synergy in the three Rio conventions (pp. 5-7).

UNCCD, 2012. United Nations Convention to Combat Desertification.

Annex 1

Table 3: Implementation matrix

Content	Delivery time	Delivery methodology	Materials/ resources
Definition of weather and climate; elements of weather/climate	40 min	Interactive lectures	LCD projector, laptop computer, flip chart board and paper, and marker
Changes in weather and climate; climate variability and change;	1 hour	Interactive lectures; group discussions;	
Global warming, GHGs; sources and sinks and their effects;	1 hour	Interactive lectures; group discussions;	
Global warming and GHGs; Sources of GHGs	1 hour	Interactive lectures; group discussions;	
External drivers of climate change	1 hour	Interactive lectures; group discussions;	
External drivers of climate change	1 hour	Interactive lectures; group discussions;	
Anthropogenic drivers of climate change	1 hour	Interactive lectures; group discussions; question and answer topics; brainstorming and case activity	
Management of anthropogenic drivers of climate change	1 hour	Interactive lectures; group discussions; brainstorming.	
Indicators of ecosystems disturbance; Climate-related indicators; Indicators related to vegetation cover and air quality;	1 hour	Interactive lectures; group discussions;	
Soil-related indicators; Indicators related to water quality; Indicators related to agricultural yields;	1 hour	Interactive lectures; group discussions; question and answer topics; brainstorming and case activity	
Challenges and opportunities of climate change on ecosystems;	1 hour	Interactive lectures; group discussions;	

Table 4: Implementation matrix

Content	Delivery time	Delivery methodology	Materials/ resources
The concept of vulnerability	1 hour	Interactive lectures; group discussions;	LCD projector, laptop computer, flip chart board and paper, and marker
Approaches to vulnerability assessment	1 hour	Interactive lectures; group discussions;	
Climate change risk management	1 hour	Interactive lectures; group discussions; question and answer topics; brainstorming and case activity	
UNFCCC: Definitions of concepts; Convention objectives; Principles;	1 hour	Interactive lectures; group discussions; and brainstorming.	
UNFCCC: commitments; implementation mecha-nisms; good practices in combating climate change; climate change and sustainable development	1 hour	Interactive lectures; group discussions; and brainstorming.	
Climate related negotia-tions; mitigation and adaptation at various scales	1 hour	Interactive lectures; group discussions; and brainstorming.	
UN Framework Convention on the Conservation of Biological Diversity; definition of concepts	1 hour	Interactive lectures; group discussions; and brainstorming.	

Lead authors

Prof. Alfred Opere
Chairman Department of Meteorology, College of Biological and Physical Sciences,
University of Nairobi
P.O. Box 30197-00100, GPO, Nairobi, Kenya
Email: aopere@uonbi.ac.ke

Prof. Dan Lansana Kourouma
Centre d'Etudes et de Recherche en Environnement. Université de Conakry,
République de Guinée;
Email: dan_lansana@yahoo.fr

List of other contributors

Name and Institution of affiliation

Dr. Abasse Tougiani
Senior Research Scientist; National Institute for Agricultural Research of Nige r (INRAN)
BP 429, Niamey, Niger;
Tel: +227 96970886;
Email: abasse.tougiani@gmail.com

Dr. Bayen Philippe
Lecturer; University of Dédougou;
Private Bag Burkina Faso;
Cel: 226-705-73-601;
Email: phbayen@yahoo.fr

Prof. Busuyi Olasina Agbeja
University of Ibadan, Nigeria; Department of Social and Environmental Forestry
Faculty of Renewable Natural Resources;
13, Ijoma Street, University of Ibadan, Nigeria;
Email: olasinagbeja@yahoo.com; bo.agbeja@mail.ui.edu.ng

Prof. Adjima Thiombiano
Université de Ouagadougou, Laboratoire de Biologie et Ecologie Végétales ;
03 BP 7021 Ouagadougou 03, Burkina Faso
Tel. +226 70 238261; Email: adjima_thiombiano@yahoo.fr

Dr. Bamba Syalla
Head of Research Cluster: Climate Change and Climate Variability, West African Science Service Center on Climate Change and Adapted Landuse (WASCAL);
WASCAL Competence Center, Ouagadougou, Burkina Faso;
Tel: Office: (+226) 25 37 54 23/29/39;
Cell: (+226) 76 76 53 85 (+226) 76 89 66 70,
E-mail: sylla.b@wascal.org; syllabamba@yahoo.fr

Mrs. Beatrice Kolie
Assistant Lecturer ; Centre d'Etudes et de Recherche en Environnement; Université de Conakry;
Private Bag; Conakry, République de Guinée

Dr. Daud Kachamba;
Lecturer; Lilongwe University of Agriculture and Natural Resources (LUANAR);
Private Bag, Lilongwe;
Tel: +265 993 605154;
Email: dkachamba@gmail.com

Dr. Dan Guimbo Iro
Senior Lecturer; Faculté d'Agronomie, Université Abdou Moumouni (Niger);
Tel: (+227)96461038/90525602 ; Email: danguimbo@yahoo.fr

Dr. Darlington Chima Uzoma
Senior Lecturer; University of Port Harcourt;
Department of Forestry and Wildlife;
Choba, P. M. B 5323; Nigeria;
Email: uzoma.chima@uniport.edu.ng

Dr. Dickson Makanji
Lecturer, Egerton University, Njoro Campus,
Department of Natural Resources;
P.O Box 536 Egerton 20115 , Kenya;
Mobile: +254. 0702115860; Email: lmakanji@hotmail.com , lmakanji@yahoo.co.uk

Dr. Doris Mutta
Senior Programme Officer; African Forest Forum (AFF);
C/o World Agroforestry Center (ICRAF), United Nations Avenue; P.O. Box 30677-00100, Nairobi, Kenya;
Tel: +254 020 7224485; Fax: +254 020 7224001;
Email: D.mutta@cgiar.org

Dr. Godfrey Hampwaye
Senior Lecturer, The University of Zambia, Dept of Geography and Environmental Studies;
Great East road, P.O Box 32379, Lusaka, Zambia;
Tel: +260 211 290 603,
Mobile:. +260-977 806 063;
Email. ghampwaye@unza.zm; hampwaye@yahoo.co.uk

Prof. Godwin Kowero
Executive Secretary; African Forest Forum (AFF); C/o World Agroforestry Center (ICRAF), United Nations Avenue; P. O. Box 30677 – 00100, Nairobi, Kenya;
Phone: +254207224203;
Email: G.kowero@cgiar.org

Prof. Eliakimu Zahabu
Department of Mensuration and Management ; Sokoine University and Agriculture, Faculty of Forestry and Nature Conservation;
P.O. Box 3013 Chuo, Kikuu, Morogoro, Tanzania;
Email: zahabue@yahoo.com; zahabue@suanet.ac.tz

Mr. Emmanuel Seck
Programme Manager; ENDA - Energy Environment Development ;
Complexe SICAP Point E Bâtiment B; 1er étage Avenue Cheikh Anta Diop X Canal IV; Dakar, Senegal;
Tél : (221) 33 869 99 48/49;
Fax : (221) 33 860 51 33;
Email : se@endatiersmonde.org ; ssombel@yahoo.fr

Dr. Emannuel Acheampong
Senior Lecturer, Department of Silviculture and Forest Management, Faculty of Renewable Resources, Kwame Nkrumah University of Science and Technology (KNUST)
Private Mail Bag, KNUST, Kumasi, Ghana
Tel: 0243412179; Email: ekachie@yahoo.com; eacheampong.irnr@knust.edu.gh

Dr. Eyob Tesfamariam
Lecturer; University of Pretoria; RM 5-15, Plant Sciences Complex;
Corner of Lynwood Rd & Roper St.; Hatfield 0028; South Africa;
Mobile:. +27-724597140;
Email: eyob.tesfamariam@up.ac.za

Dr. Franklin Joseph Opijah
Senior Lecturer; University of Nairobi; Chiromo Campus; Department of Meteorology;
P.O Box 30197-00100 ; Nairobi, Kenya;
Email: fopija@uonbi.ac.ke; fopijah@gmail.com; fopijah@yahoo.com

Prof. Jacob Mwitwa
University of Copper belt, School of Natural Resources, Zambia;
Cell: +260 977 848 462;
Email: Jacob.mwitwa@gmail.com

Prof. John Nzioka Muthama
Deputy Director; Wangari Maathai Institute for Peace and Environmental Studies; University of Nairobi, College of Biological and Physical Sciences; Head of Climate Change; Department of Meteorology;
P.O. Box 15160-00100, GPO, Nairobi Kenya;
Email: jmuthama@uonbi.ac.ke; jnmuthama@gmail.com

Dr. Joshua Ngaina
Chairman, Meteorology Department, South Eastern Kenya University (SEKU), Department of Meteorology;
P.O. Box 170-90200 , Kitui, Kenya;
Email: jngaina@gmail.com

Dr. Joyce Lepetu
Senior Lecture (Forest Sciences); Director, Centre of In Service and Continuing Education (CICE), Botswana University of Agriculture and Natural Resources (BUAN);
PB 0027; Gaborone, Botswana;
Tel: +267 3650396; +267 3650100;
Cell: (00267) 75168163 ;
Email: jlepetu@bca.bw; jlepetu@yahoo.com

Dr. Jules Bayala
Principal Scientist - Sahel Ecosystems; World Agroforestry Centre (ICRAF) ; West and Central Africa Regional Office - Sahel Node;
BP E5118, Bamako, Mali;
Tel: +223 20 70 92 20; Mobile: +223 77 71 41 90;
Email: J.Bayala@cgiar.org

Prof. Kokou Kouami
Director of the Master of Climate and Human Security, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), University of Lome, Faculté des Sciences;
BP 1515, Lomé, Domicile BP 80825 Lomé, Togo;
Tel (00) 228 90 02 04 11/
Dom. (00) 228 22 71 33 44 ;
Email: kokoukouami@hotmail.com

Prof. Kokutse Adzo Dzifa, Epse Kokou
University of Lomé; Department of Botany;
BP 80825; Lomé Togo;
Tel: 0022890865207;
Email: mimidam@hotmail.com

Dr. Kossi Adjonou
Université de Ouagadougou, Laboratoire de Biologie et Ecologie Végétales ;
03 BP 7021, Ouagadougou 03, Burkina Faso;
Tél: +226 70 23 82 61;
Email: adjima_thiombiano@yahoo.fr

Prof. Larwanou Mahamane
Senior Programme Officer and Head of Programmes Management Unit; African Forest Forum (AFF);
C/o World Agroforestry Center (ICRAF); United Nations Avenue; P.O. Box 30677–00100, Nairobi, Kenya;
Phone: +254207224624;
Email: M.larwanou@cgiar.org

Dr. Lizzie Mujuru
Senior Lecturer; Department of Environmental Science, Bindura University;
Private Bag 1020, Bindura, Zimbabwe ;
Tel/Fax: +263 271-6505, cell:+263 712 220 651/263 730 352279/+263 735302279
Email: mujuru2004@yahoo.co.uk

Dr. Louis Sawadogo
Directeur de Recherche en Biologie et Ecologie Vegetales; CNRST/INERA;
03 BP 7047, Ouagadougou 03, Burkina Faso;
Tel: 70255877; Email: sawadogo_ls@hotmail.com

Prof. Louis Zapfack
University of Yaounde 1, Faculty of Science, Department of Plant Biology;
P.O. Box 812, Yaounde, Cameroon;
Tel: +237-99-3396; Email: lzapfack@yahoo.fr

Mr. Macarthy Afolabi Oyebo
Chair, Governing Council, African Forest Forum;
No. 3 Daniel Arap Moi Close; Off Maitama Sule Street, Asokoro; Abuja, Nigeria;
Email: fola31@gmail.com

Dr. Massaoudou Moussa
Research Scientist, National Institute for Agricultural Research of Niger;
BP 240, Maradi, Niger;
Email : massaoudmoussa@yahoo.fr

Pr. Nacro H. Bismark
University Nazi Boni of Bobo Dioulasso;
Tel: 70247825;
Email: nacrohb@yahoo.fr

Prof. Paxie Chirwa
University of Pretoria; SAFCOL Forest Chair & Director, Postgraduate Forest Programme;
RM 5-15, Plant Sciences Complex; Corner of Lynwood Rd & Roper St; Hatfield 0028;
South Africa;
Tel +27(0)12 420 3213/3177;
Cell +27(0)82 852 3386;
Email: paxie.chirwa@up.ac.za
Alt Email: forestscience@up.ac.za; Extraordinary Prof of Forest Science, Stellenbosch University

Dr. Paul Donfack
Programme Officer; African Forest Forum (AFF);
C/o World Agroforestry Center (ICRAF), United Nations Avenue; P.O. Box 30677-00100, Nairobi, Kenya;
Tel: +254 020 7224485;
Email: p.donfack@cgiar.org

Dr. Ouédraogo Issaka
Lecturer; Université de Ouagadougou; Laboratoire de Biologie et Ecologie Végétales;
03 BP 7021, Ouagadougou 03, Burkina;
Email: sonrenoma@yahoo.fr

Dr. Ouédraogo Amadé
Lecturer, Université de Ouagadougou; Laboratoire de Biologie et Ecologie Végétales;
03 BP 7021, Ouagadougou 03, Burkina Faso;
Email: o_amade@yahoo.fr

Prof. Rajoelison Lalanirina Gabrielle
Head Department of Water and Forestry; School of Agronomy; University of Antananarivo;
BP 175, Antananarivo, Madagascar;
Tel. +261 32 46 060 16;
Email: g.rajoelison@yahoo.fr

Mr. Richard Banda
Principal, Zambia Forestry College; Ministry of Lands, Natural Resources and Environmental Protection
Private Bag 1, Mwekera; Kitwe, Zambia;
Tel. +260-212-252459; +260-212-251 460;
Mobile: +260-966 845 945;
Email: rbinda4@yahoo.com

Dr. Rodrigue Castro Gredomon
Head of Unit; Forest and People Livelihood Research Unit; Laboratoire de Bio-mathématiques et d'Estimations Forestières; University of Abomey-Calavi; Faculty of Agronomic Sciences;
04 P O. Box 1525, Cotonou, Benin;
Email: castro.gbedomon@fsa.uac.bj;
gbedomon@gmail.com

Dr. Shem Kuyah
Lecturer, Botany Department; Jomo Kenyatta University of Agriculture and Technology,
.O. Box 62000-00200 Nairobi, Kenya;
Mob. +254-721-590-198;
Email: kshem@jkuat.ac.ke, kuyashem@gmail.com

Dr. Salamatou I. Abdourahamane
Senior Lecturer; University of Diffa;
BP 78 Diffa, Niger;
Tel: (00227) 90316959/ 96978635;
Email: assalamat2@yahoo.com

Dr. Tajudeen Okekunle Amusa
Lecturer; University of Ilorin; Fac,. of Agriculture;
Dept.of Forest Resources Management;
P.M.B 1515, Ilorin; Kwara State, Nigeria;
Tel: 08051750289; 07033831616;
Email: amusa.to@unilorin.edu.ng; teejayui@gmail.com

Dr. Vincent Onguso Oeba
Programme Officer; African Forest Forum (AFF) ;
C/o World Agroforestry Center (ICRAF), United Nations Avenue;
P.O. Box 30677–00100; Nairobi, Kenya;
Phone: +254207224000 Ext 4048;
Email: v.oeba@cgiar.org; vongusoeba@gmail.com

Dr. Wilson Kasolo
Executive Secretary; ANAFE; c/o World Agroforestry Centre (ICRAF); P.O. Box 30677-00100, Nairobi, Kenya;
Email: W.KASOLO@cgiar.org

Prof. Winston J. Akala
Dean School of Education, College of Education and External Studies, University of Nairobi;
P.O Box 30197-00100, Nairobi, Kenya,
Tel: 066-32117/32020/29,
ΩCell: +254723432546,
Email: akala@uonbi.ac.ke; akalajumba@yahoo.com

Prof. Zac Tchoundjeu
Higher Institute of Environmental Sciences;
P.O Box 35460; Yaounde, Cameroon;
Phone: +237-677 707582;
Email: z.tchoundjeu@cgiar.org

Notes

African Forest Forum

A platform for stakeholders in African forestry

African Forest Forum
United Nations Avenue, Gigiri
P.O. Box 30677-00100
Nairobi, Kenya
Tel: +254 20 722 4203
Fax: +254 20 722 4001
Email: exec.sec@afforum.org

ISBN 978-9966-7465-3-5