African Forest Forum

A platform for stakeholders in African forestry



Forests and Climate Change Mitigation

A COMPENDIUM FOR SHORT COURSES IN AFRICAN FORESTRY

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Front cover photos: Jungle in Seychelles island. Credit: ESB Professional (left); Newlands Forest in Cape Town. Credit: Kyle O'Hagan (middle); Large tree in Kirstenbosch Gardens, Cape Town. Credit: Nick Photography (Right).

Back cover photo: Kitum cave entrance to the surrounding tropical forest of Mount Elgon National Park in Kenya. African rain forests.Tanzania (Credit: Margus Vilbas Photography).

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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 modules; in other words, it is structured based on the training modules, but updated and strengthened based on new and emerging issues in the context of forestry and climate change adaptation and mitigation, as well as case studies from various African forestry landscapes. 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. This has been through their inputs as reviewers, resource persons and participants to the validation of the draft documents. 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.

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We are also particularly grateful to the lead authors, the contributors mentioned in this compendium and the pedagogical expert.

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 in the context of changing climate.

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, as captured in African countries' Nationally Determined Contributions (NDCs). 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 affects 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 affects 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 reduction in 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 °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 °C, agriculture, forestry and land-use (AFOLU) are projected with medium confidence to remove 0-5, 1-11 and 1-5 GtCO2 yr-1 in 2030, 2050 and 2100, respectively. There are also co-benefits associated with AFOLU-related carbon dioxide removal measures such as biodiversity conservation, improved 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 (AFF) 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 updated knowledge and skills in these relatively new but highly dynamic 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 eight compendiums in a pedagogical manner, namely:

1. Basic Science of Climate Change: A Compendium for Professional Training in African Forestry 01- https://afforum.org/publication/basic-science-of-climate-change-a-compendium-for-professional-training-in-african-forestry-01/

2. Basic Science of Climate Change: A Compendium for Technical Training in African Forestry 02- https://afforum.org/publication/basic-science-of-climate-change-a-compendium-for-technical-training-in-african-forestry-02/

3. Basic Science of Climate Change: A Compendium for Short Courses in African Forestry 03- https://afforum.org/publication/basic-science-of-climate-change-a-compendium-for-short-courses-in-african-forestry/

4. Carbon Markets and Trade: A Compendium for Professional Training In African Forestry 04- https://afforum.org/publication/carbon-markets-and-trade-a-compendium-for-professional-training-in-african-forestry/

5. Carbon Markets and Trade: A Compendium for Technical Training in African Forestry 05- https://afforum.org/publication/carbon-markets-and-trade-a-compendium-for-technical-training-in-african-forestry/

6. Carbon Markets and Trade: A Compendium for Short Courses in African Forestry 06- https://afforum.org/publication/carbon-markets-and-trade-a-compendium-for-short-courses-in-african-forestry/
7. Climate Modelling and Scenario Development: A Compendium for Professional Training in African Forestry 07- https://afforum.org/publication/climate-modelling-and-scenario-development-a-compendium-for-professional-training-in-african-forestry-07/
8. International Dialogues, Processes and Mechanisms on Climate Change: A Compendium for Professional and Technical Training in African Forestry 08- https://afforum.org/publication/international-dialogues-processes-and-mechanisms-on-climate-change-a-compendium-for-professional-and-technical-training-in-african-forestry-08/

From 2019 to 2022, AFF mobilized 75 African forestry stakeholders to continue the development of the compendiums including updating, strengthening and contextualizing them with case studies, new and emerging issues in forestry and climate change in order to produce six new compendiums as follows:

1. Forests and climate change adaptation: a compendium for professional training in African forestry
2. Forests and climate change adaptation: a compendium for technical training in African forestry
3. Forests and climate change adaptation: a compendium for short course in African forestry
4. Forests and climate change mitigation: a compendium for professional training in African forestry
5. Forests and climate change mitigation: a compendium for technical training in African forestry
6. Forests and climate change mitigation: a compendium for short course in African forestry

These compendiums are being translated into French for the benefit of the Francophone African forestry stakeholders.

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: Burkina Faso (35), Côte d’Ivoire (31), Ethiopia (35), Guinea Conakry (40), Kenya (54), Liberia (39), Madagascar (42), Niger (34), Nigeria (52), Sierra Leone (35), Sudan (34), Swaziland (30), Tanzania (29), Togo (33), Zambia (21) and Zimbabwe (30). 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: Angola, Benin, Burkina Faso, Cameroon, Chad, Côte d’Ivoire, Democratic Republic of Congo, Ethiopia, Kenya, Gabon, Gambia, Ghana, Guinea Conakry, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Republic of Congo, Senegal, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

In 2021 and 2022, the validated training compendiums on “Forests and climate change mitigation: a compendium for short courses in African forestry” and on “Forests and climate change adaptation: a compendium for short course in African forestry” were used to train 165 African forestry stakeholders from forestry administrations, private sectors, civil society and community based organizations from 29 African countries including 10 from Francophone (Algeria, Benin, Burkina Faso, Chad, Mali, Mauritania, Niger, Tunisia, Togo and Senegal); 15 from Anglophone (Botswana, Egypt, Ethiopia, Kenya, Gambia, Lesotho, Liberia, Malawi, Namibia, Nigeria, Rwanda, Uganda, Tanzania, Zambia, Zimbabwe) and 2 from Lusophone Africa (Angola and Mozambique).

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. In the same vein, an evaluation done at the end of the training workshops using the compendiums for short courses indicate that the skills gained, and experiences shared were relevant to improve the capacity of trainees in developing and implementing activities, projects, programmes and policies related to forest and tree-based mitigation and adaptation in their national contexts.

These compendiums and training workshops were largely financed by the Swiss Agency for Development and Cooperation (SDC) and with some contribution from the Swedish International Development Cooperation Agency (Sida). 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
Président du Conseil d'administration du AFF

Godwin Kowero
Secrétaire exécutif du AFF

Abbreviations and Acronyms

AFF	African Forest Forum
AFOLU	Agriculture, Forestry and Other Land Use
A/R	Afforestation and Reforestation
AGC	Aboveground Carbon
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions (temporary tCER; long term lCER)
CFCs	Chlorofluorocarbons
CH4	Methane
CO2	Carbon dioxide
CO2-eq	Carbon dioxide equivalent
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GMST	Global Mean Surface Temperature
Gt	Gigaton
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
NTFPs	Non-Timber Forest Products
OECD	Organization for Economic Cooperation and Development
PES	Payments for Ecosystem Services
REDD+	Reducing Emissions from Deforestation and forest Degradation and forest conservation in developing countries
REL	Reference Emission Level
SAV	Savannah
SDG	Sustainable Development Goals
SDM	Sustainable Development Mechanism
SFM	Sustainable Forest Management
UNFCCC	United Nations Framework Convention on Climate Change
VER	Verified Emission Reduction

Executive Summary

The role of forests in fighting climate change has been acknowledged worldwide. Climate change mitigation interventions, and in particular, measures to ensure Carbon sequestration are aimed at improving the Carbon storage capacity of forest ecosystems, whereas conservation activities provide ways of reducing forest Carbon emissions. These interventions are highlighted in articles 5.1 and 5.2 of the Paris Agreement (www.unfccc.int/sites/default/files/english_paris_agreement.pdf).

Forests and trees outside forests provide huge opportunities for African countries to respond to their post-2020 climate change mitigation commitments. However, the contribution of forests and/or trees to the mitigation measures will depend on how these critical resources are incorporated into policies, strategies, programmes and projects. Success of the interventions could further depend on how stakeholders that are involved in the climate change response policy processes are informed on the potential, challenges and opportunities of forest-based climate change mitigation policies, strategies, and actions. Consequently, it is important to provide some basic information to enable relevant stakeholders to appreciate the role of forestry and forests in climate change mitigation approaches.

In line with this, the African Forest Forum (AFF) developed the "African Forests, People and Climate Change Project". The project is in its third phase of implementation and aims at addressing the effects of climate change in various landscapes in ways that will improve livelihoods, sustain biodiversity and secure quality environment. The project was also designed to strengthen the capacity of Africa's forests to adapt to climate change and contribute to mitigation efforts. In conceptualizing this project, the AFF recognizes the need for building and operationalizing human capacities to address various issues related to climate change and improve the quality of knowledge transfer. Indeed, civil society organizations (CSOs), extension agents and local communities who are part of the stakeholders in the implementation of mitigation activities implicit in many climate change strategies, need to be appropriately equipped with relevant information/capacities. In addition, CSOs and extension agents are more likely to widely disseminate relevant research results to local communities, who in the most of cases, are and will be affected by the adverse effects of climate change. It is, therefore, crucial that all levels of society are aware of the various mechanisms to employ in order to improve their livelihoods while simultaneously solving their environmental problems.

In this regard, training and updating knowledge of professional, technical, extension and CSO staff in forestry and emerging disciplines such as climate change would require appropriate knowledge and relevant skills. As part of the efforts to undertake this capacity building work, the AFF conducted during the first phase of the project, a needs assessment that involved all key stakeholders dealing with forestry and emerging issues like climate change. Based on the identified needs, the AFF developed four training modules in the form of short courses for extension agents, CSOs and non-governmental organizations in Sub-Saharan African countries. The modules were developed on thematic areas such as basic science of climate change, forests and climate change adaptation, forests and climate change mitigation, and Carbon markets and trade. AFF has continued the distribution and sharing of its training modules on the broad aspects of forestry and emerging environmental challenges in the African continent where their current uptake is very promising. However, to improve the delivery of the information contained in the modules for relevant education and training institutions, there was a need to develop in a pedagogical manner, the content for each module. This thus resulted in the development of this compendium of short courses on African forests and climate change mitigation.

The compendium is structured into the following four chapters:

Chapter 1: Definitions and concepts of mitigation of climate change. This chapter covers the definition of mitigation in the context of climate change, the concept of Carbon sequestration, the understanding of mitigation options for climate change, sources and sinks of the greenhouse gas (GHG), the linkages between mitigation and adaptation, and the actions, options and approaches to mitigate climate change.

Chapter 2: Forest-based mitigation options. This chapter provides detailed information reduction of forest Carbon emissions, role of forest and tree resources in climate change mitigation, and managing forests for climate change mitigation. In this chapter, we also cover the regulatory frameworks and policies on climate change mitigation, climate change mitigation strategies in forestry, enabling interventions and other benefits, Carbon benefits and non-Carbon benefits.

Chapter 3: Forest-based mitigation initiatives and other approaches. This chapter focuses on the clean development mechanism (CDM), the reducing emissions from deforestation and forest degradation (REDD+) initiatives and the nationally determined contributions (NDCs).

Chapter 4: Non-forest-based climate change mitigation initiatives and other approaches. The focus here is on mitigation measures in sectors other than forest, alternative livelihoods as climate change mitigation measures, and resource substitution and efficiency as a mitigation measure.

The content developed in each of these four chapters is expected to enable learners to acquire adequate knowledge on the contribution of the forestry sector to climate change mitigation, and the opportunities for supporting the implementation of forest-based mitigation policies, initiatives and actions. Specifically, at the end of this compendium, learners/trainees should be able to:

i. Explain the basics of climate change mitigation;
ii. Explain the linkages between climate change mitigation and other related concepts such as climate change adaptation and sustainable development;
iii. Appreciate climate change mitigation measures across different sectors;
iv. Explain the basics of forest-based mitigation including practices, strategies, measures and enabling conditions;
v. Assess existing international forest-based mitigation initiatives and their implications for Africa; and
vi. Explain climate change mitigation strategies in sectors other than forestry.

Compendium Overview

Change in climate over the past 130 years are unprecedented in the recent history. Over this period, global surface temperature has risen by 1.2°C. Rising temperatures are causing a loss of sea ice and ice sheet mass, sea level rise, longer and more intense heat waves, and shifts in plant and animal habitats. Understanding such long-term climate trends is essential for the safety and quality of human life, allowing humans to adapt to the changing environment in ways such as planting different crops, managing our water resources and preparing for extreme weather events. Climate change has put socio-ecological systems at risk; while in return, the interactions between social and ecological systems are responsible for the changing climate (IPCC, 2007a). Regions, countries, sectors, and ecosystems contribute differently to climate change, caused principally by GHG emissions. In the meantime, these individuals, groups, countries and ecosystems are also affected differently (IPCC, 2007a). Globally, research and policy efforts are ongoing to provide response to the threats of climate change through mitigation and adaptation.

The management of natural resources through land use, land use change and forestry activities is responsible for about 15-25 % of total anthropogenic GHG emissions (Vermeulen et al., 2012). The increase in the GHG emissions, in particular, through Carbon dioxide (CO2) emission from industries and deforestation in the forests, and the capacity of the forest ecosystems to act as Carbon sinks, have led to the increased recognition of the dual role forests played in global warning and its mitigation. The contribution of tropical forests to climate change mitigation is being enhanced through the decision to adopt the approach on reduction of emissions from deforestation and forest degradation and forest conservation in developing countries (REDD+) at Conference of Parties (COP)19 and COP21. For COP19 (Warsaw framework on REDD+), seven methodological decisions were taken: performance-based payment, coordination of support, measurement, reporting and verification (MRV), national forest monitoring system (NFMS), drivers of deforestation, safeguards, and forest reference level (FRL). Similarly, in Paris at COP21, three additional decisions on REDD+, were made: safeguards, non-market-based approach and non-Carbon benefits) of the United Nations Framework Convention on Climate Change (UNFCCC)-(UNFCCC, 2015). REDD+ includes policy approaches and positive incentives on activities that contribute to reduce emissions from deforestation and forest degradation in developing countries. It also recognizes the contribution of conservation, sustainable management of forests and enhancement of forest Carbon stocks. However, the different approaches proposed at the international level need to be translated into policies, strategies, actions (programmes and projects) at the national level.

Forests and trees outside forests provide huge opportunities for African countries to respond to their post-2020 climate change mitigation commitments. However, the contribution of forests and tree resources to mitigation will depend on how they are incorporated into policies, strategies, programmes and projects, and the financial resources allocated to these interventions. This could depend on how stakeholders involved in the climate change response policy processes are informed on the potentials, challenges and opportunities of forest-based climate change mitigation policies, strategies and actions. It is therefore important to provide basic information to enable relevant stakeholders appreciate the roles of the forestry sector in climate change mitigation.

This compendium focuses on the contribution of forests to climate change mitigation and the implementation of forest mitigation policies, initiatives and actions. It has four chapters covering; the definition of climate change mitigation in general and related concepts; forest-based mitigation concepts, strategies and practices; the basic of existing international mitigation initiatives and opportunities such as the CDMs/SDMs, REDD+, NDCs as well as non-forest-based mitigation strategies.

Target groups

This compendium is targeting learners from diverse backgrounds and disciplines, interested (i) in climate change policy making processes at local, national and international levels; and (ii) in enhancing their awareness or knowledge on curbing climate change impact in order to participate in global warming debates, advocacy and lobbying. In short, learners can come from CSOs, private sector, policymaking domain and communities.

Objectives and expected outcomes

The aim of this compendium is to enable learners acquire knowledge on the contribution of forest and tree resources to climate change mitigation and the opportunities for supporting the implementation of forest-based mitigation policies, initiatives, programmes, projects and actions.

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

i. Explain the basics of climate change mitigation;
ii. Explain the links between climate change mitigation and other related concepts such as adaptation and sustainable development;
iii. Appreciate climate change mitigation measures across relevant sectors;
iv. Explain the basics of forest-based mitigation including practices, strategies measures, enabling conditions;
v. Assess existing forest-based mitigation initiatives at the international level and their implications for Africa; and
vi. Explain non-forest climate change mitigation strategies.

Chapter 1. Climate Change Mitigation: Definitions and Concepts

1.1 Chapter overview

This chapter introduces the notion of climate change mitigation, its relationship with other concepts such as adaptation, mitigative capacity, sustainable development, mitigation actions, and options at national, regional and international levels.

1.2 Objectives and learning outcomes

The objectives of this chapter are to provide learners with an understanding of the concept of climate change mitigation, in order to facilitate their participation in national, regional, international debates and processes related to the design and implementation of climate change mitigation policies, actions and interventions.

Specifically, the chapter will:

- Define climate change mitigation, key science, policy and action concepts;
- Present the justification for climate change mitigation in terms of causes and implications;
- Link climate change mitigation to other related concepts such as adaptation, and sustainable development; and
- Present climate change mitigation actions and options across different sectors at the national level.

Learning outcomes
By the end of this chapter, the learner should be able to:

(i) Explain climate change mitigation;

(ii) Link the concept of climate change mitigation to other climate change related concepts such as adaptation, and sustainable development; and

(iii) Analyze and explain climate change mitigation aspects in the context of national level climate change response policies, strategies and actions.

1.3. Overview of forestry in Sub-Saharan Africa and link with climate change

There is a high dependence of the people in Africa on forests, mainly for wood, timber and other goods as well as for numerous services, in addition to the provision of water storage and improving the climate, Carbon sequestration and provision of Oxygen. Forests are important for food security, household wellbeing and income generation, cultural and spiritual importance. Central Africa has the second largest block of tropical rainforest in the world, with more than 40 % of the land areas being forested. Table 1 shows the forest area of Africa by regions.

Table 1: Forest area (naturally regenerating and planted) and equivalent living biomass carbon from 2000 to 2019 (source: FAO, 2020)

African region	2000			2019		
	Natural ('000 ha)	Planted ('000 ha)	C-stock in living biomass (million tons)	Natural ('000 ha)	Planted ('000 ha)	C- stock in living biomass (million tons)
Eastern	209,170.25	2,216.69	10,744.23	195,112.47	3,469.21	9,624.39
Central	319,780.21	1,249.83	35,710.81	288,416.60	1,166.72	32,616.35
West	95,280.83	703.28	5,780.93	83,237.78	1,674.49	4,965.55
South	40,670.23	3,295.44	2,880.76	36,443.99	3,256.28	2,585.63
North	36,226.46	1,455.61	946.48	26,101.05	1,729.98	862.45

Activity 1 Brainstorming (15 Minutes)

- Share your views on the concepts and terms used in climate change mitigation.

1.4 Origin and meaning of mitigation in the context of climate change

The Parties to the United Nations Framework Convention on Climate Change (UNFCCC) put forward climate change mitigation and adaptation as major pathways to address climate change in order to achieve the objective stipulated in article 2 of the UNFCCC. While climate change mitigation is meant to tackle the full range of anthropogenic activities to reduce sources or enhance the sinks of greenhouse gases (GHGs), climate change adaptation intends to help manage the adverse effects caused by climate change (Figure 1). The Intergovernmental Panel on Climate Change (IPCC) defines climate change mitigation as any human intervention to enhance the sinks and to reduce the sources of GHGs (IPCC, 2007a).

Mitigation is a response to the disruption in the earth's system, either due to anthropogenic GHG emissions or due to natural hazards. Actions that reduce net GHGs, decrease the projected magnitude and rate of climate change and thereby lessening the pressure of climate change on natural and human systems. Therefore, mitigation actions are expected to delay and reduce adverse effects of climate change, while providing environmental and socio-economic benefits (Ravindranath, 2007).

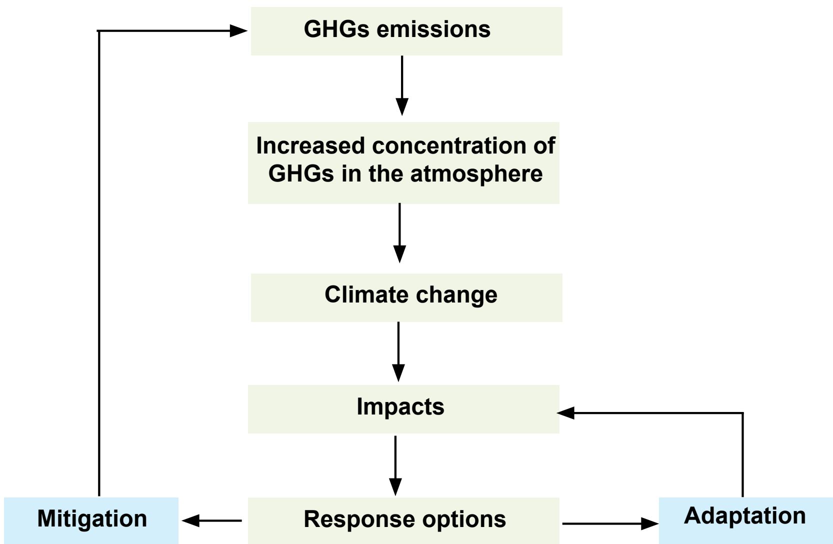

Figure 1: The context of climate change mitigation and adaptation

1.5 Definitions of some concepts used in the context of climate mitigation

The science, policy and practice in the context of climate change mitigation involve the use of many concepts. Some of the concepts that learners will come across are defined in the following subsections.

1.5.1 Additionality

Many definitions of additionality exist, including sub-concepts (Gillenwater, 2012; McFarland, 2011). In a broad sense, "Additionality" is the property of an activity being additional in this case, a mitigation activity. A proposed activity is additional if the recognized policy interventions are deemed to be causing the activity to take place. The occurrence of additionality is determined by assessing whether a proposed activity is distinct from its baseline (Gillenwater, 2012). Additionality is one of the key technical elements that must be addressed in the cycle of a mitigation project, for example, a Carbon offset project. Additionality is a condition that a Carbon reduction project must meet, to ensure the project would not have been implemented without the revenue of the Carbon markets. This condition of additionality must be satisfied if a project is being submitted to the voluntary Carbon markets—for which, voluntary buyers want to be assured that their donations actually matter for the project—or to the compliance markets since buyers need to be confident that regulators will accept their Carbon reduction purchase (McFarland, 2011).

1.5.2 Annex I, Annex II, and Non-Annex I countries

These are the categories of countries according to commitments made in the efforts to tackle climate change through the UNFCCC:

I. Annex I countries (Parties) include the industrialized countries that are members of the Organisation for Economic Co-operation and Development (OECD) in 1992, plus nations with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States (UNFCCC, 2020);

II. Annex II Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to the adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries (UNFCCC, 2020); and

III. Non-Annex I Parties are mostly developing countries, some of which being recognized by the Convention as being especially vulnerable to the adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on income from fossil fuel production and commerce), feel more vulnerable to the potential economic impacts of climate change response measures. The Convention emphasizes activities that promise to answer the special needs and concerns of these vulnerable countries, such as investment, insurance and technology transfer (UNFCCC, 2020).

1.5.3 Anthropogenic activities/ emissions/removals

The term "anthropogenic" designates an effect or object resulting from human activity. Carbon dioxide (CO2), Methane (CH4) and other gases, precursors of GHGs and aerosols, are emitted to the atmosphere by human activities such as burning of fossil fuels, deforestation, habitat degradation, land relocation and land-use changes, livestock production, fertilization, waste management and industrial processes. Anthropogenic removals refer to the extraction of GHGs from the atmosphere as a result of deliberate human activities. These include enhancing biological sinks of CO2 and using chemical engineering to achieve long-term removal and storage (IPCC, 2018).

1.5.4 Carbon

Carbon is an element that is essential to all life on earth. Carbon makes up the fats and carbohydrates in our foods and is part of molecules such as Deoxyribonucleic Acid and protein. Carbon, in the form of CO2, is a part of the air we breathe. It is also stored in places like the ocean, rocks, fossil fuels, and plants. Like Hydrogen or Nitrogen, Carbon is a chemical element and a basic building block of biomolecules. It exists on earth in solid, dissolved and gaseous forms. For example, Carbon is in graphite and diamond, but can also combine with oxygen molecules to form gaseous CO2.

CO2 is a naturally occurring gas, and also a by-product of burning fossil fuels (such as oil, gas and coal) and biomass, land-use changes and industrial processes (e.g., cement production). It is the principal anthropogenic GHG that affects the earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a global warming potential (GWP) of 1 (IPCC, 2018).

1.5.5 Carbon dioxide equivalent

Carbon dioxide equivalent (CO2-eq) is the amount of CO2 emission that would cause the same integrated radiative force or temperature change, over a given time horizon, as an emitted amount of a GHG or a mixture of GHGs. There are different ways to compute such equivalent emissions and choose appropriate time horizons. For example, the CO2-eq emission is obtained by multiplying the emission of a GHG by its GWP for a 100-year time horizon. For a mix of GHGs, it is obtained by summing the CO2-eq emissions of each gas. CO2-eq emission is a common scale for comparing emissions of different GHGs but does not imply equivalence of the corresponding climate change responses (IPCC, 2018).

1.5.6 Carbon cycle

This is a term used to describe the flow of Carbon (in various forms, e.g., as CO2, Carbon in biomass, and Carbon dissolved in the ocean as Carbonate and Bicarbonate) through the atmosphere, hydrosphere, terrestrial and marine biosphere and lithosphere (IPCC, 2018). It describes how Carbon transfers between different reservoirs on earth. Carbon cycle is an important aspect of the survival of all life on earth.

1.5.7 Carbon footprint

Carbon footprint is the amount of CO2 emissions associated with all the activities of a person or other entity (e.g., building, corporation, country, etc.). It includes direct emissions, such as those that result from fossil-fuel combustion in manufacturing, heating, and transportation, as well as emissions caused when producing the electricity associated with goods and services consumed. In addition, the Carbon footprint concept often includes the emissions of other GHGs, such as CH4, Nitrous oxide (N20), or chlorofluorocarbons (CFCs) (Selin, 2020).

Carbon footprints are different from a country's reported per capita emissions, i.e., those reported under the UNFCCC. Rather than GHG emissions associated with production, Carbon footprints focus on the GHG emissions associated with consumption. They include the emissions associated with goods that are imported into a country but are produced elsewhere and generally take into account emissions associated with international transport and shipping, which is not accounted for in standard national inventories. As a result, a country's Carbon footprint can increase even as Carbon emissions within its borders decrease (Selin, 2020).

1.5.8 Carbon sequestration

Carbon sequestration is the capture and secure storage of Carbon that would otherwise have been emitted into, or remain, in the atmosphere. In other words, it is a biochemical process by which atmospheric Carbon is absorbed by living organisms, including trees, soil micro-organisms, and crops, and involving the storage of Carbon in soils, with the potential to reduce atmospheric CO2 levels (IPCC, 2018). Through Carbon sequestration, atmospheric CO2 are bound in biomass and thus become unavailable for emission. Consequently, the amount of CO2 in the atmosphere and global climate change are reduced.

1.5.9 Carbon pool and Carbon sink

Carbon pool is a reservoir or a system that has the capacity to accumulate or release carbon (Alexandrov, 2008). Carbon sink is a process or mechanism that removes CO2 from the atmosphere. An entity that removes and stores substantial quantities of CO2 from the atmosphere. In climate negotiations, this temporary reduction of CO2 in the atmosphere is also known as negative emissions. A given Carbon pool can be a sink, during a given time interval, if Carbon inflow exceeds Carbon outflow (Alexandrov, 2008). The main natural Carbon sinks include the soil, plants, and ocean.

1.5.10 Carbon source

Carbon source is a process or mechanism that releases CO2 to the atmosphere. A given Carbon pool can be a source, during a given time interval, if Carbon outflow exceeds Carbon inflow. It is the opposite of a Carbon sink (Alexandrov, 2008).

1.5.11 Carbon stock

It is the quantity of Carbon contained in a “pool”. Carbon is stored in five different pools: (i) aboveground biomass; (ii) belowground biomass; (iii) litter; (iv) deadwood/woody debris; and (v) soil (Murdiyarso et al., 2017).

1.5.12 Clean development mechanism

Clean development mechanism (CDM) is a mechanism under the Kyoto Protocol designed to help developed countries (Annex I countries) meet their emissions reduction targets. It is an arrangement by which Annex I countries finance and implement projects that reduce emissions in developing countries (Non-Annex I countries) through credits that can be used to fulfill their own emissions reduction targets. CDM was adopted at the COP3 to UNFCCC in 1997 to enable developed countries carry out afforestation and reforestation (A/R) projects in developing countries in order to tackle global warming (JICA and ITTO, 2010). CDM aims not only to reduce emissions or increase sinks, but also to contribute to sustainable development in developing countries (Angelsen, 2008).

1.5.13 Certified emission reduction

Certified emission reduction (CER) is a technical term for the output of CDM projects. A CER is a unit of GHG reductions that has been generated and certified under the provisions of Article 12 of the Kyoto Protocol for projects. One CER equals one ton of Carbon. Two special types of CERs can be issued for net emission removals by A/R CDM projects: (i) temporary certified emission reduction (tCERs); and (ii) long-term emission reduction (lCERs) (Angelsen, 2008).

1.5.14 Climate feedback

Climate feedback is an interaction in which a perturbation in one climate quantity causes a change in a second and the change in the second quantity ultimately leads to an additional change in the first. A negative feedback is the one whereby the initial perturbation is weakened by the changes it has caused; a positive feedback is the one by which the initial perturbation is enhanced. The initial perturbation either can be externally forced or may arise as part of internal variability (IPCC, 2018).

1.5.15 Climate forcing

The climate system includes the hydrosphere, land surface, the cryosphere, the biosphere, and atmosphere. Climate forcing is the physical process of affecting the climate on the earth through a number of forcing factors. These factors are specifically known as forcings because they drive the climate to change. Climate forcing can be positive or negative. Positive climate forcing results into positive radiative forcing, hence resulting into a general increase in global temperatures. Negative climate forcing results into a decrease in global temperatures. It is important to note that these forcing exist outside the existing climate system. Climate forcing that arises from within the earth's climate system is termed internal climate forcing while the one arising outside of the climate system is termed external forcing.

Examples of some of the most important types of forcing include: variations in solar radiation levels, volcanic eruptions, changing albedo, and changing levels of GHGs in the atmosphere. Each of these is considered external forcing because these events change independently of the climate, perhaps as a result of changes in solar activity or human-caused fossil fuel combustion (Colose et al., 2020).

1.5.16 Climate model

A climate model is a numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties. The climate system can be represented by models of varying complexities; that is, for any one component or combination of components, a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrizations are involved. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as research tools to study and simulate the climate and for operational purposes, including monthly, seasonal and interannual climate predictions (IPCC, 2018).

1.5.17 Climate projection

A climate projection is the simulated response of the climate system on the basis of a scenario of future emission or concentration of GHGs and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized (IPCC, 2018).

1.5.18 Climate scenario

A climate scenario is a plausible and often simplified representation of future climate, based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. Climate scenarios are used as a tool to assess the relationship between climate change and the event, and to identify the impact thresholds to be analyzed for risk. If climate scenarios are available and reliable (i.e. they depict plausible future climate), they are always beneficial for picturing future climate and understanding its impacts. They are also useful, and probably more important, for testing the robustness of adaptation response or policies, despite their uncertainties (IPCC, 2007b).

1.5.19 Climate variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC, 2018).

1.5.20 Global warming

Global warming, which is an aspect of climate change, is the estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or the 30-year period centered on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year period that span past and future years, the current multi-decadal warming trend is assumed to continue (IPCC, 2018). Global warming occurs when CO_2 and other air pollutants collect in the atmosphere and absorb sunlight and solar radiation that have bounced off the earth's surface. The radiation would normally escape into space but the pollutants trap the heat and cause the planet to get hotter.

1.5.21 Global warming potential

GWP is the heat absorbed by any GHG in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of CO_2. GWP is 1 for CO_2. For other gases, it depends on the gas and the time frame (IPCC, 2018).

1.5.22 Greenhouse gases

GHGs are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour, CO_2, N_2O, CH_4 and Ozone are the primary GHGs in the earth's atmosphere. In addition, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride, hydrofluorocarbons (HFCs) and perfluorocarbons (IPCC, 2018).

1.5.23 Greenhouse gas effect

GHG effect is a process whereby much of the thermal radiation emitted by the land and ocean is absorbed by a cloud formed by the GHGs in the atmosphere, which instead of continuing to the atmosphere is reradiated to the earth. The glass walls in a greenhouse reduce airflow and increase the temperature of the air inside. In a nutshell, the GHGs let sunshine to enter the atmosphere but slow the loss of heat from the earth's surface (Omowole, 2008). Similarly, but through a different physical process, the earth greenhouse effect warms the surface of the planet. Without the natural greenhouse effect, the average temperature on the earth's surface would be below the freezing point of water. Thus, earth's natural greenhouse effect makes life possible as we know it. However, human activities, primarily the burning of fossil fuels and clearing of forests, have greatly intensified the natural greenhouse effect, thereby causing global warming (IPCC, 2007b).

1.5.24 Leakage

In the context of climate change, Carbon leakage is the result of interventions to reduce emissions in one geographical area (subnational or national) that lead to an increase in emissions in another geographical area. For example, if curbing the encroachment of agriculture into forests in one region, results in conversion of forests to agriculture in another region, it will be considered a 'leakage'. A forest agency may set aside part of its forests for Carbon sequestration such that it would impose limits on the size and location of harvested area, the resulting loss of harvest volume, which it may seek to compensate for by increasing harvest levels in other part of its forests (Bettinger et al., 2009). In the context of REDD, leakage is also referred to as 'emissions displacement' (Angelsen, 2008).

1.5.25 Mitigation potential

The concept of "mitigation potential" has been developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of Carbon price (expressed in cost per unit of CO_2 equivalent emissions avoided or reduced (IPCC, 2007c).

1.5.26 Permanence

Permanence is defined as the duration and non-reversibility of a reduction in GHG emissions. Bettinger et al. (2009) defined permanence as a Carbon emission reduction scheme that is implicitly assumed to be permanent. They added that naturally forests do not sequester Carbon forever because no matter how long trees live eventually they will die and the Carbon absorbed will be released. However, in the context of GHG reduction mechanisms, the temporary storage of Carbon by trees is considered "permanent" since it provides more time for scientists/decision makers to develop alternative options. Non-permanence can be seen as a form of intertemporal leakage (Angelsen, 2008).

1.5.27 Reduction of emissions from deforestation and forest degradation

Reduction of emissions from deforestation and forest degradation (REDD+) refers to the effort to create financial value for the Carbon stored in forests, offering incentives to developing countries to reduce emissions from forested lands and invest in low-Carbon technologies that are veritable paths towards sustainable development. It is, therefore, a mechanism for mitigation that results from avoiding deforestation. REDD+ goes beyond deforestation and forest degradation as it includes the role of conservation, sustainable management of forests and enhancement of forest Carbon stocks. The concept was first introduced in 2005 during the 11th Session of the Conference of the Parties (COP11) in Montreal as "REDD". It was later given greater recognition at the COP13 in 2007 at Bali and included in the Bali Action Plan. At the COP 15 in Copenhagen in 2009 "plus (+)" was added to the "REDD" after a detailed study of the programme and REDD-plus became one of the important achievements of the Copenhagen Accord (JICA and ITTO, 2010). Thereafter REDD+ has been all about 'policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation and forest conservation in developing countries, in the framework of sustainable forest management (SFM) and enhancement of forest Carbon stock in developing countries (IPCC, 2018).

1.5.28 Voluntary or verified emission reduction

Verified emission reductions (VERs) are essentially reductions in GHG emissions (GHGs) from a project that is independently audited (i.e., verified) against a third-party certification standard. Each VER represents one metric ton of CO_2 equivalent emissions (mtCO_2-eq).

1.6 Sources of greenhouse gases and their implications

1.6.1 Sources of greenhouse gases and sinks

i. Anthropogenic sources: Anthropogenic or human-made components of the greenhouse effect caused by human activities that emit GHGs into the atmosphere. Prominent among of these activities is the burning of fossil fuels. Fossil fuels contain Carbon, and when they are burnt, the Carbon combines with Oxygen in the atmosphere to form CO2. Land based activities such as forestry, agriculture (both crop cultivation and livestock production, and changes in land use and/or land cover are also important sources of GHG emissions. For example, deforestation results in the emission to the atmosphere of CO2 that was previously stored on the earth's surface in the form of biomass in trees and other vegetation, or locked up in soils. Livestock production especially of ruminants results into production of CH4. Other man-made sources of GHG emissions include industrialization, transportation etc. For example, it was indicated that the amount of CO2 emitted by the cement industry during cement manufacturing is more than 900 kg of CO2 for every 1000 kg of cement produced (Boden et al., 2009).

ii. Natural sources: These are sources of GHG that are linked to the functioning of natural systems. They include (i) natural fires in forest/savanna, caused by drought, heat; (ii) emissions from oceans; (iii) wetlands, as a result of changes in temperature and hydrological conditions; (iv) permafrost; and (v) volcanic eruptions and earthquakes (Xi-Liu and Qing-Xian, 2018).

1.6.2 Types of greenhouse gases and their sources

The increase in global temperatures is mainly due to the increase of the greenhouse effect. The greenhouse effect is a natural phenomenon and is essential for life on earth. Without the greenhouse effect, the temperature on earth surface would be below the freezing point of water and life may not be possible. The greenhouse effect is caused by gases that absorb the reflected energy from the earth. These gases are known as GHGs.

The GHGs that human activities emit directly in significant quantities are (IPCC, 2007c):

i. **CO2**: It accounts for up to one-third of the total anthropogenic GHG emissions and three-quarters of the warming impact of current human GHG emissions. Key sources of CO2 include burning of fossil fuels (such as coal, oil and gas), deforestation (especially in the tropics) and land use change;

ii. **CH4:** It accounts for about 14% of the impact of current human GHG emissions. Key sources include agriculture (especially enteric fermentation from ruminants such as cattle, goats and sheep livestock and paddy rice fields), fossil fuel extraction and the decay of organic waste in landfill sites. Many of the newer style fully vented septic systems that enhance and target the fermentation process are also sources of atmospheric CH4;

iii. **N2O:** It accounts for about 8% of the warming impact of current human GHG emissions. Key sources include burning of fossil fuels, agriculture (especially Nitrogen-fertilized soils and livestock waste) and industrial processes; and

iv. **Fluorinated gases ("F gases")**: These account for about 1% of the warming impact of current human GHG emissions. Key sources are the use of CFCs in refrigeration systems, and use of CFCs and halons in fire suppression systems and manufacturing processes.

1.6.3. Drivers of greenhouse gas emissions

The drivers of GHGs are the elements that directly or indirectly contribute to their emissions. While there is no consensus in the literature on the drivers of GHGs emissions, some researchers distinguish between proximate and underlying or ultimate drivers. The proximate drivers are generally the activities that are directly or closely related to the generation of GHGs while the underlying or ultimate drivers are those activities that motivate the proximate drivers (Blanco et al., 2014). Globally, economic and human population growth continue to be the most important drivers of increases in CO2 emissions from fossil fuel combustion. The contribution of population growth between 2000 and 2010 remained roughly identical to the previous three decades, while the contribution of economic growth has increased sharply (IPCC, 2014a).

These drivers of GHG emissions are interlinked, and can be further divided into various subcomponents. For example, emissions from transportation can be linked to an increase in international trade and economic activities, as a result of increased populations and motor-vehicle usage, thereby resulting in increased fossil fuel consumption (Blanco et al., 2014). Another example can be the increase in income in developing countries and those in transition which drive up levels of meat consumption. Increased production of meat is associated with increase in levels of CH4 from enteric fermentation as well as clearing of forests to create pasture.

1.6.4 Implications of greenhouse gases

GHGs cause a change in global temperature through positive radiative forcing. Radiative forcing is the net change in the energy balance of the earth system due to some imposed perturbation. It is usually expressed in watts per square meter averaged over a particular period of time and quantifies the energy imbalance that occurs when the imposed change takes place. According to the IPCC, there is high confidence that the rise the levels of GHGs in the atmosphere is the major drivers of global warming since the 1970s. Global warming is interfering with the functioning of biophysical, economic, social and health systems. From a biophysical perspective, ecology, agriculture and related systems are experiencing alterations, for example, the length of the growing season in large parts of the planet. Similarly, changes in temperatures and seasons are influencing the proliferation of insects, invasive weeds and diseases that can affect crops. The same is happening with livestock, where climatic changes are directly affecting important species in multiple ways: reproduction, metabolism, diseases etc. (Kilroy, 2015). Consequently, the economies of African countries will suffer most because of their high dependency on climate sensitive sectors for growth and economic development (Simbanegavi and Arndt, 2014). Up to 4% losses in Africa's gross domestic product (GDP) are projected, and agriculture is a major economic impact channel given the high share of Africa's GDP accounted for by rain-fed agriculture (Simbanegavi and Arndt, 2014). Human health is also being affected in Africa, Sub-Sahara Africa, as a result of food shortages and malnutrition (Jankowska et al., 2012), emergence and spread of diseases such as malaria, cholera etc., (McMichael, 2013). Furthermore, the deterioration of environmental conditions may facilitate the transmission of diarrhea, vector-borne and infectious diseases, cardiovascular and respiratory illnesses (Kim et al., 2014).

1.7 Trends in anthropogenic greenhouse gas emissions

Since 1750, increases in CO2 (47%) and CH4 (156%) concentrations far exceed, the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years. Total anthropogenic GHG emissions have continued to increase over the period from 1970 to 2010 with larger absolute decadal increases toward the end of this period. Annual GHG emissions increased by an average of 1.0 gigaton (Gt) CO2 equivalent (GtCO2eq) (2.2 %) per year between 2000 and 2010 compared to 0.4 GtCO2eq (1.3 %) per year from 1970 to 2000. Total anthropogenic GHG emissions in human history were the highest from 2000 to 2010 and reached 49 (±4.5) GtCO2eq/yr in 2010, with a temporary reduction in emissions in 2007 and 2008 due to the global economic crisis (IPCC, 2014a). The global GHG emissions increased by an average of 1.1% per year between 2012 to 2019, reaching 52.4 GtCO2 eq. This increase of 1.1% is a markedly lower growth rate than those seen in the first decade of the 21st is century (2.6% on average) (Olivier and Peters, 2020). The CO2 emissions from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emission increase from 1970 to 2010, with a similar percentage contribution for the period 2000 – 2010 (Blanco et al., 2014). The 2019 estimate by Olivier and Peters (2020) revealed that the share of CO2 emissions from fossil fuel combustion and industrial processes is still on the increase, with a share of 88.6% of total global emission, which amounted to about of 33.7 GtCO2. The increase was attributed to robust growth in population and economic activity.

Mitigation scenarios in which it is likely that the temperature change caused by anthropogenic GHG emissions can be kept to less than 2°C relative to pre-industrial levels, are characterized by atmospheric concentrations in 2100 of about 450 ppm CO2eq. Thus, atmospheric concentrations of above 480 ppm and above will unlikely keep temperature below 2°C relative to pre-industrial levels (IPCC, 2014a).

Without additional efforts to reduce GHG emissions, beyond those in place today, emissions growth is expected to persist, driven by growth in global population and economic activities. Baseline scenarios, those without additional mitigation, result in GMST increases in 2100 from 3.7°C to 4.8°C compared to pre-industrial levels (IPCC, 2014a).

Global surface temperature in the first two decades of the 21st century (2001-2020) was 0.99°C higher than 1850-1900. GMST was 1.09°C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59°C) than over the ocean (0.88°C). Observed warming is driven by emissions from human activities, with GHG warming partly masked by aerosol cooling.

1.8 Understanding climate change mitigation: Policy to action

Interactive questions: (5 minutes)

1) Based on your knowledge of the different activities that produce types and sources of greenhouse gases and their impacts, what policies and actions can the national governments and take to reduce their emissions?

2) Which other actors are important in the process of designing and implementing policies and actions to reduce greenhouse gas emissions or increase Carbon sequestration?

Mitigation of anthropogenic climate change can be achieved through two complementary strategies (i) reducing levels of GHG emissions released into the atmosphere; and (ii) enhancing the capacity of Carbon sinks to sequester and store Carbon. The aim of climate change mitigation is the overall reduction of GHG gases in the atmosphere. Mitigation has the goal to slow down the rise in temperature through strategies or interventions that are designed to reduce anthropogenic emissions of GHG. Mitigation may also be achieved by increasing the capacity of Carbon sinks, for example through reforestation. Because the energy sector contributes a significant amount of GHG into the atmosphere (33% of the global total), climate change mitigation has been promoted through reduced use of fossil-fuel based energy sources such as coal and petroleum. One of the most significant mitigation strategies, though, is to curb the emissions through reducing the use of fossil-fuels energy (as this is one of the main sources of CO2 emissions). Emissions can be reduced either by using less energy or by promoting alternative renewable energy sources, such as wind, photovoltaics or hydro, that produce less or no CO2 (IPCC, 2007b).

In each major industrial sector (energy supply, transportation, buildings, industry, agriculture, forestry, waste, etc.), specific mitigation options are available. In order to achieve these, policy measures for technology implementation have been identified by the IPCC (2007b). These are listed below:

i. Integrating climate policies in broader development policies;
ii. Regulations and standards;
iii. Taxes and charges;
iv. Tradable permits;
v. Financial incentives (subsidies and tax credits);
vi. Voluntary agreements;
vii. Information instruments; and
viii. Research, development and demonstration.

For example, in the energy supply sector, the reduction of fossil fuel subsidies, taxes or Carbon charges on fossil fuels (= policies) would lead to switching from the use of coal to gas (= mitigation technology). An alternative measure would be to increase access to renewable energy sources through reduction or removal of taxes on solar panels and batteries. In the waste sector, financial incentives for improved waste and wastewater management, renewable energy incentives or obligations and waste management regulations (= policies) may cause waste incineration with energy recovery, composting of organic waste, controlled wastewater treatment and recycling and waste minimization (= mitigation technology) (IPCC, 2014b). In the buildings sector, efficient lighting, daylighting and use of more efficient electrical appliances, heating and cooling devices (= mitigation technology) can be ensured through appliance standards and labelling, as well as through building codes and certification (= policies). In Agriculture, Forestry and Other Land Use (AFOLU), subsidies for agriculture intensification (= policy), improved productivity through improved crop variety can reduce deforestation (= mitigation technology). The capacity of a country to reduce GHG emissions depends on a number of factors (IPCC, 2014b), as we will see in the next session.

1.9 Mitigative capacity

The concept of mitigative capacity is a human-centered concept (Olowa et al., 2011). The concept describes a country's ability to reduce anthropogenic GHG emissions or enhance natural sinks. "Ability" connotes skills, competencies, fitness, and proficiencies that a country has attained which can contribute to mitigation of GHG emissions (Winkler et al., 2007). The IPCC, framed mitigative capacity as related to technology, policy options and resources, but also "upon nation-specific characteristics that facilitate the pursuit of sustainable development. These characteristics include the distribution of resources, the relative empowerment of various segments of the population, the credibility of empowered decision makers, the degree to which climate objectives complement other objectives, access to credible information and analyses, the will to act on that information, the ability to spread risk intra- and inter-generationally, and so on" (IPCC, 2001). The mitigative capacity concept has not yet been operationalized across the political, economic, social and natural contexts in relation to climate change mitigation.

The IPCC offers a listing of "determinants" of mitigative capacity: (i) range of viable technological options for reducing emissions; (ii) range of viable policy instruments with which the country might affect the adoption of these options; (iii) structure of critical institutions and the derivative allocation of decision-making authority; (iv) availability and distribution of resources required to underwrite their adoption and the associated, broadly defined opportunity cost of devoting those resources to mitigation; (v) stock of human capital, including education and personal security; (vi) stock of social capital, including the definition of property rights; (vii) country's access to risk-spreading processes (e.g., insurance, options and futures markets, etc.); and (viii) ability of decision makers to manage information, the processes by which these decision makers determine which information is credible, and the credibility of the decision makers themselves (IPCC, 2001).

Activity 2 (Group discussion) (20 minutes)

- Discuss climate change mitigation in the context of national level climate change response policies, strategies and actions. Align your discussions to various sectors of socio-economic development in terms of emissions and capacity to reduce emissions in those sectors. .

1.10 Inter-relationships between adaptation and mitigation

Adaptation and mitigation are two types of policy response to climate change, which can be complementary, substitutable, or independent of each other. Irrespective of the scale of mitigation measures, adaptation measures will be required, due to the inertia in the climate system (IPCC, 2007a). Over the next 20 years or so, even the most aggressive climate change mitigation policy can do little to avoid warming already 'loaded' into the climate system. The benefits of avoided climate change will only accrue beyond that time. Over longer periods (i.e. beyond the next few decades), mitigation investments will have a greater potential to avoid climate change damage and this potential is larger than the adaptation options that can currently be envisaged. With adaptation being a complementary policy strategy to cope with climate change impacts, decision-makers are required to consider possible interactions with mitigation. This purpose is twofold: on one hand, creating synergies between adaptation and mitigation can increase the cost-effectiveness of actions and make them more attractive to stakeholders, including potential funding agencies; on the other hand, the implementation of a poorly coordinated policy mix may lead to undesirable outcomes (Taylor et al., 2007).

The analysis of the inter-relationships between adaptation and mitigation, reveals techniques to support the effective application of adaptation and mitigation actions together. That is the case because elements of adaptive and mitigative capacities, such as the availability of technological options or the access to economic resources, social capital and human capital, largely overlap (IPCC, 2007b). The IPCC (2007b) claims that opportunities for synergies are greater in the agriculture, forestry, buildings and urban infrastructure sectors, than in other sectors such as coastal systems, energy and health. Mitigation activities in the AFOLU sector can play a critical role in enhancing resilience of communities and ecosystems. For example, incorporating trees in farming landscapes or agroforestry will enhance resilience of cropping systems through the trees protecting the soil from erosion, protection of crops from strong winds and provision of products such as wood or fruits that can provide additional income.

Furthermore, four different types of interaction are identified (Table 2; IPCC, 2007b):

i. Adaptation actions that affect mitigation actions ($A \rightarrow M$);
ii. Mitigation actions that affect adaptation actions ($M \rightarrow A$);
iii. Decisions that include trade-offs or synergies between adaptation and mitigation ($\int(M, A)$);
iv. Processes that have consequences for both adaptation and mitigation ($A \cap M$).

Table 2: The four types of inter-relationships between adaptation and mitigation and associated illustrative examples

Scale of action	A→M	M→A	∫ (M,A)	(A∩M)
International	Awareness of limits of adaptation motivates negotiations on mitigation	CDM trades provides fund for adaptation	Assessment of the cost of M+A in setting targets for stabilization	Allocation of special climate funds
Regional/national Strategic/sectoral planning	Watershed management e.g. hydroelectricity and land cover affect GHG	Fossil fuel tax, increases cost of adaptation through high energy prices	Testing project sensitivity to M policy, social cost of Carbon and climate impacts	National capacity e.g. self-assessment support to M and A integration in policies
Local - community, individual actions	Increasing use of air conditioning in homes, offices raises GHGs	Community Carbon sequestration can affect livelihoods	Corporate integrated assessment of exposure to mitigation policy and climate impacts	Local planning authorities implement criteria related to both M+A in land use planning

Key: A=Adaptation; M=Mitigation

Source: IPCC (2007a)

1.11 Climate change mitigation and sustainable development

Projected anthropogenic climate change appears likely to adversely affect sustainable development, with the effects tending to increase with higher GHG concentrations. Properly designed climate change responses can be an integral part of sustainable development and the two can be mutually reinforcing. Mitigation of climate change can conserve or enhance natural capital (ecosystems, the environment as CO2 sources and sinks for economic activities) and prevent or avoid damage to human systems and, thereby contributing to the overall productivity of capital needed for socio-economic development, including mitigative and adaptive capacity. In turn, sustainable development paths can reduce vulnerability to climate change and reduce GHG emissions (IPCC, 2007a). Mitigation actions have potentials to deliver co-benefits that are relevant for enhancing sustainable development such as improved air quality and good health, enhanced energy security, increased food production and livelihood improvement and protection of ecosystems services (IPCC, 2014a; UNECE, 2016).

Sectors	Key mitigation technologies and practices currently available
Energy supply	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of Carbon Capture and Storage (CCS, e.g. storage of removed CO2 from natural gas).
Transport	More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorized transport (cycling, walking); land-use and transport planning.
Buildings	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar designs for heating and cooling; green buildings, alternative refrigeration fluids, recovery and recycle of fluorinated gases.
Industry	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non - CO2 gas emissions; and a wide array of process-specific technologies.
Agriculture	Improved crop and grazing land management to increase soil Carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH4 emissions; improved Nitrogen fertilizer application techniques to reduce N2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency.
Forestry	Afforestation; reforestation; SFM; reduced, deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use.
Waste management	Landfill CH4 recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; biogas from municipal solid and sewerage; recycling and waste minimization.

1.12 Actions, options and approaches to mitigate climate change

The actions, options and approaches to mitigate climate change in various GHG emission sectors are presented in Table 3

Table 3: Key mitigation measures in different GHG emission sectors

Sectors	Key mitigation technologies and practices currently available
Energy supply	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of Carbon Capture and Storage (CCS, e.g. storage of removed CO_2 from natural gas).
Transport	More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorized transport (cycling, walking); land-use and transport planning.
Buildings	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar designs for heating and cooling; green buildings, alternative refrigeration fluids, recovery and recycle of fluorinated gases.
Industry	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non - CO_2 gas emissions; and a wide array of process-specific technologies.
Agriculture	Improved crop and grazing land management to increase soil Carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved Nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency.
Forestry	Afforestation; reforestation; SFM; reduced, deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use.
Waste management	Landfill CH_4 recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; biogas from municipal solid and sewerage; recycling and waste minimization.

Source: IPCC (2007b)

Summary

In this chapter, we have learnt the basics of climate change mitigation and its concepts in terms of science, policy and actions. We also learnt the rationale behind climate change mitigation in terms of GHG sources and types, including their implications on the functioning of biophysical, economic, social and human health systems, and mitigation policies and actions. Furthermore, we learnt the relationship between climate change mitigation and other related concepts such as adaptation, sustainable development, including key mitigation measures and options across GHG emission sectors. adaptation.

Bibliography for further readings

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Chapter 2. Forest-Based Climate Change Mitigation

2.1 Chapter overview

i. Forests ecosystems contribute to climate change mitigation through Carbon sequestration and/or Carbon emission reduction, while offering socio-economic and environmental benefits. They constitute a cost-effective way to mitigate climate change. The role of forests in climate change mitigation is explicitly stated in article 5 of the Paris Agreement, in which countries are encouraged to reduce Carbon emissions from forestry and land use, by avoiding deforestation and degradation, managing forests sustainably, enhancing and conserving forest Carbon stocks (UNFCCC, 2015). This chapter introduces the different forest-based mitigation practices, policies and strategies, the role of forests in climate change mitigation, the links between mitigation and adaptation, and mitigation and sustainable development in the context of forestry. The chapter addresses the following objectives:

i. Provide information to learners on the role of forests in climate change mitigation;

ii. Provide information on the different forest-based mitigation practices in the forestry sector; and

iii. Present factors that can enhance the contribution of the forestry sector to climate change in the context of Africa.

Learning outcomes

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

i. Explain the role of forests in climate change mitigation;

ii. Identify forest-based mitigation practices in the forestry sector;

iii. Assess different forest-based mitigation options; and

iv. Explain factors that can enhance the contribution of the forest sector to climate change mitigation in the context of Africa.

2.2. Forest and ecosystem services

Interactive questions: (10 minutes)

1. What are the benefits of forests and trees to the human society?

2. Describe the dominant forest type in a region of Sub-Saharan Africa of your choice and how this forest is important to the livelihoods of the communities that live in or around it as well as the country (ies) where it lies?

Ecosystem services are defined as the direct and indirect contributions that ecosystems make to human wellbeing (Daily and Matson, 2008). They represent a human-centred concept of the benefits people derive from nature (Mensah et al., 2017). The ecosystem services concept has become widely used and serves to emphasize the dependency of human society's welfare on natural resources (MEA, 2005; Costanza et al., 2017). Forests cover about 30% of global terrestrial area, and provide a wide variety of ecosystem services (FAO, 2018) (Box 2.1). For instance, forests provide timber and food (e.g. mushrooms, edible plants and fruits), conserve biodiversity, regulate water resources, and provide recreational opportunities (Saastamoinen et al., 2014). Forests are also essential components of the global Carbon cycle, and play an important role in regulating atmospheric concentrations of CO2 through the process of photosynthesis (Kurz et al., 2013)

Box 2.1: Forest ecosystem Services

The government of Burkina Faso's NAP includes large-scale reforestation programs using fast growing, drought tolerant tree species to reduce the impacts of desertification. The Netherlands Government's Eco-Regional Grants Programme under the International Union of Conservation of Nature National Committee of the Netherlands (IUCN NL) supports the Cambridge Programme for Sustainability Leadership (CPSL) in West Africa, focusing on climate change adaptation and resilience, as well as opportunities for development and economic growth. The programme worked with 15 members of the Economic Community of West African States (ECOWAS) undertaking research in partnerships with Green Actors of West Africa (GAWA) in countries such as Benin, Côte d'Ivoire, Gambia, Guinea, Guinea-Bissau, Mali, Niger, Sierra Leone and Togo. The Ministry of Environment, Water Resources and Forests in Côte d'Ivoire adopted a policy to establish a supervisory forestry organisation and a national forest fund, develop a programme that strengthens capability forestry, revision of the forest code, establishment of a national centre for seeds and forest plants and development of a framework controlling deforestation. The Togo government implemented strategies to generate and disseminate agro-meteorological information, promote peri-urban market gardening and livestock farming and environmental impact assessments.: (Robinson and Brooks 2010).

Tropical forest is one of the three major forest biomes. It shelters approximately two thirds of the planet's terrestrial biodiversity and provide many ecosystem services that are essential to human well-being (Box 2.2), such as CO2 fixation, water supply and flood control, soil maintenance and ecotourism (Shimamoto et al., 2018). Tropical forests could offset much of the Carbon released from the declining use of fossil fuels, helping to stabilize and then reduce atmospheric CO2 concentrations, thereby providing a bridge to a low-fossil-fuel future (Houghton et al., 2015).

The boreal forests are comprised of the circumpolar vegetation zone of high northern latitudes that cover one of the world's largest biogeoclimatic areas (Brandt et al., 2013). The ecosystem services provided by boreal forests thus benefit human society at local and global scales (Gauthier et al., 2015). Boreal forests account for about 20% of global Carbon sinks (Pan et al., 2011).

Woodlands are another vital part of the global forests. For example, the dry deciduous Miombo woodlands of central southern African cover approximately 2.7 million km2, have potential to sequester tons of Carbon annually (Gumbo et al., 2018).

Apart from forests, trees outside forests also provide ecosystem services. Available reports indicate that the world has at least 162 million hectares of land with tree covers that are not classified as forests, among which are agroforestry systems, tree orchards, trees in urban settings etc. (FAO, 2020).

Box 2.2: Local livelihoods and forest ecosystem services: Case of dry forests in Africa

Dry forests play a significant role in the livelihood sustainability of millions of people across Africa through wood fuel harvesting, exploitation of non-timber forest products (NTFPs), tourism, livestock, adaptation to climate change etc. Wood fuel contributes to income and energy consumption in different dry forest countries such as Tanzania, Malawi, and Zambia. Beyond fuel and timber, dry forests provide a wide variety of products that may supplement local livelihoods. However, in many regions the role of NTFPs is still difficult to assess as majority of the trade occurs in informal markets, and therefore their actual contributions have never been formally accounted for in the national economy. However, some evidence exists of the significant contributions of a few NTFPs, such as shea butter (obtained from Vitellaria paradoxa) in Burkina Faso which is the third most important national export while in Ethiopia gums and resins rank second after livestock in the overall household livelihood support. Dry forests are important source of been forage supporting apiary in many regions on the continent.

2.3 Forest and climate change mitigation: storing forest Carbon

Activity 3 (Group discussion) (20 minutes)

- Share your viewpoints and sketch a diagram showing the interaction between atmospheric Carbon and forest ecosystem as a vegetation.
- Identify the different forest types in Africa, and with justification, classify them according to their capacity to store Carbon?

Carbon storage in forest biomass (biological material) (Box 2.3) is an essential attribute of stable forest ecosystems and a key link in the global Carbon cycle. Biomass is defined as the dry mass of living biological organisms in a given ecosystem at a given time. It may include microorganisms, plants, and animals, and can be expressed as the average mass per unit area or as the total mass in the ecological community. About fifty percent of plant biomass (in dry weight) is attributable to Carbon, although the percentage may differ among species. After CO_2 is converted into organic matter by photosynthesis, Carbon is stored in forests for a period of time in a variety of forms before it is ultimately returned to the atmosphere through respiration, burning and decomposition or disturbance (Hui et al., 2017; U.S.EPA, 2018a). A substantial pool of Carbon is stored in woody biomass (roots, trunks, and branches). Another portion eventually ends up as organic matter in forest floor litter and in soils (Pan et al., 2011; Hui et al., 2017).

The amount of Carbon stored in forests (Box 2.4 and Box 2.5) is important for several reasons. A net change in forest biomass can indicate whether forest ecosystems are stable, growing, or declining. Carbon storage is closely related to other vital ecological processes such as primary productivity. Carbon stocks can also vary with forest type, diversity and forest age (Figure 2).

Because CO_2 is the primary GHG emitted by human activities, changes in forest Carbon can help to mitigate climate change—or they can exacerbate the problem. Forests remove CO_2 from the atmosphere. When forests store more Carbon than they lose in a given year, they serve as net Carbon sink and offset a portion of society's GHG. Conversely, when forests emit more Carbon than they store, they serve as net Carbon source and ultimately lead to increase in CO_2 emission in the atmosphere (U.S.EPA, 2018b).

Box 2.3: Assessing Carbon storage in forest biomass: key carbon pools

Forest ecosystems play a major role in the global Carbon cycle by storing large amounts of Carbon in live plant biomass. In order to understand how forest ecosystems respond and feedback to climate change, there is a need to quantify Carbon stocks in vegetation and soil in forest ecosystems. The different forms in which forest Carbon is stored are called "Carbon pools". They include:

i) Aboveground biomass - all living biomass above the soil including stems, stumps, branches, bark, seeds, and foliage, live understory;

ii) Belowground biomass - all living biomass of coarse living roots thicker than 2 millimeters in diameter;

iii) Dead wood - non-living woody biomass either standing, lying on the ground (but not including litter), or in the soil;

iv) Forest floor litter - the litter, fumic, and humic layers, and all non-living biomass with a diameter less than 7.5 centimeters, lying on the ground; and

v) Soil organic Carbon - all organic material in soil to a depth of 1 meter but excluding the coarse roots of the belowground pools.

Sources : U.S. EPA (2018a); Hui et al. (2017)

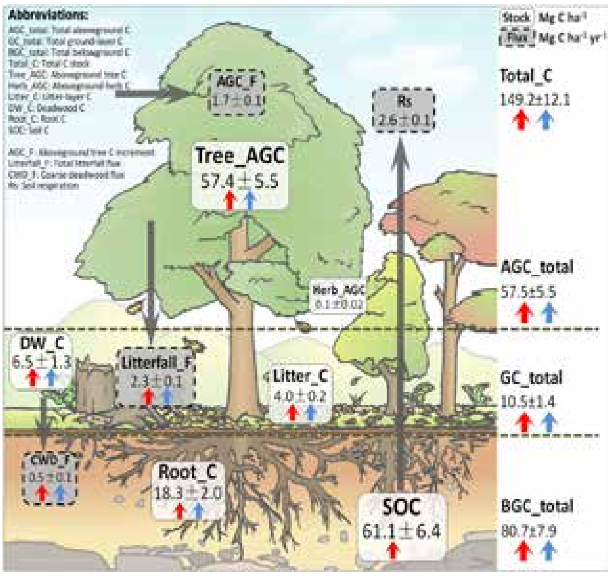

Figure 2: Benchmarking map of Carbon stocks (solid white boxes) and fluxes (dashed grey boxes) averaged across all 27 forest stands. Numbers represent means and standard errors (Liu et al., 2018).

Box 2.4: Carbon stocks in different forest types in Africa

Africa is home to a diversity of vegetation types, from the Afromontane and rain forests to dry forests, woodlands and savannas. The main vegetation types are rain forests, dry forests and tree and shrub savannas, with a grass layer dominated by annual grasses and perennials. Gallery forests are also sparsely encountered within Africa.

The Sahel zone of West Africa is characterized by arid, semi-arid, dry humid environments. Carbon stocks in the forest areas located in the Sahel zone of West Africa are estimated at 4 056 million tons, with an annual loss of 1.4% per year during the period 1990-2015 (OSS, 2018). The Congo basin rainforest is one of the world's largest block of rainforest with an area of about 1.8 million km^2 and covering six central African countries (Cameroon, Central African Republic, Republic of Congo, Democratic Republic of Congo (DRC), Equatorial Guinea and Gabon). It represents the second largest to the Amazon tropical rainforest in terms of biodiversity conservation and ecological values. It is estimated that about 46 billion metric tons of Carbon are stored in the Congo Basin tropical rainforest, while the closed evergreen lowland forests represent 60% of the Carbon stored in the sub-region, which only cover 35 % of the area (Nasi et al., 2009).

Miombo is a seasonally dry deciduous woodland dominated by trees of the genera Brachystegia, Julbernardia and Isoberlinia and is the largest vegetation formation in central, eastern and southern Africa. This woodland type covers an estimated 2.7 million km2 across seven countries (Angola, DRC, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe) and consists of both dry (650 mm mean annual rainfall) and moist miombo (1400 mm mean annual rainfall) woodlands. All Carbon stock assessment studies in the Miombo area indicate that the average above-ground Carbon stock in old growth Miombo woodland across all studies was 33.9±1.3 Mg C ha−1 , with a wide range (1.3–95.7 Mg ha−1) (Gumbo et al., 2018).

The mangroves of West and Central Africa cover a surface area of about 20,040 km2 and constitute about 13.1 % of the global total. It has an estimated mean above ground Carbon (AGC) content of about 88.9 t/ha. The mangrove forests of East and South Africa is estimated at about 7917 km2 in surface area and constitute about 5.2% of the global total, with an estimated mean AGC content of about 68.2 t/ha (Kuwae and Hori, 2018).

Box 2.5: Case studies of aboveground tree Carbon stocks in West African semi-arid ecosystems

In West Africa, forest habitats are differentiated by a variety of vegetation types from the Guinean littoral forests to the Southern Sahel, with tropical rainforests occurring at 1500-3000 mm annual rainfall, forest-savannah mosaics (1200-1500 mm), woodland-savannahs (800-1200 mm), Sahel (200-500 mm), and desert (<200 mm). In Burkina Faso, Carbon density varied between the different vegetation types, ranging from an average of 2.9 ± 0.4 Mg/ha in shrub savanna to 57.7 ± 3.9 Mg /ha in gallery forest (Dimobe et al., 2018). In Benin, stand AGC was 23 ± 5 Mg/ha in tree-shrub savannahs and 30 ± 8 Mg/ha woodlands (Mensah et al., 2020).

Source: Mensah et al. (2020)

2.4. Forest Carbon sequestration and emission

When forest ecosystems absorb CO_2, the Carbon stock increases as the levels of GHGs in the atmosphere reduce. Conversely, when CO_2 is released into the atmosphere, the Carbon stock decreases as the GHGs in the atmosphere increases causing global warming. Stock and flux are two important variables, but how are they linked? If the stock increases, it means that the forest ecosystem absorbs Carbon (Hui et al., 2017). In the case of a growing forest ecosystem, the net balance of flux is an inbound flux. It means that when CO_2 is removed from the atmosphere, the atmospheric concentration of GHG emissions decreases, and climate change is reduced. In that case, the process is called Carbon fixation, absorption or removal and the forest ecosystem is called a Carbon sink. Conversely, if Carbon stock decreases (for instance in a decaying or burning forest), an outbound flux will increase atmospheric GHG emissions concentrations and increase global warming. The process is called Carbon emission and the forest ecosystem is called a Carbon source. Changes in the amount of Carbon stored in forests can result from a variety of anthropogenic and natural influences. For example, Carbon is removed or emitted from forests when trees are harvested, when forest land is cleared for other uses such as agriculture or infrastructural development, or as a result of disturbances such as wildfire, insects, and disease attacks. Net storage of Carbon can result from reforestation -- the human-induced conversion of land that was forested but has been converted to non-forested land such as farmland (JICA/ITTO, 2010). Net Carbon storage can also result from active planting of trees and management practices that lead to an increased rate of growth—and ultimately an increase in biomass (U.S. EPA, 2018b).

2.4.1 Carbon sequestration potential from different forest types in Africa

To understand the volume of atmospheric CO2 removal by Carbon sequestration through forestry, the rate of biomass growth (i.e., the increase of tree biomass over time) under a forestry activity needs to be calculated. This rate varies with climate, landscape characteristics, tree species and management practices (IUCN and WRI, 2014). Globally, it is estimated that planted forests and woodlots have the highest CO_2 removal rates, ranging from 4.5 to 40.7 t CO2/ ha/year during the first 20 years of growth. Mangrove tree restoration was the second most efficient CO_2 removal rate, with growth rates of up to 23.1 t CO2/ha/year the first 20 years post planting. Natural regeneration removal rates were 9.1–18.8 t CO_2/ha/year within the first 20 years of forest regeneration (Bernal et al., 2018). Box 2.6 shows Carbon stock dynamics under different land use systems.

Box 2.6: Carbon stock dynamics under four land use systems in three ecological zones in Ghana

Rates of land-use change and changes in Carbon stock following degradation and deforestation are the major factors determining the emissions of C from the tropical forests. A study was undertaken to assess the impact of four land-use systems namely natural forest, Teak (Tectona grandis) plantation, fallow land and cultivated land, on C stock dynamics, and to determine C stock trends at various ecological zones. The study was carried out in three ecological zones namely: Moist Evergreen Forest (MEF), Dry Semi-Deciduous Forest (DSDF) and Savannah (SAV) zones. Carbon accumulation in trees, herbaceous plants, litter, and soil (up to 40 cm depth) was assessed. The C stock in the various land-use systems (e.g. cultivated land, fallow land, Teak plantation, and the natural forest) in the MEF and DSDF was, in the increasing order, cultivated land, fallow land, Teak plantation, and the natural forest. However, in the savannah zone, Teak plantation accumulated more C than the natural forest. Under each of the four land-use systems, the highest biomass C accumulation was exhibited by the MEF, followed by DSDF and SAV ecological zones. The trend in soil C stock under the various land-use systems within each of the ecological zones was different among all the ecological zones. The lowest soil C stock in MEF and DSDF zones was in the cultivated land, whereas in the savannah zone it was in the Teak plantation. The highest soil C stock was in the fallow land in both the DSDF and SAV zones, whereas the highest soil C stock was in the natural forest land in the MEF. Using the natural forest as the benchmark, impact of C loss on the conversion of the natural forest to the other land-use systems was found to be more pronounced in the DSDF and MEF zones than in the SAV zone. Within the land-use systems, the Carbon loss was, in the increasing order, of Teak, Fallow and Cultivated lands.

Source : Adu-Bredu et al. (2010)

2.4.2 Carbon sequestration potential from trees outside forests

Trees outside forests (in agricultural lands, pasture or parklands) are believed to be a major potential Carbon sink and could absorb large quantities of Carbon, therefore if trees are reintroduced to these systems and judiciously managed together with crops and/or animals, the scope of sink will be increased (Sharma et al., 2016; Nair and Nair, 2014). Historical evidence showed that integrating trees on agricultural land has been widely practiced through ages as a means of achieving agricultural sustainability and slowing down the negative effects of agriculture such as soil degradation and desertification (Albrecht and Kandji, 2003). In this connection, agricultural lands have the potential to remove and store between 42 and 90 Pg of Carbon from the atmosphere over the next 50–100 years (Albrecht and Kandji, 2003). In Africa, agroforestry is the most widely practiced on-farm tree system, where the land-use system involves the deliberate retention, introduction or, mixture of trees or other woody perennials with agricultural crops, pastures and/or livestock to exploit the ecological and economic interactions of the different components (Nair and Nair, 2014). The different agroforestry systems across Africa have the potentials to sequester atmospheric Carbon, though the capacity depends on biophysical, technical, economic and practical factors. Table 4 presents estimates of some agroforestry practices and their Carbon sequestration potentials.

Table 4: Carbon sequestration rates reported for agroforestry systems across Africa

Activities	Duration (years)	C sequestration rate (Mg C ha−1 year−1)
West African Sahel		
Faidherbia albida plantation in Senegal	50	0.22
Optimal agricultural intensification, including Leucaena prunings in Senegal	50	0.27
Restoring degraded grassland to woody grassland in Senegal	20	0.77
Establishment of new parklands in the Sahel	50	0.4
East Africa		
Tree planting to restore highly degraded land	25	0.4–0.8
Intensification of windrows and tree biomass	20	0.8
Conversion of cropland to home gardens	20	0.5–0.6
Southern Africa		
Regrowth of woodland on abandoned farms in Mozambique	25	0.7
Coppiced Miombo woodland in Zambia	16	0.5
Coppiced Miombo woodland in Zambia	35	0.9
Faidherbia albida plantation in Tanzania	6	1.2
Rotational woodlots in Tanzania	5	2.6–5.8
Rotational woodlots in Tanzania (wood C)	5	2.3–5.1
Rotational woodlots in Zambia	2	2.15–4.75

Source: Luedeling et al. (2011)

In addition to those presented in Table 4, another important agroforestry system in Africa that has potential for Carbon sequestration is the shade system – an agroforestry system that combines coffee, tea or cocoa shrubs with multi-purpose shade species (Somarriba et al., 2013). Cocoa-based agroforestry systems have been underscored to be of value in terms of Carbon sequestration and storage in Cameroon (Nadege et al., 2019), Nigeria (Oke and Olatiilu, 2011) and Ghana (Asase and Tetteh, 2016).

2.4.3 Challenges associated with forest and tree mitigation (Carbon sequestration/emission reduction) in Africa

Interactive questions: (10 minutes)

Looking at the forestry, environment and related land use policies, governance and institutional frameworks in your country, identify factors that can act like a barrier or can influence the role of forest in climate change mitigation?

In Africa, the implementation and outcome of forest and/or on farm tree management systems and practices relevant for climate change mitigation could be either hindered or facilitated by a number of factors. In the case of agroforestry and other related on-farm tree practices, the policy and institutional factors include: (i) unclear land and tree tenure; (ii) the capacity of seed/germ plasm supply systems; (iii) the capacity of extension systems to propagate agroforestry technology; (iv) the articulation of agroforestry in sectoral policy and strategy documents; (v) the opportunities of agroforestry in incentive approaches such as REDD+ and payment for ecosystem services (PES); and (vi) subsidies to enhance adoption of agroforestry practices (Ajayi and Place, 2012).

Forest-based climate change mitigation actions could be hindered or facilitated by a mix of financial, economic, governance, and technical factors as well as the political will of country governments. Governance factors include tenure and resource rights, political will to improve upon existing policies - influenced by the level of pressure or demand for forest resources (Korhonen-Kurki et al., 2014), availability of information and ideas that favour forest-based programmes etc. (Brockhaus and Angelsen, 2012). Technical issues are linked to the capacity of countries to develop bankable projects in general and on issues related to robust measuring, reporting and verification (MRV) of Carbon and non-Carbon benefits in particular (Gizachew et al., 2017; Fobissie et al., 2019). Economic factors relate to the availability of incentives for project proponents (Nasi et al., 2012). The financial aspect of the enabling environment denotes the availability of sufficient and sustainable financing (both results and non-results based) to cover the opportunity and implementation cost of the chosen forest management system (Gizachew et al., 2017). More details are provided by Unruh (2008), Jindal et al. (2008) and Gizachew et al. (2017).

2.4.4 Capacity to access climate finance

Most forest and tree-based mitigation interventions cannot be implemented on a cost recovery way, these have to get financing from other sources. Governments need to get funding from their own resources or from existing climate mitigation financing mechanisms such the Global Environmental Facility (GEF) and REDD+. At national level, resources mobilisation is crucial to roll out programmes aimed at achieving the objectives of formulated strategies. Box 2.7 shows some examples of strategies implemented in response to climate change in Sub-Sahara Africa.

Box 2.7: Examples of some strategies implemented in response to climate change in selected countries

Country	Strategy	Vision/Objective	Time span	Target	Budget
Ethiopia	Climate Resilient Green Economy Strategy	Achieve middle-income status by 2025 in a climate-resilient green economy	2010–2025	Economy	US$ 150 billion
Malawi	Malawi's Strategy on Climate Change Learning	Strengthen human resources and skills development for the advancement of green, low emission and climate resilient development	2021–2030	Environment and Natural Resources Management	US$ 9.9 million
Côte d'Ivoire	Integrating Climate Change Adaptation into Development Planning	Shape a resilient society and enable people to develop the capacity to cope with climate hazards	2019–2022	Multi-sector: agriculture, water resources, land use, coastal resources and health	€ 2 million (over 1.3 billion CFA francs)
Kenya	National Climate Change Response Strategy and National Climate Change Action Plan	Adaptation and mitigation	2010–2030	Multi-sector	US$ 2.75 billion per year

2.5 Climate change mitigation strategies and practices in forestry

Activity 4 (Group discussion) (20 minutes)

Discuss how forest and tree resources contribute to climate change mitigation in your country or sub region or region. Provide specific case studies/examples of any project(s) being implemented in the area that you know.

Literature on forestry and climate change carries a mix of concepts, terminologies that lead to the same aspects in terms of operationalization. For example, forest mitigation measures, practices, options, actions, strategies, approaches, etc, are frequently being used in the forest and climate change literature, policy and practice. At this level, it should be noted that forest mitigation projects and programmes are always linked to Carbon sequestration and Carbon stock enhancement or Carbon stock conservation objectives. Strategic orientations of these objectives are enveloped in different forms at the national, regional and international levels as part of policies and strategies. A good example is the REDD+ strategies being developed by some African countries to reduce emissions from deforestation and forest degradation presented in Chapter 3.

According to the IPCC, options to reduce emissions by sources and/or increase removals by sinks in the forestry sector are grouped into four general categories (IPCC, 2007b):

Maintaining or increasing forest area, for example reducing deforestation and forest degradation, and increasing A/R rates;

i. Maintaining or increasing the site-level Carbon density, for example, forest management in plantations, and management in native forests;
ii. Maintaining or increasing the landscape-level Carbon density, for example increasing substitution of fossil energy intensive products by wood products; and
iii. Increasing off-site Carbon stocks in wood products and enhancing product and fuel substitution, for example bio-energy production from forestry.

Each mitigation objective has a characteristic time sequence of activities, Carbon and other co-benefits (Table 5). Relative to a baseline, the largest short-term gains are always achieved through mitigation activities aimed at avoiding emissions (reduced deforestation or forest degradation, fire protection, slash burning, etc.).

The African continent - from the dry forest of West Africa, to the rainforest of Central Africa and the woodlands of Southern Africa is already implementing, and has the potential to develop more forest climate change mitigation projects and programmes on one or a combination of the management systems and practices presented in Table 5. Visit the GEF and the Forest Carbon Partnership Facility (FCPF) sites for details. Restoration initiatives and Carbon sequestration potential of restoration activities are summarized in Box 2.8.

Interactive question: (10 minutes)

Based on the relationship between forest and climate change, identify strategies that your country, sub-region or/and region have put in place to enhance the role that forests and trees play in climate change mitigation?

Table 5: Summary of forest-based mitigation options and their effects on Carbon stocks

Mitigation activity	Impact on Carbon stocks
1. Increase forest area (e.g. new forests)	Enhance sink
2. Maintain forest area (e.g. prevent deforestation, land use change)	Reduce source
3. Increase site level Carbon density (e.g. intensive management)	Enhance sink
4. Maintain site level Carbon density (e.g. avoided degradation)	Reduce source
5. Increase landscape-level scale Carbon stocks (e.g. SFM, agriculture)	Enhance sink
6. Maintain landscape-level scale Carbon stocks (e.g. suppress disturbances)	Reduce source
7. Increase off-site Carbon in products (but must also meet 2, 4, 6)	Enhance sink
8. Increase bioenergy and substitution (but must also meet 2, 4, 6)	Reduce source

Source: IPCC (2007a)

Box 2.8: Restoration of degraded lands and forests for climate change mitigation

The restoration of degraded forests and lands aims to improve the landscape for people and biodiversity, through several approaches – agroforestry, tree planting, natural regeneration, connecting forest fragments etc. – so that it can better provide ecosystem services, support biodiversity and mitigate climate change. Forest landscape restoration has been adopted by governments and practitioners across the globe, to mitigate climate change and restore ecological functions across degraded landscapes. For example: (i) the Bonn Challenge to restore 150 million hectares of the planet's deforested and degraded lands by 2020; and (ii) the Convention on Biological Diversity in 2010 through the Aichi Biodiversity Targets, called for countries to restore at least 15 percent of their degraded ecosystems by 2020 (van Oosten et al., 2014).

The importance of landscape restoration in Africa led to the AFR100 initiative, where African nations have forged international partnerships with financial interests both donor and business, technical organizations, and local interest to restore 100 million hectares of land in Africa by 2030. About 27 countries have made commitments ranging from 0.5 to 12 million hectares of land to be restored (more from www.afr100.org).

In terms of Carbon sequestration potential of restoration activities, planted forests and woodlots were found to have the highest CO_2 removal rates, ranging from 4.5 to 40.7 t CO_2 ha^{-1} year^{-1} during the first 20 years of growth. Mangrove tree restoration was the second most efficient activity at removing CO_2, with growth rates of up to 23.1 t CO_2 ha^{-1} year^{-1} within the first 20 years post restoration. Natural regeneration removal rates were 9.1–18.8 t CO_2 ha^{-1} year^{-1} during the first 20 years of forest regeneration, followed by agroforestry (10.8–15.6 t CO2 ha^{-1} year^{-1}) (Bernal et al., 2018).

2.6 Linking mitigation and adaptation in forestry

A lot of forest-based mitigation activities provide adaptation co-benefits. For example, protection of natural forests and woodlands will promote resilience of production systems through provisioning and regulating services. These services might be contributing to longer term resilience of the landscape or to short-term coping mechanisms. Many natural forests and woodlands are important sources of bee forage supporting apiculture as an alternative livelihood activity in many countries. In land use and forestry, mitigation and adaptation might demand and/or compete for the same type of land use activities, financial and technical resources. Planning and using the same activities, institutional arrangements and inputs for mitigation and adaptation outcomes and impacts are possible and necessary (Ravindranath, 2007; Guariguata et al., 2008; Chia et al., 2016). A broad range of forest and on farm tree-based practices and management systems are implemented across Africa and they have the potential to contribute to both mitigation and adaptation (Table 6).

Table 6: Forestry practices and management systems and their mitigation and adaptation potential

Practices and management systems	Mitigation potential*	Adaptation of forest**	Forest for adaptation***
Carbon conservation			
Avoided deforestation and forest degradation	+++	+++	++
Creation and management of protected areas	+++	+++	++
Sustainable management of forests	+++	++	+++
Fire management techniques	++	++	+
Managing invasive species, insects, pests and diseases	++	+++	++
Carbon sequestration			
Afforestation (A)	++	++	++
Reforestation (R)	+++	++	+
Agroforestry	++	++	+++
Urban forestry	++	++	+++
Industrial plantations	++	+	+++

Sources: Ravindranath (2007); Locatelli et al. (2008); Lasco et al. (2014); Guariguata et al. (2008).

*Carbon emission reduction or sequestration potential; **potential to enhance the adaptive capacity of forest ecosystems; ***capacity to enhance the adaptive capacity of forest dependent communities +++high positive potential, ++medium positive potential, +low positive impact

African countries need to take the opportunity of article 5 (2) of the Paris Agreement that underscores the need for Parties "to take action to implement and support alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests" (UNFCCC, 2015). This implies that there is a need to develop policies, strategies, programmes that enhance integrated mitigation and adaptation options. A number of strategies at the policy and landscape levels can enhance integrated options in the context of African forestry (Table 7) (Chia and Fobissie, 2019).

Table 7: Key measures to enhance integrated mitigation and adaptation forestry interventions in Africa

Policy level	Landscape level
Promote inter- and intra-organizational collaboration and coordination	The health of forests ecosystems should be maintained or enhanced
Institutionalize integrated M+A interventions and promote them in current and future programmes	The adaptive capacity of forest-dependent communities should be ensured
Enhance regulatory and policy frameworks	Robust Carbon and adaptation indicators should be developed, monitored and verified
Develop financial and stakeholders' awareness of and technical capacities on integrated M+A interventions	Forestry and tree-based interventions should demonstrate the need to plan and expect both M+A outcomes

Key: A=Adaptation; M=Mitigation

Source: Chia and Fobissie (2019)

Activity 4 Group Work

Discuss, with examples, the importance of integrating forest and tree-based adaptation and mitigation options in Africa. Identify good case studies and share learned lessons.

2.7 Sustainable development implications of forestry mitigation

Sustainable management of both natural and planted forests is essential to achieving sustainable development. It is a means to reduce poverty, reduce deforestation, halt loss of forest biodiversity, reduce land and resource degradation, and contribute to climate change mitigation (IPCC, 2007a). Forests play an important role in the reduction of GHG concentrations in the atmosphere while promoting sustainable development. Thus, forests must be seen in the framework of the multiple dimensions of sustainable development, if the positive co-benefits from forestry mitigation activities are to be maximized. Important environmental, social, and economic ancillary benefits can be gained by considering forestry mitigation options as elements of the broader land management plans (IPCC, 2007b). Forestry mitigation produce a mix of positive and negative consequences on sustainable development dimensions (Tables 8, 9 and 10). Box 2.9 shows case studies linking forest mitigation and sustainable development goals (SDGs).

Many countries in the region have developed green growth development strategies. For example, charcoal is major source of energy for many rural and urban households in the region. Charcoal making and use promotes cutting down of trees and forests. Countries either need to provide access to affordable alternative sources of energy such as gas and hydroelectricity or promote sustainable making of charcoal through establishing of charcoal woodlots.

Table 8: Forestry mitigation and the environmental dimension of sustainable development

Forestry mitigation activity	Environmental dimension
Increasing or maintaining forest area	
Reducing deforestation and forest degradation	Positive: Biodiversity conservation. Watershed protection. Soil protection. Amenity values (Nature reserves, etc.).
Afforestation/reforestation	Positive and negative Impacts on biodiversity at the tree, stand, or landscape levels depend on the ecological context in which they are found. Potential negative impacts in case on biodiversity conservation (monocultures species plantations replacing biodiverse grasslands or shrub lands). Watershed protection (except if water hungry species are used) Losses in stream flow. Soil protection. Soil properties might be negatively affected.
Changing to sustainable forest management	
Forest management in plantations	Positive: Enhance positive impacts and minimize negative implications on biodiversity, water and soils.
SFM in native forest	Positive: Sustainable management prevents forest degradation, conserves biodiversity and protects watersheds and soils.

Forestry mitigation activity	Environmental dimension
Substitution of energy intensive materials	
Substitution of fossil intensive products by wood products	Negative: Non-sustainable harvest may lead to loss of forests, biodiversity and soil.
Bioenergy	
Bio-energy production from forestry	Positive and negative: Benefits if production of fuelwood is done in a sustainable way. Mono specific short rotation plantations for energy may negatively affect biodiversity, water and soils, depending on site conditions.

Source: IPCC (2007b)

Table 9: Forestry mitigation and the economic dimension of sustainable development

Forestry mitigation activity	Economic dimension
Increasing or maintaining the forest area	
Reducing deforestation and forest degradation	Provides sustained income for poor communities. Forest protection may reduce local incomes.
Afforestation/reforestation	Positive or negative Creation of employment (when less intense land use is replaced). Increase/decrease of the income of local communities. Provision of forest products (fuelwood, fibre, food construction materials) and other services.
Changing to sustainable forest management	
Forest management in plantations	Positive: Creation of employment. Increase of the income of local communities. Provision of forest products (fuelwood, fibre, food, construction materials) and other services.
Sustainable forest management in native forest	Positive: Creation of employment. Increase of the income of local communities. Provision of forest products (fuelwood, fibre, food, construction materials) and other services.
Substitution of energy intensive materials	
Substitution of fossil intensive products by wood products	Positive Increased local income and employment in rural and urban areas. Potential diversification of local economies. Reduced imports.

Bioenergy	
Bio-energy production from forestry	Positive and negative Increased local income and employment. Potential diversification of local economies. Provision of renewable and independent energy source. Potential competition with the agricultural sector (food production, fibre production, etc.).

Source: IPCC (2007b)

Table 10: Forestry mitigation and the social dimension of sustainable development

Forestry mitigation activity	Social dimension
Increasing or maintaining the forest area	
Reducing deforestation and forest degradation	Positive: Support livelihoods.
Afforestation/reforestation	Positive or negative Promotes livelihood. Slows population migration to other areas (when a less intense land use is replaced). Displacement of people may occur if former activities are stopped, and alternate activities are not provided. Influx of outside population has impacts on local population.
Changing to sustainable forest management	
Forest management in plantations	Positive: Support livelihoods.
SFM in native forest	Positive: Support livelihoods.
Substitution of energy intensive materials	
Substitution of fossil intensive products by wood products	Positive and negative Forest owners may benefit. Potential for competition with the agricultural sector (food production, fibre production, etc.).
Bioenergy	
Bio-energy production from forestry	Positive and negative Forest owners may benefit. Potential for competition with the agricultural sector (food production, fibre production, etc.).

Source: IPCC (2007b)

Box 2.9: Linking forest mitigation and Sustainable Development Goals

DRC is one of the leading countries in the design and implementation of forest mitigation measures such as the REDD+ initiative. In November 2016, DRC was one of the eight pilot countries selected for mainstreaming of the 2030 SDGs. It is stipulated that REDD+ actions in DRC are relevant to the achievement of national SDGs and can contribute to 15 (out of 17) of the SDG goals, but in particular to: Climate action (SDG 13), Life on land (SDG 15), No poverty (SDG 1), Quality education (SDG 4), Affordable and clean energy (SDG 7), and Peace, justice and strong institutions (SDG 16) (Bernard et al., 2018).

The Chyulu Hills REDD+ Project in Kenya is a forest mitigation project that aims to protect the Chyulu Hills landscape, its forests, woodlands, savannahs, wetlands and springs, and its wild populations of Africa's best-known animals - lions, cheetahs, wild dogs, rhinos, elephants, and various antelopes. Apart from Carbon (climate change benefit) sequestration, the project is expected to also deliver a wide range of community benefits relevant for the SDGs, for example in the form of revenue sharing, alternative livelihood development, jobs, sustainable infrastructure development, environmental awareness and education, watershed protection, biodiversity conservation among others (CI, 2017).

In Burkina Faso, a forest Carbon mitigation project in Cassou district, Ziro province, in the Centre-South Region proposed mitigation activities such as afforestation/reforestation of degraded lands, restoration and assisted regeneration. The project documents indicate that the project will deliver on other outcomes that are important to SDGs, such as improved economic sustainability through income diversification, increased resilience of local people to climate variability, education and capacity building on forest and environmental conservation (ICRAF, 2015).

2.8 Policies influencing mitigation potential in the forestry sector

Many factors influence the efficacy of forests in achieving intended impacts on the objectives of climate change mitigation. Some include land tenure, institutional and regulatory capacities of governments, the financial competitiveness of forests as a land use system, and a society's cultural relationship to forests. Some of these factors differ between industrialized and developing countries. In the case of the African continent, the role of forests and on-farm tree-based interventions in climate change mitigation is influenced by a mix of institutional, governance, and economic factors (Table 11).

Table 11: Factors influencing the capacity of the forestry sector to contribute to mitigation

Forest-based interventions	On farm tree-based interventions
Inadequate political will and governance	Unclear land and tree tenure
Inadequate sectoral coherence	Weak capacity of seed/germ plasm supply systems
Weak technical capacity	Weak capacity of extension systems to propagate agroforestry technology
Inadequate policies and strategies addressing climate change	Insufficient articulation of agroforestry in sectoral policy and strategy documents
Lack of economic incentives for project proponents	Insufficient subsidies to enhance adoption of agroforestry practices
Lack of sufficient and sustainable financing	Limited opportunities of agroforestry in incentive approaches such as REDD+ and PES

Source: Chia and Fobissie (2019)

All the factors presented in Table 11 are similar in the forestry and climate change contexts across many African countries. These factors interact in many ways in these countries and have been underscored as barriers for countries to develop and implement viable, sustainable and bankable forest Carbon projects and programmes (Further reading: Unruh, 2008; Jindal et al, 2008; Gizachew et al., 2017; Chia and Fobissie, 2019).

2.9 Other benefits (co-benefits and non-Carbon benefits)

In forest-based climate change mitigation research and policy making, other benefits of forest-based mitigation practices and management systems are presented through different terms such as "co-benefits", "non-Carbon benefits", and "multiple benefits". However, the content and variables are the same. The following are key benefits other than Carbon that can be expected from forest-based mitigation initiatives:

Enhancement of local livelihoods. Through improved management of different types of forests and forest resources, forest-based mitigation activities can contribute to generating employment opportunities in the forest-based industry, provide food and nutrients from forests, enhance quality of water and provide wood fuel to meet energy requirements;

Increase in the value of biodiversity. Implementing forest-based mitigation activities will contribute substantially to conserving biodiversity and wildlife habitat. This translates to increased local and national income, from, inter alia, wild flora and fauna;

Better ecosystem services to people and the environment. As the state of forests improve, the resulting ecosystem goods and services such as provisioning, regulation, cultural and supporting functions will benefit the people and the environment;

More resilient ecosystems for climate change adaptation. With effective and efficient management of forests, the local environment and associated ecosystems will be less vulnerable to adverse impacts of climate change. Ecosystem based adaptation measures can provide sufficiently resilient ecosystems that will mitigate climate change impacts on people and ecosystems; and

Improved governance, institutional setup and policies for natural resource management at local to national levels. Effective implementation of forest-based mitigation initiatives such as REDD+, requires a compliance process that is transparent and promotes participatory decision making, as well as equitable benefit sharing mechanisms at various levels which can contribute to improved forest governance.

Summary

In this chapter, we have learned about (i) the role of forests in climate change mitigation; (ii) forest-based mitigation practices in the forestry sector that includes Carbon sequestration and conservation in different forestry types in Africa; (iii) factors that can enhance the contribution of the forest sector to climate change mitigation; and (iv) the links between adaptation and mitigation in forestry, and sustainable development and mitigation in forestry. The chapter also highlighted benefits other than Carbon that can emerge from the implementation of forest mitigation measures.

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Chapter 3. Forest-Based Mitigation Initiatives And Other Approaches

3.1 Chapter overview

This chapter focuses on forest-based mitigation initiatives and other approaches like CDM, REDD+, and Nationally Determined Contributions (NDCs) that are fundamental tools or mechanisms for climate change mitigation. It specifically addresses the following learning objectives:

i. To provide learners with in-depth knowledge on the CDM; and

ii. To improve learners' understanding of REDD+ and NDCs.

Learning outcomes

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

i. Improve their understanding of CDM, REDD+ and NDCs;
ii. Describe the role of CDM, REDD+ and NDCs in climate change mitigation; and
iii. Identify mitigation and adaptation benefits realised from implementation of CDM, REDD+ and NDCs initiatives in Africa

Activity 6 Brainstorming (20 minutes)

1. Share your understanding and experiences on the following in your respective countries/subregions/region.
   CDM.
   REDD+.
   NDCs.
2. How does each of these initiatives contribute to climate change mitigation?

3.2. Clean Development Mechanism

CDM is a United Nation-run Carbon offset scheme allowing countries to fund GHG emission-reducing projects in other countries and claim the saved emissions as part of their own efforts to meet international emission targets. It is one of the flexible mechanisms defined in the Kyoto Protocol (IPCC, 2007b). It provides for emission reduction projects that generates CERs, which may be traded in emissions trading schemes (ETS)(IPCC, 2007b). The CDM, defined in Article 12 of the Protocol, is intended to meet two fundamental objectives namely:

i. To assist Parties not included in Annex I or non-Annex I countries (i.e. developing countries) in achieving sustainable development and in contributing to the ultimate objective of UNFCCC, which is to prevent drastic climate change; and

ii. To assist Parties included in Annex I (i.e. industrialised countries) in achieving compliance with their quantified emission limitation and reduction commitments (GHG emission caps).

CDM addresses the second aforementioned objective by allowing the Annex I countries to meet part of their emission reduction commitments under the Kyoto Protocol by buying CER units from CDM emission reduction projects in developing countries (Carbon Trust, 2009). Both the projects and the issuing of CER units are subject to approval to ensure that these emission reductions are real and "additional." The CDM is supervised by the CDM Executive Board under the guidance of COP of UNFCCC.

CDM allows industrialized countries to buy CER units and to invest in emission reductions where it is cheapest globally. CDM projects first registered in 2001; by 7 September 2012, the CDM issued 1 billion CER units (UNFCCC, 2012). By 1st June 2013, 57% of all CER units had been issued for projects based on destroying either HFC-23 (38%) or N2O (CDM, 2013). CCS was included in the CDM Carbon offsetting scheme in December 2011.

CDM projects are expected to meet a set of requirements prior to the issuance of CER units. These requirements are articulated in the Kyoto Protocol and in subsequent decision taken during the Conference and Meeting of the Parties. These requirements can be summarised under the following categories: eligibility, additionality, acceptability, externalities, and certification.

Eligibility specifies that only A/R activities qualify under current rules. Afforestation would mean planting trees on land that has not been under forest cover for a period of at least 50 years (that is according to the host country's definition of forest). Reforestation would mean planting trees on land that has previously carried forest but the forest was recently removed or degraded.

According to the Kyoto Protocol and several Carbon credit schemes, the concept of additionality means a Carbon reduction emission project is "additional" only when it was developed solely for the mitigation of climate change; i.e. projects implemented under a "business as usual or required by other laws and regulations" set of management actions are not considered. Acceptability stipulates that all projects must contribute to sustainable development based on a country's criteria (Minang, 2007). Externalities require all projects to carry out impact assessment study and present impact mitigation strategies if need be. Certification means that the project must be independently verified and certified.

The revenues of CDM constitutes the largest source of mitigation finance for developing countries (World Bank, 2010). Over the 2001 to 2012 period, CDM projects raised $ 18 billion ($ 15 billion to $ 24 billion) in direct Carbon revenues for developing countries. Actual revenues will depend on the price of Carbon. It was estimated that some $ 95 billion in clean energy investments benefited from CDM over the 2002-08 period. By 2018, CDM had 7,803 registered projects in 140 countries (Box 3.1)(including 36 of the worlds 48 least developed countries), invested about $ 303.8 billion in climate and sustainable development projects and achieved almost 2 billion tonnes of CO2eq reduction in the developing world (UNFCCC, 2018a).

Box 3.1 CDM forestry project examples in Africa

The Nile Basin Reforestation Project in Uganda was one of the first forest projects to be designed and implemented under CDM in Africa and was implemented by Uganda's National Forestry Authority in association with local community organizations. The growing trees will absorb CO2 from the atmosphere, in exchange for revenues from the World Bank BioCarbon Fund paid to Uganda National Forestry Authority and the communities. The project was expected to establish a plantation of Pine and mixed native species over a surface area of 2,137 hectares, in the Rwoho Central Forest Reserve, grasslands that were degraded due to deforestation and erosion. This project was an example of SFM in a country that currently only has a few thousand hectares of timber plantations remaining. The project was also expected to generate about 500 jobs during planting and 200 jobs during management of the forest, and an estimated 117,626 tCO2e GHG after the first 20 years (UNFCCC, 2010).

Ethiopia also hosted one of the first large-scale CDM forestry projects - the Humbo Assisted Regeneration project. The project involved the restoration and replanting of indigenous tree species on 2,728 hectares of degraded mountain forest area that has been stripped for fuel wood in south-western Ethiopia. The project is estimated to remove about 28,773 tCO2e annually for the first 20 years (UNFCCC, 2018b).

Kenya has also hosted forestry projects under the CDM. For example, the Aberdare Range/Mt. Kenya Small Scale Reforestation Initiative, that was designed to reforest degraded forest lands in the Aberdare Range and Mt. Kenya Regions. Net anthropogenic GHG removals by sinks of the proposed small-scale A/R CDM project activity were estimated at 148,539 tCO2e (UNFCCC, 2011).

3.2.1 Role of Clean Development Mechanism in climate change mitigation

According to Burniaux and Barker (2009), crediting mechanisms like the CDM could play three important roles in climate change mitigation :

i. Improve the cost-effectiveness of GHG mitigation policies in developed countries;

ii. Help to reduce "leakage" (Carbon leakage) of emissions from developed to developing countries. Leakage is where mitigation actions in one country or economic sector result in another country's or sector's emissions increasing, e.g., through relocation of polluting industries from Annex I to non-Annex I countries (IPCC, 2007b); and

iii. Boost transfers of clean, less polluting technologies to developing countries.

As Burniaux and Barker (2009) further opined, the cost-saving potential of a well-functioning crediting mechanism appears to be very large. Compared to baseline costs (i.e., costs where emission reductions only take place in Annex I countries), if the cap on offset use was set at 20%, one estimate suggests mitigation costs could be halved. This cost saving, however, should be viewed as an upper bound: it assumes no transaction costs and no uncertainty on the delivery of emission savings. Annex I countries who stand to gain most from crediting include Australia, New Zealand, and Canada. In this economic model, non-Annex I countries enjoy a slight income gain from exploiting low cost emission reductions.

3.2.2 Difficulties with the Clean Development Mechanism

(i) Carbon leakage

In theory, Carbon leakage may be reduced by crediting mechanisms (Burniaux and Barker, 2009). In practice, the amount of Carbon leakage depends partly on the definition of the baseline against which credits are granted. The current CDM approach already incorporates some leakages. Thus, reductions in Carbon leakage due to the CDM may, in fact, be small or even non-existent.

(II) Additionality, transaction costs and bottlenecks

In order to maintain the environmental effectiveness of the Kyoto Protocol, emission savings from CDM must be additional (World Bank, 2010). Additionality is a principal condition for the eligibility of a project under CDM. A project is additional if it reduces GHG emissions below those that would have occurred in the business-as-usual scenario. Without additionality, CDM amounts to an income transfer to non-Annex I countries (Burniaux and Barker, 2009). Additionality is, however, difficult to prove, being the subject of vigorous debate. Burniaux and Barker (2009) further observed on the large transaction costs of establishing additionality. It must also be noted that assessing additionality has created delays (bottlenecks) in approving CDM projects. According to the World Bank (2010), there are significant constraints to the continued growth of CDM to support mitigation in developing countries.

(iii) Incentives

CDM rewards emissions reductions, but does not penalize emission increases (Burniaux and Barker, 2009). It therefore comes close to being an emissions reduction subsidy. This can create a perverse incentive for firms to raise their emissions in the short-term, with the aim of getting credits for reducing emissions in the long-term.

Another difficulty is that CDM might reduce the incentive for non-Annex I countries to cap their emissions. This is because most developing countries benefit more from a well-functioning crediting mechanism than from a world ETS, where their emissions are capped. This is true except in cases where the allocation of emissions rights (i.e., the amount of emissions that each country is allowed to emit) in the ETS is particularly favourable to developing countries.

(iv) Local resistance

While C in CDM stands for Clean, most projects might be better defined with B from Big, from large hydropower to HFC or waste to energy and clean coal projects (which all together account for the majority of credits generated through CDM). The argument in favour of CDM is that it brings development to the South. However, in all continents, the mainly Big Development it stands for is resisted by local people in those countries where the projects are to be implemented (Carbon Market Watch, 2012).

A global coalition of researchers published a large report on African civil society resistance to CDM projects all over the continent (Bond et al., 2012). In New Delhi, India, a grassroots movement of waste pickers is resisting another CDM project on what the makers call ‘the waste war’ in Delhi. In Panama, a CDM project is blocking peace talks between the Panamanian government and the indigenous population (Carbon Market Watch, 2012). Civil society groups and researchers in both North and South have complained for years that most CDM projects benefit big industries, while doing harm to excluded people. As local protests against CDM projects are arising in every continent, the notion that CDM ‘brings development to the South’ is contested (Carbon Market Watch, 2012).

(v) Market deflation

Most of the demands for CER from the CDM comes from the European Union Emissions Trading Scheme, which is the largest Carbon market. In July 2012, the market price for CER fell to new record low of €2.67 a ton, a drop in price of about 70% in a year. Analysts attributed the low CER price to lower prices for European Union emissions allowances, oversupply of European Union emission allowances and the slowing European economy (Chestney, 2012).

In September 2012, The Economist described the CDM as a “complete disaster in the making” and “in need of a radical overhaul”. Carbon prices, including prices for CERs, had collapsed from $ 20 a ton in August 2008 to below $ 5 in response to the Eurozone debt crisis reducing industrial activity and the over-allocation of emission allowances under the European Union ETS (The Economist, 2012). The Guardian reported that the CDM has “essentially collapsed”, due to the prolonged downward trend in the price of CERs, which had been traded for as much as $ 20 (£ 12.50) a ton before the global financial crisis to less than $ 3. With such low CER prices, potential projects were not commercially viable (Harvey, 2012).

In October 2012, CER prices fell to a new low of € 1.36 a metric ton on the London ICE Futures Europe exchange (Vitelli, 2012). In the same period, Thomson Reuters Point Carbon calculated that the oversupply of units from CDM and Joint Implementation would be 1,400 million units for the period up to 2020 and Point Carbon predicted that CER prices would to drop from € 2 to 50 cents (Thomson Reuters, 2012). On 12 December 2012, CER prices reached another record low of 31 cents (Allan, 2012). Bloomberg reported that CER prices had declined by 92 percent to 39 cents in the 2012 year (Bloomberg, 2013).

However Schwieger et al. (2019) reported a remarkable rebounding of the CER prices, especially from 2016, when it rose from multi-year lows of less than $ 6/tCO2 to a 10-year peak of $ 31/tCO2 in April 2019, which was a result of much-needed supply restrictions enabled by the Market Stability Reserve). In fact, the High-Level Commission on Carbon prices estimated that Carbon prices of at least $ 40–80/tCO2 by 2020 and $ 50–100/tCO2 by 2030 are required to cost-effectively reduce emissions in line with the temperature goals of the Paris Agreement (Schwieger et al., 2019).

3.2.3 Status of forest-based Clean Development Mechanism projects in Africa

In the context of Africa, the share of African CDM projects is still very low. By the end of 2014, only 191 African CDM projects were registered, representing a share of only 2.51% of the total 7,399 registered projects worldwide. South Africa, Kenya, Egypt, Morocco registered the highest number of projects with 55, 20, 19, 15 projects respectively. Only 17 out of the 191 are forestry projects (A/R). Uganda and Kenya are hosting 7 and 5 of the forestry projects respectively. The largest share of CDM investors active on the African Carbon market are based in Japan, the United Kingdom and Germany. The investors operate in very diverse sectors. The largest group consists of entities whose main business is the Carbon market. A second category of investors are from public institutions such as national governments and ministries, mainly from European countries. Another large group of investors are organisations from the energy sector, including utilities, energy companies as well as businesses from the oil and gas sector. Investors are comprised of both private and public entities. However, the private sector plays a pivotal role: 75% of the investors involved in African projects are private entities (Kreibich et al., 2017).

3.2.4 Challenges of low uptake of forest-based Clean Development Mechanism projects in Africa

The low uptake of CDM forestry projects in Africa is associated with a combination of constraints. These include, but are not limited to:

(i) Weak institutional capacity

Lack of institutional and organizational capacities to establish and manage Carbon projects, and to establish links with international buyers, is a major weakness for the success of CDM A/R projects in Africa. Adequate national institutional capacity is required to mobilize relevant stakeholders, in both the private and public sectors, and to facilitate the establishment of viable carbon projects (Jindal et al., 2008).

(ii) Weak governance capacity

A/R projects for the Carbon markets have long gestation periods and any investment is likely to be risky, unless backed by sustained economic and political stability. Good governance practices at the national and local levels are essential to attract and support international Carbon project investments in the long-term (Jindal et al., 2008).

(iii) Complex land tenure systems

Tenure security is crucial for the implementation of A/R projects. Without clear and defendable rights to land and forests and/or Carbon rights, service providers cannot make any trustworthy long-term engagement to supply Carbon credits (Jindal et al., 2008). On the demand side, investors may have little or no confidence to invest in project activities with unclear tenure arrangements. In Africa, land tenure is complex and characterized by: (i) prevalent disconnect and conflict between customary and statutory land rights; (ii) legal pluralism i.e. lack of uniform set of statutory laws regarding tenure; (iii) tree tenure i.e. contested position over using tree planting as a mechanism to claim rights over land; and (iv) and the challenge in using abandoned land (Unruh, 2008).

(iv) Financial constraints

There are a number of financial weaknesses associated with the design and implementation of CDM A/R projects in Africa. A/R Carbon projects take long time to start receiving revenue from emission credits generated. This delay in return serves as a disincentive for landowners to engage in CDM A/R projects. This is coupled with the fact that many project proponents lack investment capital to cover the start-up and other associated costs over the many years before income from Carbon sales starts to ensue (Thomas et al., 2010). Project proponents in Africa are often discouraged by the transaction cost involved in designing and operationalizing A/R Carbon projects. Transaction costs include cost of negotiating, contracting, implementing and monitoring project activities. These are different cost portions that need to be covered by upfront investments before actual sales of emission credits proper. CDM A/R projects with multiple contract holders, which are often the situation for projects in Africa, incur high transaction cost as compared to when dealing with single landholders (Thomas et al., 2010; Jindal et al., 2008).

(v) Limited technical capacity

The CDM A/R project development process is complex for African countries. The project development process is required to respond to several prerequisites including the establishment of a baseline, proof of additionality, selection of appropriate methodology, managing leakage and non-permanence, and the clarification of monitoring and validation procedures. There is lack of national technical capacity to respond to the technical demands of the CDM A/R process without reliance on expensive external technical support (Desanker, 2005; Fobissie et al., 2017). However, technical capacity related to forest Carbon project development and implementation is being enhanced progressively by national and international governmental and non-governmental initiatives.

3.2.5 Outlook of forest-based clean development mechanism in Africa: Transitioning to sustainable development mechanism

African countries have the potential to develop and implement A/R forest Carbon projects through CDM. For the past decades, countries in Africa have been making efforts to overcome the challenges hindering their uptake of CDM projects. Article 6 of the Paris Agreement established the sustainable development mechanism (SDM) as a new Carbon market instrument for the period after 2020. Its purpose inter alia is to replace the existing mechanisms under the Kyoto Protocol, for example CDM, with a more effective climate tool. The building blocks to operationalise SDM are underway and CDM provides a valuable basis on which to learn and improve, as well as some valuable infrastructure and setting to adapt. CDM experience in Africa, could provide lessons for the design of the new SDM that will enable and boost A/R forest Carbon project development in Africa. This is relevant for the countries of the region to meet their emission reduction commitments under the Paris Agreement (UNFCCC, 2015; Carbon Market Watch, 2017).

3.3. Reducing emissions from deforestation and forest degradation

REDD+ is a mechanism for supporting the voluntary efforts of developing countries to mitigate climate change by reducing emissions from deforestation and forest degradation, promoting conservation and the sustainable management of their forests, and enhancing forest Carbon stocks (UNFCCC, 2008). In addition, REDD+ is an incentive for developing countries to protect and better manage their forest resources as they provide financial value on the carbon that is sequestered in the forests of these countries (UNFCCC, 2008).

Indeed, REDD+ envisages a mechanism in which countries elect to reduce national level deforestation to a level below an agreed baseline and receive post facto compensation or rewards. Key principles for REDD+ agreed in Cancun, Mexico in 2010 (Decision--/CP.16) indicate the following:

i. Participation by countries is voluntary;
ii. Compensation is subject to monitoring, reporting and verification;
iii. Reductions are obtained through "reducing emissions from deforestation", "reducing emissions from degradation", "conservation of forest Carbon stocks", "sustainable management of forests" and "enhancement of Carbon stocks"; and
iv. REDD+ should generate sustainable development benefits.

3.3.1 Key decisions on design and implementation of reducing emissions from deforestation and forest degradation

Decision 1/CP 16 requests all developing countries aiming to undertake REDD+ to develop the following elements (UNFCCC, 2014):

(i) A national strategy or action plan with regards to REDD+ implementation

National REDD+ strategies or action plans present the vision of a country in terms of REDD+ implementation. It outlines all the necessary enabling and sectoral activities to be put in place to reduce emissions from the forestry sector. Enabling activities include among other: land use planning, strengthening of policy development and implementation, sensitisation and awareness creation about REDD+ etc. Examples of sectoral activities are actions taken on the ground in the agriculture, wood fuel, mining, infrastructure, livestock and forestry sectors to reduce deforestation and forest degradation. Many countries in Africa such as Ghana, DRC, Republic of Congo, Cameroon, Liberia, Zambia, Ethiopia etc., have already developed their REDD+ strategies.

(ii) A national forest reference emission level and/or forest reference level

Reference levels are key components for any national REDD+ programme and critical in at least two aspects. Firstly, they serve as a baseline for measuring the success of REDD+ programmes in reducing GHG from forests. Secondly, they are available for examination by the international community to assess the reported emission reductions or enhanced removals. In that sense, they establish the confidence of the international community in the national REDD+ programme. The results measured against these baselines may be eligible for results-based payments. Setting the reference levels too relaxed will erode the confidence in the national REDD+ programme, while setting them too strict will erode the potential to earn benefits with which to operate the national REDD+ programme. Very careful consideration of all relevant information is therefore crucial.

A reference level is expressed as an amount, derived by differencing a sequence of amounts over a period of time. For REDD+ purposes, the amount is expressed in CO2-equivalents (CO2e) of emissions or removals per year. If the amounts are emissions, the reference level becomes a reference emission level (REL). However, these RELs are seen by some as incomplete as they do not take removals into account. Reference levels are based on a scope – what is included? – a scale – the geographical area from which it is derived or to which it is applied – and a period over which they are calculated (Minang, 2007). The scope, the scale and the period can be modified in reference to national circumstances: specific conditions in the country that would call for an adjustment of the basis from which the reference levels are constructed. A reference level can be based on observations or measurements of amounts in the past, in which case it is retrospective, or it can be an expectation or projection of amounts into the future, in which case it is prospective (UNFCCC, 2009). Reference levels eventually have national coverage, but they consist of a number of sub-national reference levels. For example, forest degradation may have a reference emission level for commercial selective logging and another one for extraction of minor timber and firewood for subsistence use by rural communities. Effectively, every identified driver of deforestation or forest degradation must be represented in one or more REL(s). Similarly, for reference levels for enhancement of Carbon stocks, there may be a reference level for plantation timber species and another for natural regeneration, possibly stratified by ecological regions or forest types.

(iii) A robust and transparent national forest monitoring systems

In Decision 2/CP.15 of the UNFCCC, countries are requested to develop NFMS that support the functions of MRV of actions and achievements of the implementation of REDD+ activities. NFMS are the key component in the management of information for national REDD+ programmes. A fully functional monitoring system can go beyond the requirements posted by the UNFCCC to include issues such as a record of projects and participants, and evaluation of programme achievements and policy effectiveness. It may be purpose-built or integrated into existing forest monitoring tools.

It is suggested that measurements are suggested to be made using a combination of remote sensing and ground-based observations. Remote sensing is particularly suitable for assessment of forest areas and stratification of different forest types. Ground-based observations, include forest surveys to measure the Carbon pools used by IPCC, as well as other parameters of interest such as those related to safeguards and eligible activity implementation (UNFCCC, 2010).

(iv) Safeguards

In response to concerns over the potential for negative consequences resulting from the implementation of REDD+, the UNFCCC established a list of safeguards that countries need to address, respect, promote and support in order to guarantee the correct and lasting generation of results from the REDD+ mechanism. These safeguards are (UNFCCC, 2010) as follows:

- Actions that complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements;
- Transparent and effective national forest governance structures, taking into account national legislation and sovereignty;
- Respect for the knowledge and rights of indigenous people and members of local communities, by taking into account relevant international obligations, national circumstances and laws, and noting that the United Nations General Assembly has adopted the United Nations Declaration on the Rights of Indigenous Peoples;

- Full and effective participation of relevant stakeholders, in particular indigenous people and local communities;
- Actions are consistent with the conservation of natural forests and of biological diversity, ensuring that the actions are not used for the conversion of natural forests, but are instead used to incentivize the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits;
- Actions to address the risks of reversals; and
- Actions to reduce displacement of emissions.

In essence, the REDD+ safeguards help to consider national circumstances and respective capabilities, recognize national sovereignty and legislation, relevant international obligations and agreements as well as respecting gender considerations. The safeguards information systems are developed to provide transparent and consistent information that is accessible to all stakeholders and one that is regularly updated. Countries are required to regularly provide a summary of information on how these safeguards were addressed and respected. This could come in the form, for instance, of explaining the legal and regulatory environment with regards to the recognition, inclusion and engagement of indigenous peoples, and information on how these requirements have been implemented.

Decision 12/CP.19 established that the "summary of information" on the safeguards will be provided in the National Communications to the UNFCCC, which will be once every four years for developing country Parties. Additionally, and on a voluntary basis, the summary of information may be posted on the UNFCCC REDD+ web platform (UNFCCC, 2011). As of 2021, only three countries in Sub Saharan Africa have submitted information on safeguards to the Secretariat that is Cote d'Ivoire, Ghana and Zambia.

3.3.2 The three phases of reducing emissions from deforestation and forest degradation

A three-phased approach was adopted for REDD+ implementation under the agreements reached in Cancun, Mexico, in 2010 (paragraph 73, Decision 1 CP.16), namely readiness phase (Phase 1), investment and implementation phase (Phase 2), and performance-based payment phase (Phase 3). In Phase 1, readiness actions such as planning, establishment of FRLs or RELs, MRV and benefit-sharing frameworks, development of REDD+ strategy and safeguard information systems should be initiated. Other readiness activities such as capacity-building, institutional and policy developments, demonstrations, piloting, and investments can be continued throughout Phase 1 and into Phase 2. Phase 2 includes implementing national policies and measures, and national strategies or action plans. These might involve additional capacity building, technology development and transfer and results-based demonstration activities. In phase 3, there should be a full-fledged REDD+ implementation characterized by quantified emission reduction, result-based payments and benefit-sharing of proceeds (Minang et al., 2014).

Since the first discussion on REDD+ in 2005, and particularly at COP-13 in 2007 and COP-15 in 2009, many concerns have been raised on aspects of REDD+ programme. Though it is widely accepted that REDD+ programme will need to undergo full-scale implementation, many challenges need to be resolved before this can happen. One of the key issues is how reduced emissions and the removal of GHG will be monitored consistently on a large scale, across a number of countries, each with separate environmental agencies and laws. Other issues are related to the conflict between REDD+ approach and existing national development strategies, the participation of forest communities and indigenous peoples in the design and maintenance of REDD+, the programme's funding, and the consistent monitoring of said funding to ensure equitable distribution across the programme members. In response to the concerns, COP responded by establishing REDD+ safeguards (discussed earlier), though the mechanisms themselves face criticisms for being overly generic, non-enforceable, and failing to establish a specific set of requirements for participation in REDD+ programme. However, if well designed and implemented, REDD+ approach will not only help developing countries that are rich in forests to participate in achieving the global climate change mitigation objective, but it will also lead to the non-Carbon benefits that will make contributions to climate change adaptation (Fobissie et al., 2019). Box 3.2 is a summary of the importance of REDD+ to Africa.

Box 3.2 Why is REDD+ important for Africa?

The continent's rapid deforestation is threatening the flow of key ecosystem goods and services at the local, national and global levels. Forests cover 675 million hectares of land accounting for 23% of Africa's total land area. Humid forests are particularly important in Central Africa, the Congo Basin being the second largest tropical rainforest in the world. At the same time, dry forests are important in the Sahel, Southeast and North Africa and represent 42% of tropical forest area in the continent. Eastern, Central and Southern Africa are endowed with the savannah woodlands, the most notable being the Miombo woodland–which is the most extensive tropical woodland formation in Africa. Forests provide crucial environmental goods such as wood, bushmeat and wild fruits, and services such as Carbon sequestration, biodiversity conservation, soil conservation and watershed protection. More than half of the continent's population rely directly or indirectly on forests for their livelihoods. In spite of this reality, in recent decades, Africa has experienced the highest rate of deforestation, i.e. 0.49% per year (AfDB, 2016). In addition, forest types, coupled with national circumstances such as deforestation and degradation rates and the potential for implementation and the levels of engagement in REDD+, vary by regions and countries. Consequently, African countries may pursue different approaches with regards to adoption and implementation of REDD+, and the types of primary REDD+ activities in which they may engage (Gizachew et al., 2017).

3.3.3 Status of Reducing Emissions from Deforestation and forest Degradation in Africa

African countries involved in REDD+ are making efforts to have the enabling conditions in place for effective REDD+ implementation. These efforts are also contributing to achieve the requirements of the UNFCCC regarding REDD+. African countries are in different phases of REDD+ presented in section 3.3.2, with support from either the FCPF or UN-REDD. More information on the status of REDD+ in Africa REDD+ countries with respect to the three phases can be obtained from FCPF and UN-REDD web pages.

In terms of operationalization of REDD+ on the ground, many African countries have developed REDD+ projects and programmes with support from bilateral, multilateral, and private sector partners. These projects are scattered all over Africa, and are at different levels of implementation. Details on projects in Africa, can be accessed from the International Database on REDD+ projects and programmes (https://www.reddprojectsdatabase.org/). The mitigation and non-Carbon potential of these projects are also available in the project and programme description in the database (Simonet et al., 2018).

3.3.4 Challenges of the implementation of Reducing Emissions from Deforestation and forest Degradation in Africa

REDD+ development and implementation in Africa is facing several challenges that are more or less related to the enabling environment for the design and implementation of the programme. Some key challenges include:

(i) Governance and institutional challenges

The governance of the forestry sector in Africa is characterized by poor institutional capacity and performance, weak forest conservation programmes and insecure land and forest tenure by indigenous and local communities. Furthermore, lack of cross-sectoral coordination of REDD+ and compatibility between REDD+ and other sectoral interests like agriculture and mining, are suggested to have impeded REDD+ implementation (Atela et al., 2016). In this regard, REDD+ implementation requires reforms in governance such as land tenure, cross-sectoral collaboration and institutions that address the rights and interests of a wide range of stakeholders, particularly local and indigenous communities (Mbow et al., 2012; Gizachew et al., 2017).

(ii) Financial challenges

The development and implementation of REDD+ require huge financing, that surpasses the capacity of African countries to mobilize at the national levels. Hence, ongoing REDD+ actions are dependent on external financing, which appears to be insufficient to respond to the funding requirements in REDD+ countries. In a context where external finance is available, national financial institutions in Africa often lack the capacity and competence to meet fiduciary standards, transparency and the capacity to manage large funds in efficient and transparent ways. An additional challenge is that REDD+ has not shown concrete indications to generate funds large enough to reduce business-as-usual activities, which include agriculture and wood extraction that would otherwise lead to deforestation or forest degradation (Gizachew et al., 2017).

(iii) Technical capacity

REDD+ countries require sufficient technical capacities to meet the payment-based requirements of REDD+. For example, the methodological guidance for monitoring recommends the use of a ground-based forest Carbon inventory, remote sensing or a combination of the two in estimating forest Carbon stocks and forest area changes. In Africa, forest inventory is characterized by a general lack of regular and frequent data collection, absence of standardized methods for data collection and lack of complete and up-to-date inventories. In addition, institutions that have forest information are poorly coordinated, and data are often scattered across agencies. In this regard, the prevalence of a capacity gap for monitoring forest Carbon in Africa could possibly limit the potential benefits from REDD+ in Africa (Romijn et al., 2012; Gizachew et al., 2017; Mbow et al., 2012).

3.3.5 Outlook of reducing emissions from deforestation and forest degradationin Africa

Despite the relevance of REDD+ to Africa, its implementation is facing a number of challenges. Progress has been slow and inadequate, and most African countries are still struggling to graduate from the readiness phase. Consequently, the much anticipated environmental, social and financial benefits do not seem to be accomplished, and the optimism of the early days of REDD+ appears to have been smashed. Evidently, governance, financial and technical challenges all represent significant roadblocks in implementing REDD+ on the ground. However, there are some reasons for optimism. Among others, the potential benefits of REDD+ (social, economic and environmental) provide strong incentives for governments and communities to invest in the mechanism (Mbow et al., 2012; Gizachew et al., 2017).

There is a need to mainstream REDD+ into economic development policies. This ensures sustainability and provides a possibility for REDD+ to address the drivers of deforestation, and prompts domestic financing, governance reforms and technical developments (Gizachew et al., 2017).

Some decades ago, many African countries lacked the capacity to monitor their forests and report Carbon emissions. Since the emergence of REDD+, some progress has been made in forest area and Carbon change monitoring through remote sensing. The increasing availability of free or low-cost technologies, should facilitate the data requirement of REDD+ implementation in Africa (Mbow et al., 2012; Gizachew et al., 2017).

The shared interests of African countries in REDD+ and the common features and challenges across the continent, are indications that robust cooperation is needed for representation on the UNFCCC negotiation platforms in order to illustrate their particular contexts and challenges (Gizachew et al., 2017).

Activity 7 Group work (20 minutes)

- Identify REDD+ projects in your country/sub region/region and evaluate its role in climate change mitigation and adaptation benefits.
- Describe the required enabling environment to support effective implementation of the identified projects.

3.4 Nationally Determined Contributions

3.4.1 Context of nationally determined contributions and climate change mitigation

NDCs are at the heart of the Paris Agreement and the achievement of long-term goals in as much as climate change action is concerned. NDCs encompass efforts by each country to reduce national emissions and adapt to the impacts of climate change (UNFCCC, 2019). The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve. According to the Agreement, Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions (UNFCCC, 2019).

Well-designed NDCs are a signal to the world that the country is doing its part to combat climate change and limit future climate risks. In preparing NDCs, countries are to follow a clear process in order to build trust and accountability with domestic and international stakeholders. A good NDC should be ambitious, leading to transformation in Carbon-intensive sectors and industry; clear, so that stakeholders can track progress and ensure countries meet their stated goals; and equitable, so that each country does its fair share to address climate change (WRI, 2017). A fair and ambitious contribution can be described in terms of the country's potential to act to the greatest extent possible, given its emissions responsibility, its emissions projections (including planned actions), its capabilities, and its vulnerability and capacity to adapt to climate change impacts. It should be a contribution that maximizes the opportunities presented by climate action in a way that is in line with broader SDGs (WRI, 2015).

Countries may explain fairness in terms of NDC development through multiple criteria, such as emissions responsibility (e.g., such as historical, current or projected future emissions per capita or total emissions), economic capacity and development indicators (such as GDP per capita), as well as relative costs and benefits of action, in line with their potentials to act (WRI, 2015).

Ambitions about NDC development can be demonstrated through evidence that the contribution goes as far as possible to realize the country potential to act and drive transformation in key sectors, like energy and forestry, while taking into account the country's economic development status, its resources, and other national characteristics. Countries may express ambitions through multiple criteria, such as: total mitigation potential based on technically and economically-feasible benchmarks for annual rate of emissions reductions, and other factors (WRI, 2015).

Because NDCs are at national level, each country decides its own appropriate contribution based on its national circumstances and capabilities. Consequently, an NDC must be linked to national priorities and processes. An NDC that exists in a vacuum– unmoored from other national priorities, policies and institutions–is unlikely to be implemented effectively or serve the country's objectives. A robust NDC will therefore link clearly to other national objectives, such as climate policies, adaptation planning processes such as National Adaptation Plans, or development plans or vision statements. Moreover, it will be consistent not only with climate-focused plans and policies, but also with those of key sectors (e.g. energy and forests) that drive emissions–or it will provide for a process to work towards this consistency over time (WRI, 2015).

A strong NDC will be backed-up by a political commitment at the highest level, with clear mandates and defined roles, responsibilities and timelines for design and implementation. Likewise, coordination among relevant institutions is essential and can improve efficiency and problem solving. It is also important to build knowledge and technical capacities, and to secure and manage the right resources. The NDC development and implementation process must be inclusive and transparent and reflect a range of stakeholder perspectives if it is to adequately respond to needs and gain long-term support.

NDCs may represent national aspirational goals that will require the implementation of specific policy instruments–sometimes through new legislation, regulation or executive order–so as to encourage changes in technologies, processes and practices that drive GHG mitigation and adaptation (WRI, 2017). The more clearly governments can articulate how their NDC goals will support policy interventions that will drive these changes, the more confidence stakeholders will have that the NDC is credible and that the government is serious about implementing it.

Countries should also consider the means of implementation–such as technology, finance and capacity building they will need in order to execute the NDC. For developing countries, this may also include international support, in addition to domestic resources. If all or part of the NDC will depend on international support, specificity on both the types and quantities of the support and what exactly it will achieve, can facilitate effective delivery of support and enhance accountability for both developed and developing countries.

It is important that NDCs be communicated transparently in order to understand the individual and aggregate impacts of countries' proposed commitments, including whether global emissions after 2020 will be in line with the goal to hold the increase in global average temperature below 20C. Determining the collective impact of all countries' NDCs requires an understanding of the assumptions and methodologies that underpin these commitments. Providing detailed information about an NDC can also be useful for enhancing domestic implementation by clarifying assumptions needed to implement the contribution and communicating those assumptions to domestic stakeholders. Additionally, communicating an NDC may help provide a better understanding of finance, capacity and technology needs, if relevant.

It is therefore imperative that NDCs be clearly communicated so that domestic and international stakeholders can anticipate how these actions will contribute to global emissions reductions and climate resilience in the future. NDCs should also articulate how the country is integrating climate change into other national priorities, such as sustainable development and poverty reduction, and send signals to the private sector to contribute to these efforts (WRI, 2017). In accordance with Article 4, paragraph 12 of the Paris Agreement, NDCs communicated by Parties shall be recorded in a public registry maintained by the Secretariat of the UNFCCC (UNFCCC, 2019).

Together, these climate actions determine whether the world achieves the long-term goals of the Paris Agreement and to reach global peaking of GHG emissions as soon as possible, and to undertake rapid reductions thereafter in accordance with best available science. This will make it possible to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century. It is understood that the peaking of emissions will take longer for developing country Parties, and that emission reductions are undertaken on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty, which are critical development priorities for many developing countries.

In developing NDCs, countries will need to intensify efforts to increase investments and innovation in sectors that could help close the gap between intentions and the goal before and after 2030 (Fobissie et al., 2019). One of such relevant sectors is the forestry sector, especially for countries in the tropics. The forestry sector is responsible for about one quarter of anthropogenic GHG emissions and is therefore a very important sector to meet the emission targets of countries especially as indicated in the NDCs (Bustamente et al., 2014).

In a study conducted by Fobissie et al., (2019), it is reported that forests are included in the mitigation and adaptation sections of almost all the NDCs of African countries that were analyzed in this study. This is an indication that the forestry sector is important within their NDCs as each of the countries established one or more goals in the forestry sector (Fobissie et al., 2019). The reviewed NDCs of these African countries, indicated that A/R activities are commonly employed to mitigate climate change (Fobissie et al., 2019). The high reference of A/R as a major contributor to Carbon emissions reduction in the NDCs of African countries, is a sign that many countries in Africa are making more efforts to restore degraded lands as compared to efforts to conserve and sustainably manage existing forests and standing trees.

i. According to WRI (2017) the benefits of developing an NDC that considers the forestry sector as Carbon sinks (hence playing an important role in climate change mitigation) include the following:
ii. Enabling each Party to compare its contribution regarding climate change mitigation with that of its peers (i.e. countries with similar national circumstances);
iii. Enabling each Party to address whether it is doing its fair share of the collective level of efforts required to avoid catastrophic climate change impacts;
iv. Explaining the link between climate action and SFM objectives;
v. Explaining how the contribution achieves synergies between mitigation and adaptation, for Parties that are including a mitigation component;
vi. The opportunity to explain why means of implementation (funding) is needed or has been provided to other countries that are rich in forest as part of the contribution;
vii. Recognition for existing domestic efforts and demonstration of leadership; and
viii. Enhanced credibility for the contribution, gained through a demonstrated willingness to be transparent about national circumstances.

3.4.2 Challenges in developing nationally determined contributions in African countries

Among the surveyed countries, 85% reported that they were challenged by the short time frame that was available to develop NDCs. Other challenges reported included difficulty to secure high-level political support, a lack of certainty and guidance on what should be included in the NDCs, and limited expertise for the assessment of technical options (UNFCCC, 2019). However, despite these challenges, less than a quarter of countries said they had received international support to prepare their NDCs, and more than a quarter indicated they were still applying for international support (New Climate, 2013). The NDC process and the challenges it presents are unique to each country and there is no “one-size-fits-all” approach or methodology. Despite these challenges, African countries were able to put forward their commitments in their NDCs,that were characterized by vagueness in their mitigation ambitions and adaptation aspirations, lack of cost estimates for achieving their adaptation and mitigation goals, absence of clarity on sources of funding and absence of up-to-date national GHG emissions records. Other challenges included mitigation commitments that exceeded current level of emissions and lack of coherence between some of the NDCs and national development plans and strategies.

Despite the mentioned challenged, a number of countries on the African continent have submitted their first revisions to the initial NDCs, some with improved ambition for emissions reduction.

3.4.3 Opportunities for developing nationally determined contributions

The Climate and Development Knowledge Network (2015) prepared a guide for developing NDC for Least Developed Countries, setting out an NDC approach that could provide economic and development opportunities. It included:

i. Showing that economic growth is compatible with low-Carbon and climate-resilient pathways, which will avoid lock-in to high Carbon-intensive infrastructure;
ii. Highlighting the adaptation-related benefits of mitigation actions, as well as other co-benefits including poverty alleviation, health, energy access and security;
iii. Capturing the potential for mitigation within planned and potential adaptation activities;

iv. Encouraging other countries to take equivalent action, increasing global ambition and reducing climate impacts; and

v. Attracting financial, capacity-building, technology transfer and other types of international support.

3.4.4 Integrating nationally determined contributions with national development planning

A report from Climate and Development Knowledge Network (2017) made the following recommendations to integrate international climate change commitments in the form of NDCs into national development planning:

i. NDCs should be consistent with national development policies;

ii. NDCs should follow SMART design principles;

iii. NDCs should have broad national support;

iv. NDCs should have clear political backing;

v. NDC development should have clear institutional leadership;

vi. National coordination for climate change and development actions should exist;

vii. NDC institutions should respond to local development needs;

viii. NDC spending should be part of national budget planning;

ix. NDC spending should be monitored and reported; and

x. NDC spending should be subject to national oversight and scrutiny.

Activity 8 Group work (30 minutes)

Discuss forest-based related commitments in the NDCs of African countries.

Discuss the factors that are necessary to enhance the implementation and achievement of NDC objectives in your country/sub-region..

3.4.5 Forest-based nationally determined contributions in Africa

Forestry sector interventions are well represented in the climate change mitigation and adaptation commitments that many African countries made to the international community towards achieving the objectives of the Paris Agreement. A/R interventions are referenced by 77% of the countries as relevant for achieving their commitments. Key A/R activities presented in the NDCs include agroforestry, tree planting, revegetation, drought-resistant forest species, national reforestation programmes, assisted and natural regeneration among others. About 90% and 75% of East and West African countries respectively, referenced A/R as a key activity for climate change mitigation. In terms of forest types, the NDCs of 92% and 80% of dry and Mediterranean forests countries respectively, mentioned A/R activities as relevant for climate change mitigation. Forest management is also critical for the implementation of the NDCs of African countries. Some activities highlighted in the NDCs include sustainable/improved forest management, fire management, ecosystem resilience activities, land management plans, reduced impact logging, certified logging, community forest management among others (Fobissie et al., 2019; Fobissie et al., 2017).

3.4.6 Enabling conditions for nationally determined contributions implementation in Africa

The successful implementation of NDCs in Africa requires countries to consider a number of measures. The measures include but are not limited to the following:

i. The NDCs show clear origin and links to sectoral development priorities. Thus, design and implementation should be strongly linked to existing sectoral development plans and strategies to ensure coherence and effective implementation and resource management (ACPC, 2018);

ii. The private sector has a major role to play in the implementation of NDCs in Africa. Thus, there is a need to create an enabling regulatory and policy framework to mobilise private sector entities. For example, ingredients of such enabling environment include favourable fiscal policies, economic and financial incentives, financial guarantees to promote long-term investments (Horstink et al., 2019);

iii. Proper costing of NDCs is very important as it is impairing implementation efforts. NDCs of African countries are deficient in terms of presenting the detailed cost of implementing their commitments (Fobissie et al., 2017). Proper costing is important for mobilising financial resources, prioritisation and planning;

iv. The implementation of the NDCs of African countries depends hugely on external financing. High level of financial resource mobilisation is relevant. Providing technical support for climate finance tracking, improving planning and formulation of bankable projects in order to access climate funds is necessary (Fobissie et al., 2017; ACPC, 2018); and

v. Sufficient capacity and up to-date technology is required for NDC implementation, and African countries are lagging in these aspects (Fobissie et al., 2017). As such, countries need to carry out proper capacity and technology needs assessment, to enable partners to tailor their support for effective implementation. Furthermore, there is a need to build capacity and skills for mainstreaming climate change into development policies and practices, defining and implementing, monitoring and evaluating technology transfers for climate change mitigation and adaptation (ACPC, 2018).

In the NDCs implementation process, countries are progressing differently in the targeted sectors related to resource mobilisation, technology transfer, implementation etc. Thus, there is a need for strengthening platforms for sharing knowledge, information and best practices over the short, medium and long term (ACPC, 2018).

3.4.7 Outlook of forest-based nationally determined contributions in Africa

The forestry sector interventions and activities are well represented in the adaptation and mitigation approach in the NDCs of African countries. The forestry sector is a key contributor to GHG emissions in Africa. The sector is already experiencing the impacts of climate change throughout the different regions of the African continent. Furthermore, the sector is relevant for food security, poverty alleviation and national development for many countries in the continent. The NDCs clearly stress the need for financial support, technology transfer and capacity building assistance, in order to implement and meet all or part of their intended contributions. Detailed information about the financial, technology and capacity building needs are absent in many of the NDCs of African countries (ACPC, 2018; Fobissie et al., 2017).

There is significant overlap between mitigation and adaptation interventions in the NDCs of African countries in relation to the forestry sector. This is an important opportunity for African countries to re-organize mitigation and adaptation processes in their respective strategies and policy frameworks for synergy outcomes. For example, in the adaptation strategies and plans, priority should be given to adaptation activities that exhibit the potential to deliver mitigation benefits, and vice-versa (Fobissie et al., 2019).

African countries should be cautious when making requests for financial support in future NDCs revisions and updates. Today, mitigation finance falls short of what is needed to deliver ambitious targets. There are no clear signals at the international levels on how funds will be generated, distributed and sustained to support the implementation of NDCs, especially for developing countries (Fobissie et al., 2019).

In many African countries, complex political economic situations drive competition between sectoral policies and interests. This calls for transformational changes to achieve any meaningful emission reductions from the forest sector. Following their national contribution pledges, governments should be able to initiate and facilitate transformational changes i.e. changing from the "business as usual" conditions through changes in economic interests and power relations. To achieve results in an efficient and effective manner, it is important to break the sectoral barriers, for example, between agriculture and forestry through a holistic and cross-cutting approach when fixing emission reduction targets (Fobissie et al., 2019).

Summary

In this chapter, we have learned about CDM, REDD+ initiatives and NDCs in the context of Africa.

We touched issues related to their roles in climate change mitigation, their challenges and opportunities in terms of policy and practice, in the context of Africa.

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https://unepdtu.org/impact/?fwp_status_project=current.

Chapter 4. Non-Forest Climate Mitigation Initiatives And Other Approaches

4.1 Chapter overview

This chapter discusses non-forest climate change mitigation initiatives, as well as other major approaches that are fundamental to climate change mitigation options. It covers non-sectoral climate change mitigation measures, alternative livelihoods and resource substitution and efficiency. It specifically addresses the following objectives:

i. To provide detailed information on sectoral climate change mitigation measures, alternative livelihoods (alternative to forests) as climate change mitigation measures; and

ii. To provide resource substitution and efficiency as a mitigation measure.

Learning outcomes

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

i. Describe sectors other than forestry, where climate mitigation approaches apply; and

ii. Explain non-forest-based mitigation initiatives and measures.

Activity 9. Brainstorming (20 minutes)

1. Discuss forest-based related commitments in the NDCs of African countries.
2. Discuss the factors that are necessary to enhance the implementation and achievement of NDC objectives in your country/sub-region..

4.2 Non- forest-based climate change mitigation measures

Apart from the forestry sector, there is immense potential for other sectors such as agriculture, transport, energy, industry in African countries to contribute to climate change mitigation. These sectors contribute in different ways to GHG emissions. The measures to mitigate climate change in these sectors, revolve strongly around energy substitution and energy efficiency.

(i) Agriculture sector

Agriculture produces more GHG emissions than any other sector in Sub-Saharan Africa. FAO (2015) projected that direct agricultural emissions in Sub-Saharan Africa will increase by a third between 2012 and 2050, from 600 million to 800 million tCO2e. The main source of projected growth is from livestock (ODI, 2015), contributing more than 70% of the region's GHG emissions (ILRI, 2017). Livestock production system in Sub—Saharan Africa are mainly grazing-based. Other sources of emissions in the agriculture sector include (ODI, 2015):

- Clearing of forests to expand pasture and cropland;
- Burning of savannah;
- Cropland management and cultivation practices;
- Exposure of the soil through poor cultivation; and
- Draining and cultivation in wetlands.

In order to reduce emissions in the agricultural sector, the most important assets and processes to manage are: (i) livestock breeds and livestock diets; (ii) crop production techniques and processes; and (iii) post-harvest storage, transport, and processing facilities (see ODI, 2015, for further information).

(ii) Energy sector

According to the International Energy Agency (IEA) (2014), total consumption of wood fuel in Sub-Saharan Africa, including what was consumed directly by households and that used to produce charcoal, amounted to 658 million tons in 2012, or 0.5% of the total available biomass stock of 130 Gt. It is difficult to estimate the overall level of GHG emissions produced by biomass burning. If harvested and consumed at a sustainable rate, biomass is a renewable resource and could have a net zero emission or even negative impact on GHG emissions. However, if harvested unsustainably, biomass consumption can contribute to climate change through deforestation and forest degradation (ODI, 2015).

GHG emissions can be reduced along the entire wood fuel and charcoal value chains, from sustainably managing the tree resources, better kilns for charcoal making, and use of energy efficient stoves. The first asset to manage is the forest Carbon stock itself, which is presented in the forest mitigation section. Other important measures to reduce emissions include improved charcoal production processes and cooking technologies (ODI, 2015).

Energy consumption makes a big component of emissions from other sectors. As a result, many opportunities to reduce emissions from energy, involve actions within other sectors to either switch to lower-emissions fuel sources or adopt more energy efficient technologies and practices. These will be presented in the other subsections - manufacturing, construction, and transport. Here focus will be made on biomass energy and electricity generation (ODI, 2015).

In 2012, electricity generation in Sub-Saharan Africa (excluding South Africa) accounted for approximately 63 million tCO2e, only 2% of the region's total GHG emission. Emissions from electricity are produced primarily where fossil fuels are used for generation. As electricity access and generation are expanded in SSA, it will be important to ensure that emission levels remain low. The main assets and processes to manage include the fossil fuel-fired power plants, increase renewable energy investments (wind, solar, hydropower and sustainable biomass use) and investments in transmission and distribution infrastructure (ODI, 2015). Efforts are underway to establish solar generation plants on the continent. This has benefitted from falling unit costs for solar panels. Sustainable rural bioenergy solutions in Africa are described in Box 4.1.

Box 4.1: Energy substitution in Africa: Case of sustainable rural bioenergy solutions in Africa

Southern African countries possess substantial sugarcane industries that could also be significant sources of sustainable heat, power and biofuels. The Southern Africa Centre for Renewable Energy and Energy Efficiency has specifically identified the potential for sugarcane bioenergy development in Eswatini (formerly Swaziland), Malawi, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe. Substantial potential exists to scale up the sustainable production of bioenergy from sugarcane cultivation in all seven countries. An estimated 1.4 billion litres of ethanol could be produced at an average cost of $ 0.71 per litre of gasoline equivalent within the 554,000 hectares of land already cultivated with sugarcane in the seven countries. Land for sugarcane cultivation could expand as much as nine-fold, to some 5.1 million hectares of rain-fed land without irrigation, while bioenergy output could expand to some 72 billion litres of ethanol, at prices highly competitive with gasoline, and 156 terawatt-hours of electricity per annum.

Source: IRENA (2019)).

(iii) Transport sector

In Africa, the GHG emissions resulting from fossil fuel combustion put the transport sector at the top with 42% share of total emissions from fuel consumption. Road transport alone accounts for 50% of the total transport sector emissions, while the other 50% comes from aviation, maritime transport and railways. Almost all the NDCs of countries indicated that the transport sector is relevant for their contribution to the global climate change mitigation effort. The three most common mitigation actions proposed in the African transport sector's NDCs are: the acquisition of hybrid mass rapid transportation systems; the promotion of a shift from fossil fuel powered transport to low Carbon biofuels and policy formation; and legislation and implementation of transport codes and low Carbon emissions standards (Gicheru and Nkem, 2016). Other mitigation opportunities in the transport sector relate to reducing traffic congestion in urban areas. Development of green transport system in Africa is shown in Box 4.2.

Box 4.2: Development of green transport systems in Africa: Case of Sugarcane bioenergy in Southern Africa

Emissions from the transport sector in South Africa account for 10.8% of the country's total GHG emissions. In addition to these direct emissions arising from the combustion of fossil fuels, there are indirect emissions from the production, refining and transportation of fossil fuels. Continued growth within the transport sector, is likely to have an increasing impact on land resources, water quality, air quality and biodiversity. To address the significant contribution of the transport sector to national GHG emissions, the government through the Department of Transport has developed a Green Transport Strategy, which aims to minimize the adverse impacts of transport on the environment, while addressing current and future transport demands. The strategy underpinned by sustainable development principles will promote green mobility to ensure that the transport sector supports the achievement of green economic growth targets and the protection of the environment. The strategy will: support the low Carbon transition of the sector, including the development of policies that promote energy efficiency and emission control measures in all transport models; facilitate the sector's transition to climate resilient transport system and infrastructure; promote behavioural changes towards sustainable mobility alternatives through information, education and awareness creation.

Source: RoSA (2018)

(iv) Extractives industry

Many of the GHG emissions associated with the extractives sector are downstream emissions, particularly in electricity generation and transportation. The major sources of direct emissions from the extractives industry are (ODI, 2015):

Fugitive emissions: Fugitive emissions from oil, gas and coal mining operations represent 7.3% of total GHG emissions in Sub Saharan Africa. Fugitive emissions result from the liberation of stored GHGs during mining of oil, gas and coal. Traditionally, CH_4 from coal mining has been flared, emitting significant GHGs. CH_4 and N_2O also escape through oil and gas production via leaking equipment, natural gas transmission, distribution lines and storage facilities (ODI, 2015);

Energy used in production: Through the processes required to produce fossil fuels and minerals, the extractives sector is a major producer of GHG emissions in Sub Saharan Africa (Climate and Development Knowledge Network, 2014). In Botswana and Namibia, for instance, emissions from energy used in mining and quarrying account for 80% of national emissions from industrial energy use, and in Zimbabwe for 18.6% (IPCC, 2012). Most of this energy comes from the direct consumption of fossil fuels by power heavy machinery used for excavation and the vehicles used for transportation (ODI, 2015).

Mitigation opportunities in the extractives sector targets:

The energy consuming technologies and processes of extractives operations: Upgrading to newer and more efficient technologies offers an opportunity to reduce GHG emissions in the mining and quarrying processes and fossil fuel production processes; and

The fuels used by the extractives sector: Switching from diesel-powered machinery to low-Carbon energy sources is an important GHG mitigation strategy for the extractives industry (ODI, 2015).

(v) Manufacturing sector

Emissions from the manufacturing sector are predominantly from energy consumption – either directly at an industrial facility, or through the use of fossil fuel-based electricity. Process-oriented GHG emissions from production of cement, chemicals and other metals and from waste also contribute to the manufacturing industries' total emissions (IEA, 2007).

The most important opportunities to reduce emissions in the manufacturing sector targets:

- Energy-intensive technologies and processes in heavy manufacturing;
- Fuels used in heavy and light manufacturing: Changing or substituting energy sources used to power and heat manufacturing processes and plants presents a second opportunity to decarbonize the heavy manufacturing sector in Africa (ODI, 2015).

Box 4.3 shows a case study of energy efficient lighting and appliances project in Southern and Eastern Africa.

Box 4.3: Promoting energy efficiency in Africa: Case of Energy Efficient Lighting and Appliances project in Southern and Eastern Africa

The Energy Efficient Lighting and Appliances project aims to support the development of vibrant markets for energy efficient lighting and appliances across East and Southern Africa. The project will be implemented over a period of five years (2019 – 2024), and will implement a broad range of activities on energy efficient lighting and appliances in four key areas across the 21 member countries of the Southern African Development Community and the East African Community.

It will address issues related to vibrant markets for energy efficient lighting and appliances consumer choice, policies and regulations, as well as private sector engagement. In markets awash with outdated and inefficient products that use a lot of costly energy, consumers need more choice. Stronger policies and regulations are also urgently needed to cover a range of issues, such as protecting local markets from becoming dumping grounds for technologies that are banned in other countries. Meanwhile, incentives are needed to encourage the private sector to offer energy efficient products and services.

Some benefits will include a drop in the burden on national grids, giving more people reliable electricity, while businesses become more competitive, households save, and CO2 emissions fall. In addition, energy efficient lights and appliances will also offer cheap and reliable options for communities managing decentralized renewable energy systems.

Source: EACREEE, 2020.

4.3. Alternative livelihoods as climate change mitigation measures

Alternative livelihood (alternative to forests) projects are interventions that seek to alleviate human threats to biodiversity through providing, or encouraging the use of, an alternative resource and an alternative occupation. Alternative livelihood projects are sometimes stand-alone initiatives and at other times part of a broader integrated conservation and development programme. In all cases, the alternative livelihood initiatives share a common objective: to provide local people with alternative means of livelihood, that reduces pressure on a particular element of biodiversity. Examples of alternative livelihood projects that can be implemented as climate change mitigation strategy include the following (Wicander and Coad, 2018): Beekeeping, fish farming, pig farming, agroforestry, snail farming, poultry farming, vegetable farming/gardening, cattle rearing and small mammal rearing.

It is suggested that poverty-reduction and better social welfare strategies can represent sound and effective methods for reducing tropical deforestation (Miyamoto, 2020). In Ghana, deforestation has been linked to the high dependence of communities on forest resources. Thus, this indicates that much attention should be given to other practices such as (e.g. snail farming, bee keeping, fish farming, and vegetable production) as efforts to reduce deforestation (Appiah et al., 2009).

Charcoal production, which is one of the causes of deforestation, is a major source of income for rural households in Sub-Saharan Africa. Thus, reducing rural household dependence on charcoal requires coordinated policies providing alternative income opportunities for local household farmers (Zulu and Richardson, 2013).

Generally, alternative livelihood projects have been used by a variety of organizations as a tool for enhancing biodiversity conservation, which is relevant for conserving old Carbon stocks in protected areas or improving forest Carbon stock capacity through enhanced tree conservation. But very little is known about what impacts alternative livelihood projects have had on biodiversity conservation, as well as what determines the relative success or failure of these interventions (Roe et al., 2015). There has been an extensive investment in alternative livelihood projects, in Central, Eastern and Southern Africa but, there has been little reporting on the outcomes of these projects (Wicander and Lauren, 2015; Wei et al., 2018),

Summary

In this chapter, we have learnt about non-forest sectoral mitigation measures and alternative livelihood options and their relationships to climate change mitigation variable such as reducing emissions from deforestation. The chapter presented the GHG emission context of key economic development sectors in Africa and the opportunities for reducing emissions from these sectors.

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