THE FORESTS OF THE CONGO BASIN

Forests and climate change

The Forests of the Congo Basin - Forests and climate change

Special issue of the State of the Forest ~ 2015 ~

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Cover picture: Open canopy of a rain forest in the south-west of Gabon. Photo taken from a track in a forest concession. © Frédéric Sepulchre

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THE FORESTS OF THE CONGO BASIN

Forests and climate change

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ACRONYMS

AF	Adaptation Fund
AfDB	African Development Bank
AGEDUFOR	Appui à la Gestion Durable des Forêts de la RDC
ARECO	Association Rwandaise des Ecologistes
ASAP	Adaptation for Smallholder Agriculture Program
ASECNA	Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar
AUDD	Avoided Unplanned Deforestation and Degradation
AU-NEPAD	African Union - New Partnership for Africa's Development
BBOP	Business and Biodiversity Offset Program
BIOM	Biosphere Management Model
BMU	German Federal Ministry for the Environment
BP	Before present
BSM	Benefit-sharing mechanisms
CA	Central Africa
CAR	Central African Republic
CBFF	Congo Basin Forest Fund
CBFP	Congo Basin Forest Partnership
CCAFS	Climate Change, Agriculture and Food Security
CDM	Clean Development Mechanism
CED	Center for Environment and Development
CEMAC	Central African Economic and Monetary Community
CER	Certified Emission Reductions
CGIAR	Consultative Group on International Agricultural Research
CICOS	International Commission for the Congo-Oubangui-Sangha Basin
CIFOR	Center for International Forestry Research
CIRAD	Center for International Agricultural research for development
CN REDD	REDD National Coordination
CNCM	National Centre for Meteorological Research - Coupled Models
CNRS	National Center for Scientific Research
CO_2	Carbon dioxide
COBAM	Climate Change and Forests in the Congo Basin
CoFCCA	Congo Basin Forests and Climate Change Adaptation
COMIFAC	Central African Forests Commission
COP	Conference of the Parties
CSC	Climate Service center
DFID	Department for International Development
DMC	Disaster Monitoring Constellation
DRC	Democratic Republic of Congo
EbA	Ecosystem-Based Adaptation
ECCAS	Economic Community of Central African States
ECHAM	European Centre Hamburg Model
ECOFORAF	Eco-certification of forest concessions in central Africa
ENSO	El Niño Southern Oscillation
ERA	Extension of Rotation Age
ESA	European Space Agency
EU	European Union
FAO	Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility
FIP	Forest Investment Program
FLEGT	Forest Law Enforcement, Governance and Trade
FORAFAMA	Support for the sustainable management of forests in the Congo Basin and the Brazilian Amazon Basin
FRA	Forest Resources Assessment
FRELs	Forest Reference Emission Levels
FRLS	Forest Reference Levels
FRM	Forêt Ressources Management
FSC	Forest Stewardship Council
FSCD	ClimDev Special Fund
FSF	Fast-Start Financing
GCCA	Global Climate Change Alliance
GCF	Green Climate Fund

GCM	Global Climate Models / General Circulation Model
GCOS	Global Climate Observing System
GCS	Global Comparative Study
GDP	Gross domestic product
GE	Green economy
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
GLOBIOM	Global Biosphere Management Model
GTS	Global Telecommunication Systems
HCVF	High Conservation Value Forests
ICF	International Climate Fund
ICRAF	International Centre for Research in Agroforestry
IFAD	International Fund for Agricultural Development
IFM	Improved Forest Management
IIASA	International Institute for Applied Systems Analysis
IKI	International Climate Initiative
INDC	Intended Nationally Determined Contribution
INDEFOR	National Institute for Forest Development - Equatorial Guinea
IOC	Interoceanic Convergence
IPCC	Intergovernmental Panel on Climate Change
IPSL	Institut Pierre Simon Laplace des Sciences de l'Environnement Global
IRD	Institute of Development Research
ITCZ	Inter-Tropical Convergence Zone
ITF	Inter-Tropical Front
IUCN	International Union for Conservation of Nature
JMA	Joint Mitigation and Adaptation Mechanism
JRC	Joint Research Centre
LCBC	Lake Chad Basin Commission
LDC	Least Developed Countries
LDCF	Least Developed Countries Fund
LED	Low Emissions Development
LEDS	Low Emissions Development Strategy
LPJ-ml	Lund-Potsdam-Jena-managed lands
LTPF	Logged to Protected Forest
LUCF	Land-Use Change and Forestry
MDG-F	Millennium Development Goals Achievement Fund
MODIS	Moderate Resolution Imaging Spectroradiometer
MRV	Measurement, Reporting and Verification
NAP	National Adaptation Plan
NAPA	National Adaptation Program of Action
NCBs	Non-Carbon Benefits
NCs	National Communications
NGO	Non Governmental Organization
NTFP	Non-Timber Forest Product
OECD	Organization for Economic Co-operation and Development
OFAC	Observatory for the Forests of Central Africa
OLB	Origin and Legality of Timber
ORSTOM	Office of Scientific and Technical Research Overseas
PAPPFG	Gabonese project for development of small forestry permits
PES	Payments for Ecosystem Services
PFES	Payment for Forest Ecosystem Services
PNIA	National Agricultural Investment Program
PPCR	Pilot Program for Climate Resilience
PS6	Performance Standards 6
RAFM	African Network of Model Forests
REDD	Reducing Emissions from Deforestation and Degradation
REDD - PAC	REDD+ Policy Assessment Centre
RIL	Reduced Impact Logging
RMTN	Regional Meteorological Telecommunication Network
ROSE	Network of local NGOs in south-eastern Cameroon
R-PIN	Readiness Plan Idea Note
R-PP	Readiness Preparation Proposal
SATCOM	Satellite Communications

SBSTA	Subsidiary Body for Scientific and Technological Advice
SCCF	Special Climate Change Fund
SFM	Sustainable forest management
SIEREM	Système d'Informations Environnementales sur les Ressources en Eau et leur Modélisation
SIS	Safeguard Information Systems
SOF	State of the Forest
SPA	Strategic Priority for Adaptation
SRES	Special Report on Emission Scenarios
SST	Sea Surface Temperatures
TLTV	Timber Legality and Traceability Verification
TREES	Tropical forest monitoring from Satellite remote sensing
UCL	Catholic University of Louvain
UEFA	Union pour l'Emancipation de la Femme Autochtone
UK	United Kingdom
UN	United Nations Organization
UN-DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
VCS	Verified Carbon Standard
VIC	Variable Infiltration Capacity
VPA	Voluntary Partnership Agreement
WAM	West African Monsoon
WATCH	Water and Global Change
WCMC	World Conservation Monitoring Centre
WFD	WATCH Forcing Data
WMO	World Meteorological Organization
WRI	World Resources Institute

PREFACE

For several decades, climate change has been a fixture on the global agenda as a highly dangerous scourge whose consequences can jeopardise the survival of the planet and all humanity. Since 1992 the international community has been trying to find solutions to the problem. In fact, the United Nations Framework Convention on Climate Change and the Kyoto Protocol adopted respectively in 1992 and 1997 laid down the legal basis for international cooperation to combat the causes and effects of climate change around the world.

While the adoption of these instruments held much promise, their implementation has proven more complicated in light of difficulties faced by the country parties to annex 1 in fulfilling their commitments to reduce greenhouse gas emissions (GHG). Furthermore, funding provided in support of climate change adaptation and mitigation efforts in developing countries has fallen short of needs and expectations.

It was in a bid to provide a more comprehensive and better coordinated response to the scourge that a new round of negotiations has been underway for a few years with the aim of adopting a new global climate agreement. The 21st Conference of the Parties to the Convention, slated to take place at the end of 2015 in Paris would be the culmination of these negotiations where the international community is expected to adopt the new cooperation instrument.

Similar to other Parties to the Convention, the Central African countries have been actively involved for years in international climate change negotiations. Concerted positions on various issues and topics of interest to the sub-region have been regularly developed and defended by these countries during negotiations. In fact, given that the Central Africa harbours the Congo Basin forests, the world's second largest contiguous tropical forest, the sub-region's countries have always desired to see the role of these forests being taken into account in the fight against climate change.

As a matter of fact, tropical forests play an undeniable role in the fight against climate change. According to the Intergovernmental Panel on Climate Change (IPCC), deforestation in tropical areas accounts for approximately 15 % of GHG emissions. In this respect, it has been recommended that the trend be reversed by putting in place policies and actions at national level to combat deforestation ; hence the emergence of the reduction of emissions resulting from deforestation and forest degradation mechanism (REDD+).

The Congo Basin countries have an exemplary record in preserving their forest resources. The last 2013 State of the Forests Report (EDF) is quite revealing in this respect, as the sub-region registered very low deforestation and degradation rates (0.14 per cent per year) compared with other tropical regions around the world. The REDD+ mechanism which is supported by most countries in Central Africa is rightly regarded as a development opportunity for these countries. Considering the countries' long and medium term aspirations for economic growth and development, implementing the REDD+ strategy should help the Central African countries access the funding and technologies necessary to minimize their carbon footprint, by modernizing their agricultural and livestock production systems, etc.

While the REDD+ concept may seem easy on the face of it, the pre-requisites for its implementation at national level are more complex. In fact, several methodological and technical aspects constitute hurdles to the operationalization of this instrument by our countries.

Beyond REDD+-related issues, climate change adaptation issues are also a priority for the sub-region. There has been an increase in extreme events arising from climate change with consequences for both ecosystems and populations. There is therefore a need to take action by putting in place appropriate measures and actions to make these populations less vulnerable.

To address all these challenges, the Central African countries must of necessity develop an integrated approach to addressing climate change with forests being an important part of this strategy.

It is in consideration of the foregoing, that it was deemed needful within the framework of the 21st Conference of the Parties to the Convention in Paris, to take stock of the dual issue of "forests and climate change" in Central Africa. This report on forests and climate change produced by the Central African Forest Commission (COMIFAC) with the support of its partners aims to update the international community and the authorities of countries in sub-region on progress achieved in sustainable forest management and tools being developed for REDD+ on the one hand, and issues and challenges related to climate change mitigation and adaptation on the other hand.

In the hope that this report will help to strengthen the Central African countries' advocacy at current and future international negotiations on climate change in Central Africa,

I wish you all a pleasant reading,

Raymond Mbitikon

Executive Secretary of the
COMIFAC

INTRODUCTION

On the occasion of the 21st Conference of Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) held in Paris from 1 to 10 December 2015, the member States of the COMIFAC wish to address the climate issues for their region and in particular with regard to the role of forests. As a result, the COMIFAC is proud to release this special publication on climate and forests in Central Africa. The redaction of this special report was put under the coordination of the Executive Secretariat of COMIFAC and OFAC with support from CIFOR.

This report is the fruit of a long participatory process of information gathering, exchanges between experts, debates and the building of consensus to provide elements for the improved sustainability of the Central African ecosystems. This vital undertaking responds to a groundswell request from diverse stakeholders for consolidated information in a joint report. The process of creating the report comprises many stages, wherein many actors are involved over a period of more than one year. The production of this new edition began in October 2014 on the occasion of the CBFP meeting in Brazzaville.

The drafting of each chapter is led by a 'chapter coordinator'. His role is to:

(i) Propose a structure for the chapter, based on the topics proposed,
(ii) Stimulate the group of co-authors to generate their respective contributions,
(iii) best achieve arranging of the different contributions, and
(iv) Prepares the first version of the chapter for the reviewing workshop and the final chapter based on feedback received from the workshop.

The 3 days workshop held in Kribi in July 2015 constituted a key step in the production of this publication. The principal goal of the workshop was to encourage the authors and partners of the Congo Basin forest sector to examine, amend and validate the texts proposed for publication. In that sense, the workshop can be considered as a "real time peer reviewing" process. First, each draft chapter, including its themes and key elements, was presented, thus enabling each participant to identify the topics to which they could best contribute. Secondly, the participants were divided into working groups so as to make suggestions and contributions towards improving chapter content. During these discussions, there was a high degree of participation, and participants helped to make available to the authors better and more accessible information. The authors then proceeded to work on these texts.

Once the texts – often drafted partly in French and partly in English – have been finalized, a proofreading committee works on improving their coherence and presentation in order to reach as wide an audience as possible. The translation, formatting, proofreading, printing and dissemination of the document are the final stages in this adventure, but they are nonetheless intensive and time-consuming and involve substantial human resources.

In terms of content, this special publication pays primary attention to forests, the climate and the possible policies linked to this topic. Its content, divided into 6 chapters is the result of the collaboration of many stakeholders.

The first 3 chapters focus on describing the central African forest and climate features with scientific evidences, but also the relations and mutual interaction between the forest and the climate.

The first chapter describes the key role of tropical African forest as a reservoir of carbon and biodiversity. Thanks to the latest development in remote sensing technologies, the state of forests and the dynamics of tropical forest cover types are increasingly well described. It addresses also the cause of forest cover changes and the possible evolution of the forest cover with regards with new economic development opportunities, demography increase and political and management challenges.

The second analyzes the Central African climate, concentrating in particular on (i) the key features of the climate, (ii) the historical evolutions and changes (iii) the way in which this climate could change in years to come, and (iv) the possible impacts of these changes on the hydrological regime, evaporation and consequently on the vegetation and human population.

After having described the forest and the climate of central Africa, the third chapter addresses the question of the relation between these 2 elements. This is made through the exchanges in water content, the energy conversion with the role of the sensible and latent heat and the influence of atmospheric carbon. The chapter analyses also the historical mutual influence with vegetation extent driven by the climate evolutions and the possible impact of climate modifications on vegetation and conversely the impact of deforestation on the climate features.

The second part, with the 3 last chapters, is related to policies issues and options to face the challenges of sustainable forest in a context of climate change issues.

The chapter 4 is dedicated to vulnerability and adaptation of forest and communities in a situation of changing climate. Indeed not only the biophysical aspect are important to address, but also the changes in environmental policies related to access to forest resources in a context of increasing pressure on natural resources mainly due to population increase. The vulnerability is also depicted with regards to the economic and social sectors, hydrology and energy, agriculture, health and urbanization. Then, the adaptation is tackled regarding the ecosystem point of view, recalling that the forest provide ecosystem goods and services, then, regarding the policies and strategies, with some Lesson learnt from early initiatives.

The fifth chapter is addressing the contribution of forests in the mitigation to climate changes. Indeed, the forest analyzed as a carbon stock, a carbon sink or as carbon emission, is a key aspect for the carbon balance assessment and climate based policies. Mitigation of climate change is approached by three main sets of policies and measures i.e. sustainable forest management techniques, the improvement of forest governance and the current engagement in the REDD+ process. There is also a new thinking to favour traditional policies that additionally provide climate regulation services as co-benefit while internalizing new international initiatives such as Reducing Emissions from Deforestation and forest Degradation (REDD+). The status and the implementation of REDD+ in central Africa, together with Lessons learned from early mitigation initiatives and the remaining challenges, the region have to face are also described in the chapter.

In the Congo Basin countries given that there is urgency for both mitigation and adaptation actions, the sixth and last chapter analyses the synergies and trade-offs between mitigation, adaptation and development interventions. This chapter addresses the political and institutional prerequisite for synergies in central Africa while stressing the importance of multi-sectorial approaches and the roles of the different actors in the designing and implementation of actions tackling both adaptation and mitigation outcomes. Entry points for synergy is illustrated through the promotion of carbon and non-carbon benefits together, and the new tendency towards the Joint Adaptation and Mitigation Mechanism (JMA) proposed as a non-market based alternative to REDD+.

CHAPTER 1

THE IMPORTANCE OF CENTRAL AFRICA'S FORESTS

Baptiste Marquant[1], Aline Mosnier[2], Blaise Bodin[3], Hélène Dessard[4], Laurène Feintrenie[4], Quentin Molto[1], Valéry Gond[4], Nicolas Bayol[1]
With contributions from: Ahmed Batti, Richard Eba'a Atyi, Jean-François Chevalier and Charles Doumenge
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1. Introduction

Tropical forests are extraordinary reservoirs of carbon and biodiversity. Within a few decades they have become a centre of attention in the scope of international challenges in climate change and conservation. The Congo Basin is the second largest tropical forest in one piece after the Amazon. Relatively well preserved, it plays an important role in the regulation of global and continental climatic systems.

These Central African forests provide subsistence means to 60 million people who live either inside or in the vicinity of the forests. They also fulfil social and cultural functions essential to local and indigenous populations, and contribute to feed 40 million people who live in the urban centres close to these forestry areas (Nasi *et al.*, 2011 ; de Wasseige *et al.*, 2014). The importance of tropical forests in the Congo Basin has gradually given these ecosystems the value of a world common asset and many multilateral agreements address today the management and conservation of these ecosystems in partnerships with the states of the region.

Since the first field works until the latest developments in remote sensing technologies, the state of forests and the dynamics of tropical forest cover types are increasingly well described. This crucial knowledge is a central prerequisite for the definition and then monitoring of national and international economic and environmental policies. They require some important funding that the States alone cannot provide. As a matter of illustration, the REDD+ process in which several countries in the Congo Basin have got involved incurs the set-up of an integrated Measurement, Reporting and Verification system (MRV) of changes related to deforestation and / or forest degradation[1] as well as those resulting from an improvement of the forest cover. Identifying and mapping areas where the forest cover has been changing and, more generally, land use characteristics is central to the elaboration of policies locally adapted to on-going dynamics.


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Photo 1.1: The African Padauk (Pterocarpus sp.), is a tree species prized by logging companies

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[1] The definition of « forest degradation » or « degradation of forests » in tropical humid forest is subject to many debates among experts and scientists. This article does not address this topic.

2. Forest types and forest cover in 2015

Schematically speaking, the Congo Basin consists of five main forest types as follows:

- A central zone which includes a huge swampy forest, hard to access, hence less impacted by human activities – except hunting – as compared to other forest types;
- Around this central basin, the bulk of the Congo Basin's forests is dryland rainforest, sometimes relatively well preserved but more or less fragmented depending on the degree of degradation from anthropogenic origin;
- In the north and in the south of the Congo Basin dryier forests types are found, adapted to more seasonal climates;
- Moving away from the centre of the basin, one finds patchwork forests and savannahs where dense forest areas alternate with grassland areas;
- Finally, woodlands and wooded savannahs (savannah including isolated trees) cover some important areas in i) the north of Cameroon and in CAR showing a northern degradation trend towards the Saharan desert, and ii) in the south of DRC.

A representation of the main land cover types and their areas is given in Figure 1.1. The rainforests stretches on about half of Central Africa (excluding Chad Sahelian country). A more accurate mapping of forest types in the Congo

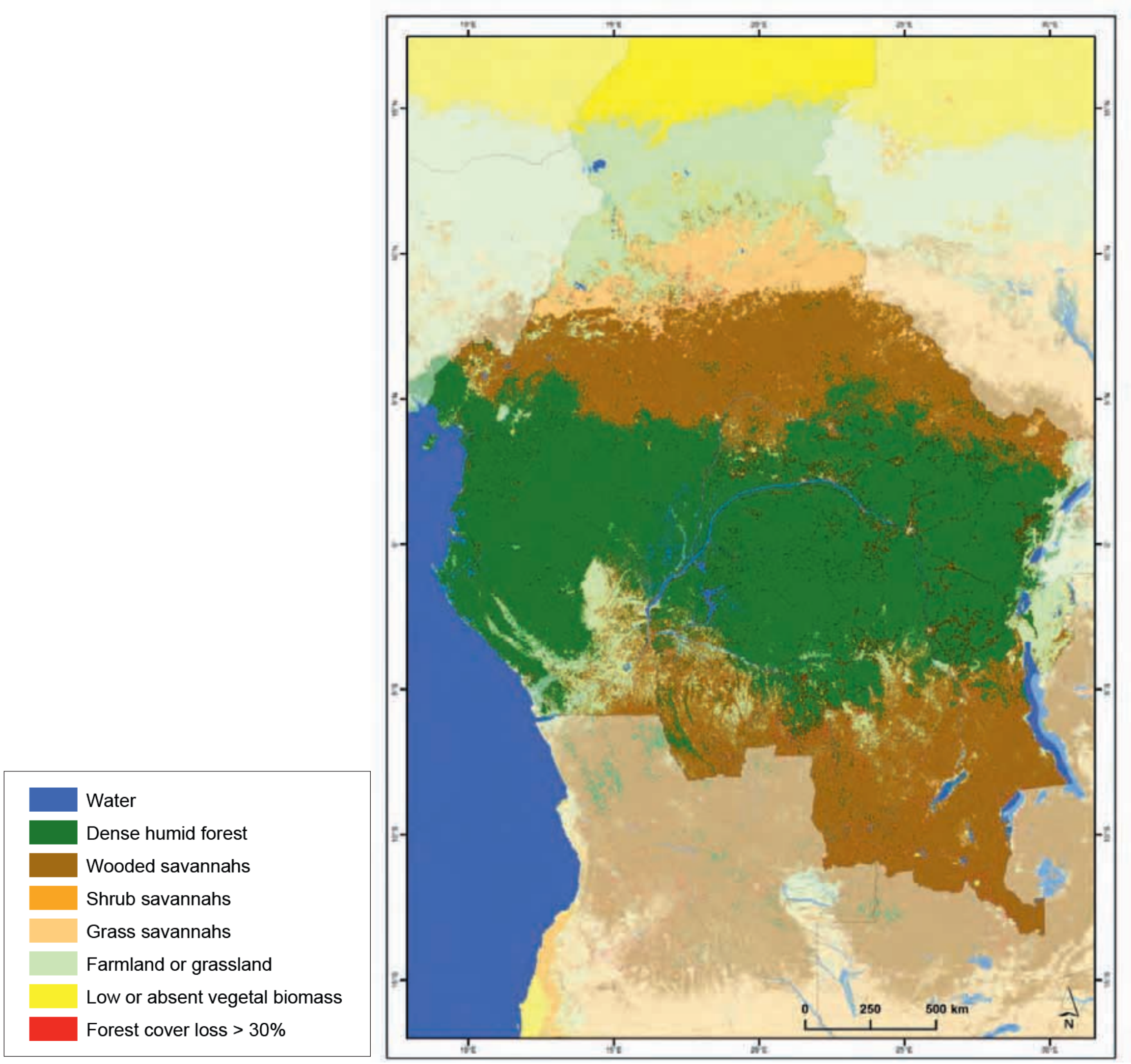

Figure 1.1: Forest cover in Congo Basin and forest covers loss between 2000 and 2012 according to data from MODIS Land Cover Type product – MCD12Q1

Source: Hansen et al., 2013

Basin and related carbon sinks is discussed further in this chapter (see Figure 1.5).

The forest cover is usually determined through satellite monitoring. In the Congo Basin and as technologies evolve, several initiatives have been launched. Approaches involving satellite monitoring at national scale offer some advantage in terms of accuracy but they make further sub-regional comparisons between countries more difficult, notably because of lack of standardization in mapping classes and definitions. Besides, satellite monitoring at national scale is seldom comprehensive even at the country scale as a result of the lack of funding (Desclée *et al.*, 2014).

Assessments of the sub-regional forest cover in the Congo Basin have developed for several years. A comprehensive cartography technology – wall-to-wall – which needs important satellite imagery processing with advanced technical tools[2] delivers its first results and enables some monitoring of the evolution of the forest cover loss at a regional scale. The Figure 1.1 shows areas where the forest cover loss exceeds 30 % and where some forest stand disturbance was observed between 2000 and 2012 (Hansen *et al.*, 2013). This data processing allows to assess the deforestation between 2000 and 2012 to circa 4.6 % of the remaining rainforest cover in 2012 (Table 1.1).

Research on mapping forest cover currently focus on the processing of radar signals that will allow to address cover changes despite the constraint of clouds, main hindrance to proper interpretation of satellite imagery in the Congo Basin. A more accurate interpretation of the forest degradation according to the drivers of deforestation is also in progress.

In parallel to mapping forest cover, numerous studies allow to assess the changes in the forest cover in the entire Congo Basin. Data presented hereafter originates from works carried out in the scope of the TREES/FRA approach, and from chains of processing based upon DMC, SPOT and Landsat imagery using a 30 m resolution in each case (Rasi *et al.*, 2013). Thus, only small and isolated distorted areas less than 30 m in size could remain undetected in terms of forest cover change. The area of this noise is reportedly small, but yet is the technical limit of this study.

Figure 1.2 gives the estimations of deforestation rate by country over the entire rainforest in Central Africa between 1990 and 2000 and between 2000 and 2010. The gross deforestation added to afforestation, reforestation and forest regeneration gives the net deforestation. The general trend is some decrease in the deforestation rate coming from 0.19 % to 0.14 % for the whole rainforest in the Congo Basin while afforestation decreases or even becomes negligible.

A similar analysis carried out in dry forests in Central Africa is given in Figure 1.3. While gross deforestation is approximatively the same between 1990 and 2000 and between 2000 and 2010, respectively 0.36 % and 0.42 %, the reforestation drop from 0.14 % to 0.03 % between these two periods of time.

The dynamics of the private sector in the Congo Basin may indicate an upward trend intree plantations. New projects have been launched in Gabon, for example, as an initiative from companies such as Lignafrica.

Table 1.1 : *Land cover surfaces in 2012 and forest cover loss since 2000 of the COMIFAC countries*

Strata	Surfaces km² (Proportion %)	
	With Chad	Without Chad
Water	140 332 (3)	92 452 (3)
Dense humid forest	1 707 185 (36)	1 706 256 (48)
Wooded savannahs	1 167 234 (24)	1 143 835 (32)
Shrub savannahs	129 363 (3)	125 999 (4)
Grass savannahs	355 581 (7)	219 522 (6)
Farmland or grassland	508 291 (11)	225 217 (6)
Low or absent vegetal biomass	782 585 (16)	71 463 (2)
TOTAL	4 790 571 (100)	3 584 744 (100)
Forest cover loss > 30 %	78 726 (4.6)	

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[2] Using Landsat imagery, complex IT methods involving a lot of data allow to query each Landsat pixel and define forest covers according to threshold values given to Landsat pixels for characterized forest cover types (Potapov *et al.*, 2012).

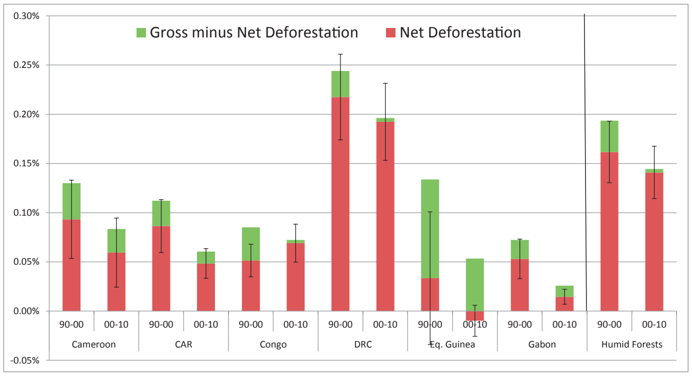

Figure 1.2 : Annual deforestation rates (gross and net) of Central Africa rainforests between 1990 and 2000, and between 2000 and 2010.

Sources : UCL (1990-2000) and JRC (2000-2010) in Desclée et al., 2014

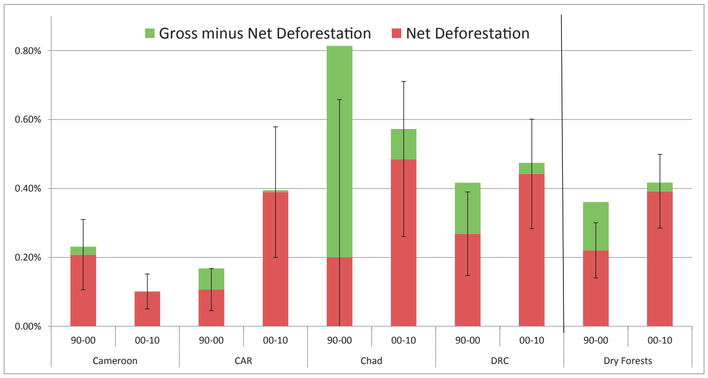

Figure 1.3 : Annual deforestation rates (gross and net) of dry forests in Central Africa between 1990 and 2000, and between 2000 and 2010.

Sources : JRC in Desclée et al., 2014

The forest cover cartography of the Congo Basin is a valuable support tool for decision-making in the scope of elaboration and monitoring of climatic and environmental policies. This tool, often static in the past, is nowadays built in the context of studying forest cover and land use dynamics, and allows targeting priority intervention zones relevant to public policies and international agreements pertaining to climate. This cartography of forest types and related threats might play an increasing role in the development of country planning and land use planning in line with both national and local problems, and in line with international commitments made by States.

3. Drivers of deforestation and degradation

Policy programmes defined by Central Africa States aim at economic emergence in 2025 (Regional Economic Programme from CEMAC) or 2030 and 2035 (DRC and Cameroon). These programmes are based upon the continuation of natural resources exploitation (wood, oil, and minerals), agricultural production for domestic needs and exports, as well as the strengthening of industrial processing activities. Forests in Central Africa have so far been relatively well protected thanks to low demographic pressure reinforced by rural exodus, difficult access, absence of transport and communication infrastructure, and a business climate very little conducive to long term investments (Burgess *et al.*, 2006 ; Megevand *et al.*, 2013). Social and political stability prevailing over the last decade in certain countries of the sub-region has allowed the development of large-scale road infrastructure, power supply in the main urban areas and counties, and an improvement in the business climate. Added to this context, the rise in the price of minerals and agricultural products in the international market place in the early 2000s have acted like investment incentives. At present, small-scale agriculture and to a lesser extent the harvest of fuelwood are considered the main drivers of deforestation in the Congo Basin (Defourny *et al.*, 2011) but projects for large scale agribusiness plants are developing in various countries and may become more and more important in the future.

3.1 Agriculture and agro-industries

Historically, agriculture was covering large areas in the Congo Basin. Current research, based on phytoliths and some fragments of charcoal or tools used by men show that prior to the triangular trade and more recently the massive rural exodus towards urban areas, the vast majority of forests in Central Africa was spotted with agricultural areas (Morin-Rivat *et al.*, 2014).

Agriculture currently practiced and spread in the sub-region is either household-based or small-scale. This subsistence agriculture lies on fields combining various annual and perennial edible crops (mainly cassava, maize, groundnut, banana, vegetables and tubers) alternating with short or long-term fallows depending on local land availability (Meunier *et al.*, 2014 ; Feintrenie *et al.*, 2015). Fallows can last over more than 20 years in less populated forest regions or conversely they can be as short as 3 years in regions where access to land is under harsh competition (Floret *et al.*, 1993 ; Feintrenie *et al.*, 2015). On forest fringes, some pieces of arable land are under permanent cultivation.

Slash and burn subsistence agriculture is partly a driver of forest degradation but allows some plant species adapted to perturbation to maintain themselves in otherwise unfavourable habitat. It results in deforestation only when the anthropogenic pressure exceeds an estimated threshold of 8 inh./km² in the Congo Bassin (Desclée *et al.*, 2014). Beyond this population density peasants are obliged to decrease the fallow length in order to increase production and meet minimal food needs.

The settlement of shifting cultivation and preventing from using fire to clear land could lower the impact of this activity on forest cover and decrease the release of carbon in the atmosphere. Techniques of ecological intensification of agriculture can provide solutions in this direction. They are based on a shallow ploughing, keeping some protection on the soil such as covering plants or mulching, as well as some improvement of soil fertility through an adequate combination of species and crop rotation. These three principles are the pillars of conservation agriculture (Corbeels *et al.*, 2014) and are also used in agroforestry systems (Nair, 1985). Several applied research projects have been undertaken to adapt these techniques to specific agriculture conditions encountered in the rainforest context and in relation with the issue of fuelwood production. This is the case of the Makala Project in DRC (Marien *et al.*, 2013) and others in the Amazonian Basin (Sist *et al.*, 2014). Some techniques are also under development, with the enrichment of soils with small charcoal particles and organic matter, mimicking the formation of black earth (or terra preta) from the old Indians of the Amazon. These production techniques still need to be tested and assessed then popularized in order to go beyong the research activity and to become operational in rural households in the Congo Basin.

Photo 1.2 : Itinerant household agriculture

Household farming goes beyong food production to meet the needs of the producers themselves. A growing urban population means some increasing needs for food and prompt farmers benefiting from a marketing chain to produce more. It is about household farming or non-industrial farming involved with a combination of subsistence farming, oil palm and cocoa tree production. The main issues arising from this type of commercial non-industrial agriculture are of social nature, before being of environmental nature, because it involves land acquisition by "village elites" (Pédelahore, 2012 ; Ndjogui et Levang, 2013) or encroachement of pieces of land under forest management without any control neither by the administration nor by the logging companies.

Photo 1.3 : Industrial planting of oil palm trees

Industrial agriculture in Central Africa is dominated by European, Asian and domestic investments and is mainly about palm oil, natural rubber, banana and sugarcane (Feintrenie, 2014). The majority of industrial plantations were established between 1910 and 1960. Today, some of them are neglected waiting for a new start, some of them are being rehabilitated, but very few have been under permanent management and exploitation.

For this historical reason, industrial planting have not caused major deforestation until recently. However, this is changing because new concessions are being granted inside the forest zones. Thus, some areas under forest management are removed from permanent forest land and can be converted into agricultural land. This land use alteration results in deforestation of those pieces of land granted to the agribusiness. However, there are success stories of agro-industrial projects such as those in the mining industry. These successful projects are undertaken by companies which abide by national regulations and implement social responsibility and environmental accountability policies or engage in certification processes (Feintrenie *et al.*, 2014).

3.2 Mining activities

The African continent would include 30 % of the world reserves of minerals and one can assume that at least 60 % of that total is under the forest of the Congo Basin (Edwards *et al.*, 2014). Just like other natural resources, industrial mining requires permits. Many mining exploration permits have been granted by the Central African countries and such permits concern large areas of rainforests already granted to logging companies, to communities or simply reserved as conservation areas. In order to prevent land tenure and land use conflicts, consultative frameworks involving all parties (loggers, mining companies, local population, State) are sometimes established. They are meant to ease negociations and reach acceptable social, economic and environmental compensations for all users. The principles of compensation mechanisms are integrated in international norms and standards (PS6, BBOP) that guide or constrain good practices in mining activity. These norms and standards are largely not included in national laws and regulations, and could appear based on a voluntary behaviour by the mining industry. Nevertheless, some financial institutions grant financial resources and lower interest rates for companies that provide credible impact studies and implement ecological compensation policy in line with certain international standards (Quétier *et al.*, 2015). The development of industrial-scale mining activity being strongly dependent of access to capital, conditional financing and requirement of international standards could be a strong leverage in setting up a social and environmental compensation mechanism.

Photo 1.4: Illustrations of impacts from artisanal mining activities

Direct impacts of industrial exploitation can be relatively reduced while indirect impacts on forests and forest-dependent communities can be considerable. Direct impacts include deforestation and various pollutions of water systems, air and soils. Other impacts result from the construction of infrastructures required to transport minerals and energy or the construction of settlements required by the mining activity. Thus, mining activity make relatively intact forest zones accessible to populations, who not only can hope for a job with the mining company but also

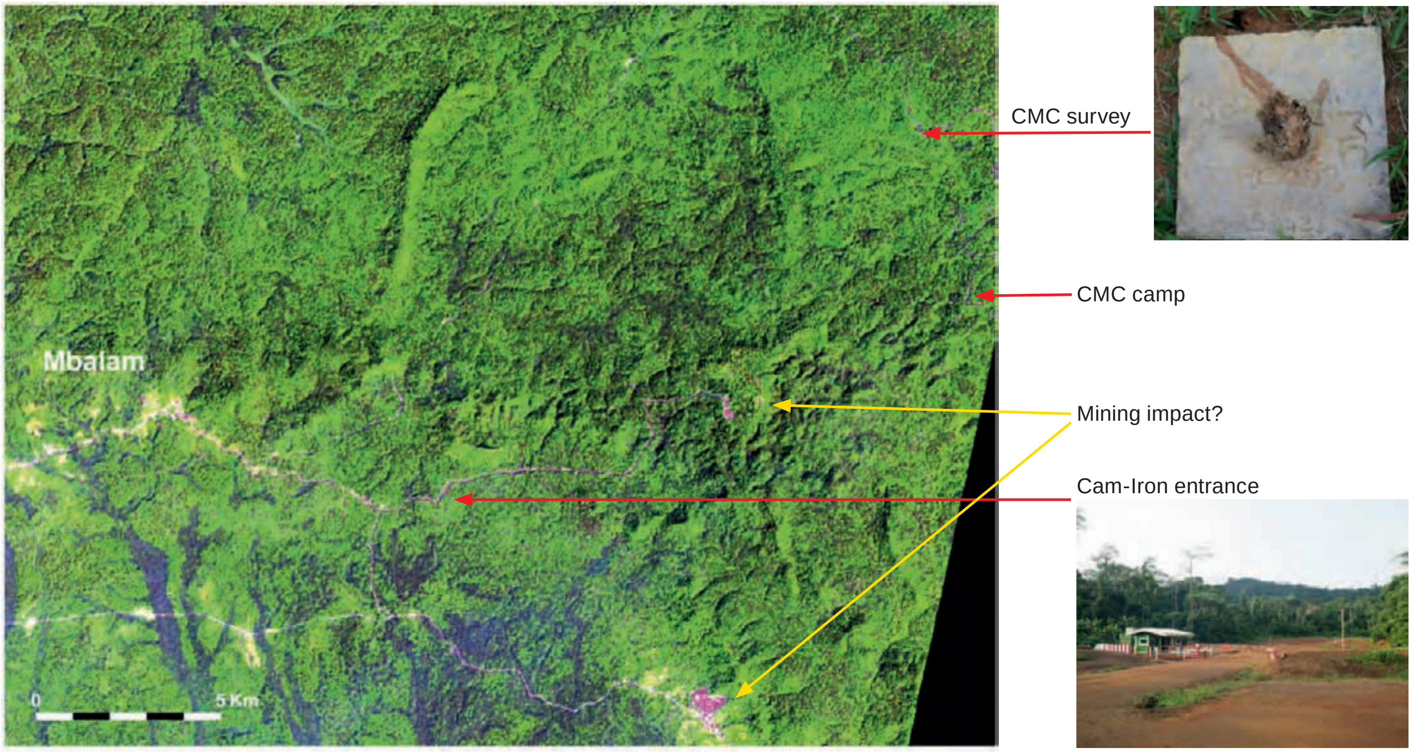

Figure 1.4: Cartography of impacts in a mine in the south-east of Cameroon

Source: Gond, 2013 (Landsat 8 of 17th december 2013)

can develop agricultural activity on new pieces of land and excert some more pressure on fuelwood resources and wild fauna. The disruption of socio-economic systems, with the rise of local prices or the development of trafficking, are also notable indirect impacts of mining activities that have to be taken into account.

In summary, if deforestation needed to access the deposit is often relatively low (Figure 1.4 and photo 1.4), degradation and deforestation side-effects resulting from mining activity can be serious. This can be exhacerbated in areas where administration is absent. Many ecosystem services provided by forests will be deteriorated by mining. Therefore it raises an issue which is not resolved by the scientific community: how to make a proper assessment of the degradation of services over the lifespan of the mining activity in relation with the financial profits derived from the mining activity? What kind of cost-benefit analysis of the mining activity and other ecoystem services can address these possible degradations over the lifespan of the mine?

As a matter of fact, few mining projects were allowed to start in 2015 in the forests of the Congo Basin due to financial and administrative reasons as well as the volatility of market prices for minerals, which have discouraged investors. Given the current dynamics, this diagnosis could be reviewed in a few years from now.

Photo 1.5: Industrial mining in DRC : 50 years later

Photo 1.6: Coltan and cassiterite are mainly extracted by artisanal miners (eastern DRC)

Besides the industrial exploitation, there is some artisanal exploitation, mainly of gold and diamonds, which was established in certain forest areas long ago (albeit very scaterred and local operations). It causes much degradation to forests, perhaps to a greater extent when contrasted to industrial mining, said obervers in the field. In the mining sector, the hope for quick profits is attractive and causes illegal artisanal activities which are usually practiced by the poorest populations (Hammond *et al.*, 2007). These artisanal mining activities are carried out under very poor working conditions and thus open the door to the degradation of social and sanitary conditions.

At present there is little documentation on small mining exploitation and no study cover forest areas in Central Africa while these activities can cause, just as it happens in the Amazonian forest basin, many environmental degradations and serious polutions of rivers due to inappropriate techniques (Gond and Brognoli, 2005).

3.3 Logging, and planned and un-planned degradation

In the Congo Basin countries, timber exploitation is usually allowed through exploitation permits. Beyond a certain size, logging companies holding such permits must have management plans in order to sustainably manage the forest resource. Albeit this type of exploitation can cause some local degradation of the forest cover, it cannot be considered as a major driver of deforestation in itself because of low logging rates, targeting a few species of high commercial value (Desclée *et al.*, 2014).

By extrapolating findings from on-going studies in DRC (FORAFAMA and Carbon Map and Model), one estimates that 7 % of the forest is degraded due to road network, 0.5 % is degraded by annual falling activities (one year out of 30 when rotation is set to be 30 years). Besides, forest cover regeneration, dissemination of Reduced Impact Logging[3] (RIL) techniques and the development of legal or sustainable certification schemes in certain concessions, favour limited direct forest degradation in areas logged to produce timber. However, some indirect impact of forest operations (such as the opening of roads to new settlements or agricultural activities, the development of hunting activities…) can be rather important and need to be addressed by the companies as well.

In short, 49 million hectares of forests have been allocated as forest concessions in the Congo Basin. If those concessions should be sustainably managed on the basis of management plans, they are not under the threat of deforestation but remain under the threat of forest degradation. The impacts of timber exploitation can nevertheless be partly alleviated over the rotation period (25 to 30 years) if natural or facilitated regeneration is allowed. However, one must admit that the bulk of forest exploitation in the Congo Basin countries is not conducted according to management plans as of today. In the whole region, 40 % of concessions are under management plans but it is necessary to reach 100 % in the medium run. Table 1.2 presents a synthesis of progress by country of logging companies in pursuing sustainable forest management and legal or sustainable certification schemes.

In obvious contrast to the trend towards sustainable forest management, the whole forest is, at various levels, prone to illegal exploitation which, depending on the country, can cause some degradation or even deforestation of greater magnitude when compared with legal exploitation.

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[3] Reduced Impact Logging – RIL – aims at improving forest exploitation techniques, notably by decreasing the width of primary, secondary roads and skidding trails and in controlling felling direction.

Table 1.2: *Total areas of forest concessions under management and certification schemes*

	Forest concessions			**Managed concessions**		**Certified concessions**	
	Area (ha)	**Number**	**Average area (ha)**	**Area (ha)**	**% (1)**	**Area (ha)**	**% (2)**
Cameroon	7 058 958	111	63 594	5 071 000	72 %	2 393 061	34 %
Congo	12 600 221	51	247 063	3 504 159	28 %	2 584 813	21 %
Northern Congo	5 822 597	14	415 900	3 504 159	60 %	2 584 813	44 %
Southern Congo	6 777 624	37	183 179	0	0 %	0	0 %
Gabon	14 272 630	150	95 151	7 181 420	50 %	2 435 511	17 %
Equatorial Guinea	0	0		0		0	
CAR	3 058 937	11	278 085	3 058 937	100 %	0	
DRC	12 184 130	80	152 302	0	0 %	828 033	7 %
Total	49 174 876	403	247 063	18 815 516	38 %	8 241 418	17 %

(1) Percentage of area of concessions - (2) FSC, OLB and TLTV certificates

Sources: WRI 2011 (Cameroon), Gally and Bayol 2013 (Congo), PAPPFG Project (Gabon), AGEDUFOR Project (DRC), ECOFORAF Project (CAR and certification)

4. Forest types and carbon stocks

4.1 Stocks and dynamics of forest carbon

According to experts[4] (Ciais *et al.*, 2014), the earth atmosphere contains circa. 830 Gt of carbon. One estimates that vegetation, soils, water and garbages store 2,400 Gt of carbon. This stock is small in comparison with deep oceans (37,100 Gt of carbon) and fossil fuels (1,000 Gt of carbon). However, forests represent a major stake because of their relatively fast carbon storage cycle (when compared to other forms of sinks) and because of the paramount role of anthropogenic drivers of positive or negative changes in the forest cover.

Tropical forests can be an important source of greenhouse gases. Emissions related to deforestation at a global level are estimated at circa. 1.6 Gt of carbon/annum, i.e. roughly 20 % of global emissions of greenhouse gases. Drivers of deforestation in the Congo Basin have been mentioned earlier and they result in a significant release of forest carbon into the atmosphere.

Conversely, it is feasible – if one cannot exert total conservation of forest areas – to promote more responsible exploitation methods enabling to sustain the global carbon stock at the scale of forest ecosystems. The regeneration of degraded areas, reforestation or other appropriate silvicultural practices can lead to an increase of the quantity of carbon stored and could contribute to mitigate some Greenhouse Gases (GHG) emissions from other carbon reservoirs (including fossil fuels) or to mitigate activities inducing deforestation or degradation.

Tropical forests can also evolve naturally under the influence of environmental factors. Depending on forest types, climate change could increase the tree mortality or alter the specific composition of these forest types (Allen *et al.*, 2010; Lewis *et al.*, 2011). Climate changes could threaten important stocks of tropical forest carbon (see chapter 3 on the evolution of forests in the Congo Basin relating to the climate). Conversely, a rise in temperature and in atmospheric CO_2 could increase the storage ability of carbon by plants but these plants' properties have their limits depending on various parameters including soil fertility (Oren *et al.*, 2001). But this issue of resilience is central to current research works on tropical forests: how will forests respond to climate changes and what evolutions of related carbon stocks are to expect?

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Photo 1.7: The Umbrella tree (Musanga cecropioides) in the foreground, is a characteristic species of young secondary forests

[4] Figures in this paragraph are estimated and have significant variability depending on the source. The objective is to present here orders of magnitude rather than precise data.

Photo 1.8: The Ozouga (Sacoglottis gabonensis) is a giant of the coastal forests

4.2 Current estimates of forest carbon stocks and forest types

The Congo Basin is covered by a continuous forest which stretches from the Gulf of Guinea, in the west, to the Rift Valley, in the east. According to experts, forests in the sub-Saharan Africa account for 10 to 20 % of global plant carbon. This forest is uneven and includes different forest types where grow various tree species and present specific issues in terms of exploitation and conservation. It is possible to quantify large sets of forest carbon stocks (given hereafter) but actual research results don't enable to establish accurate correlation between the variation in carbon quantities and forest types in the Congo Basin. Biomass studies at the scale of the Congo Basin are on-going (Shapiro and Saatchi, 2014) and will complete previous analyses at a global scale (Saatchi *et al.*, 2011).

A typology of forests and related carbon storage can be established (Figure 1.5):

- The central zone includes a huge swampy forest. It stretches across a long and dense river network and is partly found on wet soils. In these forests, the carbon stock amount to circa. 100 to 150 tons of carbon/hectare;

- In other areas in DRC, Cameroon, Gabon and Equatorial Guinea, it is mainly about dense rainforest, more or less fragmented in the vicinity of villages and along roads. Current satellite data processing techniques allow quantifying with increasing accuracy the degradation in these areas: "intact" forest, fallow, plantations. These forests, when undisturbed, may store up to 200 tons of carbon/hectare but upland forests do not seem to excess 150 tons of carbon/hectare;

- In the north and in the south of the Basin (south of DRC and south of CAR), the dryier forest types show trees of lower height and carbon stocks are less important, which amount to circa. 150 tons of carbon/hectare;

- Moving away from the centre of the basin, patchwork forests and savannahs can store quantities up to 100 tons of carbon/hectare in the denser forest types but usually much less than that;

- Finally, woolands and wooded savannahs in the north of Cameroon, in CAR and in the south of DRC store low quantities of carbon, as low as 50 tons per hectare.

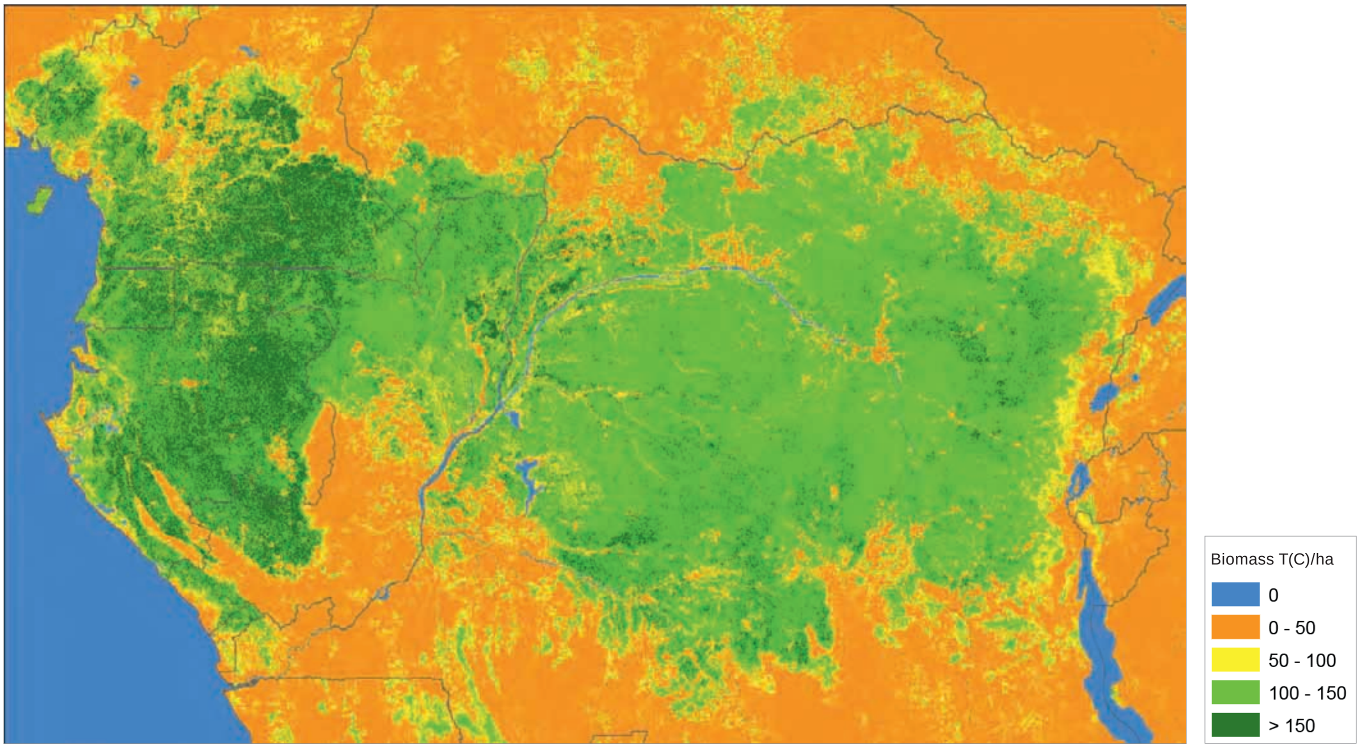

Figure 1.5: Distribution of biomass stocks of the main forest types in the Congo Basin.

Source: Saatchi et al., 2011

5. Other benefit from forest than carbon

Carbon storage is not the sole ecosystem service provided by these forests. Optimizing carbon storage should not be detrimental to biodiversity, to the cost of the speading of exotic species or without respecting some traditional uses by local and indigenous people. The full range of goods and services specific to each forest type has to be taken into account and studied, prior to defining land planning policies and strategies.

Negotiations on REDD+ within the United-Nations Framework Convention on Climate Change (UNFCCC), and the many variant of this mechanism as projects on the ground, have recently focussed on carbon in the scope of tropical forest management. However, forests offer many functions beyond carbon sink and storage or timber production, what is usually refered to as "ecosystem services" such as production of Non Timber Forest Products (NTFP), soil erosion and siltation control, water quality or local climate regulation, etc. These services are of paramount importance with regard to the subsistence of certain populations and their livelihood, and bring some diverse sources of revenue at local and national level.

The priority currently given to economic emergence in the sub-region[5] national policies could appear at first glance as conflicting with the maintenance of the forest cover. Nevertheless, the depletion of forest cover usually relates to soils more prone to erosion, which may impact on the quality of water, and result in silting of navigable waterways in certain areas, or cause some damage to hydraulic turbines or decrease the reservoir capacity of dams (Bernard *et al.*, 2009). It is thus possible that the deforestation and degradation of forests may – in the long run – negatively impact on hydro-power production or agricultural sector and hamper ambitions about promoting these strategic sectors in support to development.

Besides, some level of deforestation will also cause decrease in evapotranspiration, which is a key phenomenon in the maintenance of a healthy hydrologic cycle. The bulk of precipitations in the Region comes from the Atlantic ocean monsoon and the recycling of forest humidity (Brummett *et al.*, 2009). The depletion of forest cover could impact on the climate at a local and regional level, beyond carbon emissions contributing to global warming (see Chapter 3).

Legal timber exploitation in the forest concessions account for a significant part of the income of States. For instance, it represents the second economic pillar in the Republic of Congo and accounts for 2 to 6 % of GDP depending on the year. In the scope of forest management or exploitation certification scheme, logging companies also engage in perennial social undertakings (schools, health centres, roads, jobs, etc.) in favour of local and indigenous population. In so doing they partly contribute to some redistribution of revenue from forest exploitation. As opposed to non renewable resources (oil, minerals, etc.), sustainable management of forest resources, through the elaboration and implementation of management plans, allow for a source of wealth for the States in the long run.

At present, forest plantations are not much developed in the Congo Basin, notably because of the need for major investments required to start with planting species of high genetical value, as well as because of the risky country profile over rotation period (which may exceeds ten years). Nevertheless, this part of the forestry sector could and should develop in the next decades, and play a more prominent role both in the national economies and national strategies against climate change.

As a complement to forest exploitation, an important fraction of the population in the Congo Basin still relies on forests to sustain their livelihood and the diversification of income sources. The NTFP[6], fuelwood, or artisanal timber significantly contribute to local subsistence as well as to national economies in the sub-region (Ingram *et al.*, 2012). The twin markets of fuelwood and charcoal account for circa. 143 million dollars and 300 000 jobs for Kinshasa City alone (Schure *et al.*, 2011). Bushmeat is a cost-effective source of proteins to many rural households and it is also transported over long distances and sold on urban market places (Bowen-Jones *et al.*, 2002). The estimate of bushmeat consumption ranges from 1.1 to 1.7 million tons per year in DRC (CIFOR, 2007). Caterpillars and leaves from Gnetum species are both an indispensable source of oligoelements and proteins to certain populations and very much appreciated by them,

[5] Notaby Cameroon : Vision Cameroun 2035 http ://www.minepat.gov.cm/index.php/en/modules-menu/doc_download/106-vision-2035-du-cameroun ; Democratic Republic of Congo : Document de la Stratégie de la Croissance et de la Réduction de la Pauvreté II (2011) http ://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/RDC_-_2011-2015_-_Document_de_stratégie_de_réduction_de_la_pauvreté.pdf ; Republic of Congo : Document de Stratégie pour la Croissance, l'emploi et la Réduction de la Pauvreté (DSCERP 2012-2016) http ://www.afdb.org/fr/documents/document/congo-document-de-strategie-pour-la-croissance-lemploi-et-la-reduction-de-la-pauvrete-dscerp-2012-2016-30118/

[6] Some of the most common NTFPs in the sub-region are bushmeat, caterpillars, bush mangoes (*Irvingia spp.*) or gnetum (*Gnetum spp.*).

Photo 1.9: Fuelwood collection in the countryside in Burundi

which gives these products some high commercial worth (Hoare, 2007). Forests in the Congo Basin also play an important role in traditional medicine. Ninety percents of the population in DRC has reportedly used medicinal plants from forests for their treatment (Ingram, 2009). Forest ecosystems can also provide molecules useful to developing treatments in modern medicine. Despite the difficulty to get some estimates about economic worth of certain products, these sometimes fulfil an important role in the population's livelihood.

Forests in the Congo Basin are home to over 150 different ethnic groups (Megevand *et al.*, 2013). Certain places or "holy forests" are of cultural or religious value to numerous communities in Central Africa. The great diversity of forest ecosystems includes many species such as the forest elephant (*Loxodonta cyclotis*), the forest buffalo (*Syncerus caffer nanus*), various Primates or birds such as the bare-eaded rockfowl (*Picathartes oreas*). The sub-region holds approximately 1,300 bird species, 336 amphibian species and 400 reptile species; 20,000 plant species are recorded whose 8,000 are endemic (Billand, 2012) and 32 "ecoregions[7]" have been determined.

These ecosystems are unevenly exposed to land conversion or to degradation, as a result of uneven degree of pressure and because the protected areas network has some uneven representativity (Bodin *et al.*, 2014; Table 1.3). Areas where iconic species (bonobos, elephants, gorillas, etc.) and certain access conditions and facilities are met can enable the development of ecotourism activity (Wilkie and Carpenter, 1999). These activities can generate some substantial economic wealth: direct economic benefits from tourism activity built up on gorilla tourism (tour permits and other expenditure, guide wages, etc.) in both Kahuzi-Biega and Virunga National Parks exceeded $800,000 in 1990, before armed conflicts forced parks to shut down (Weber, 1998).

***Table 1.3:** Brief survey of protected areas found in the Congo Basin countries having rainforest areas*

Country	Number of protected areas	Area (ha)	Proportion of national territory(%)
Cameroon	30	3 825 024	8.1
Congo	15	3 992 422	11.7
CAR	16	7 014 500	11.3
DRC	51	26 415 737	11.3
Gabon	18	3 459 542	12.9
Equatorial Guinea	13	591 000	21.1
Total	143	45 298 225	11.1

Source: Doumenge et al., 2015

An important aspect of the notion of ecosystem services lies in the fact that beneficiaires from services from an ecosystem belong to various levels. A given piece of forest provides local benefits (e.g. wood and non timber forest products) while it also benefit the global community through carbon sequestration or through the biodiversity it includes. The focus given on a particular service can impact, positively or negatively according to case, on other services or on the economic viability of management choices in the related territory. This issue is illustrated by the prominent attention given by carbon in global efforts to improve forest governance, which has been detrimental to other ecosystem services.

Taking into account the potential risks associated with forest management practice solely based on carbon, UNFCCC parties have enacted a set of "garantees" that those countries claiming result-based payments must "promote and respect" (UNFCCC, 2010). These guarantees cover various aspects related not only to risks but also to additional benefits that REDD+ could bring, with a special emphasis on "benefits related to forest multiple functions and their importance with regard to biodiversity conservation[8]".

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[7] « Ecoregion »: a classification of ecosystems at a global scale (Olson *et al.*, 2001)

[8] Garantees: Measures which are compatibles with the preservation of natural forests and biological diversity, while making sure that activities [REDD+] do not favour some conversion of natural forests but instead favour protection and conservation of these forests and ecosystem services, as well as strengthening other social and environmental benefits.

The thematic and cartographic analysis of these benefits is one of the tools which enable to address the complexity of this issue, while allowing to identify the riskiest zones and the zones suitable to synergies between combined actions increasing the value of ecosystem services. Figure 1.6 illustrates a graphical representation of information about carbon combined with information on the presence of endangered species. Albeit the analysis at regional level gives a general idea about the various contexts in the region, more detailed analyses are necessary to support the conception of appropriate national and subnational policies.

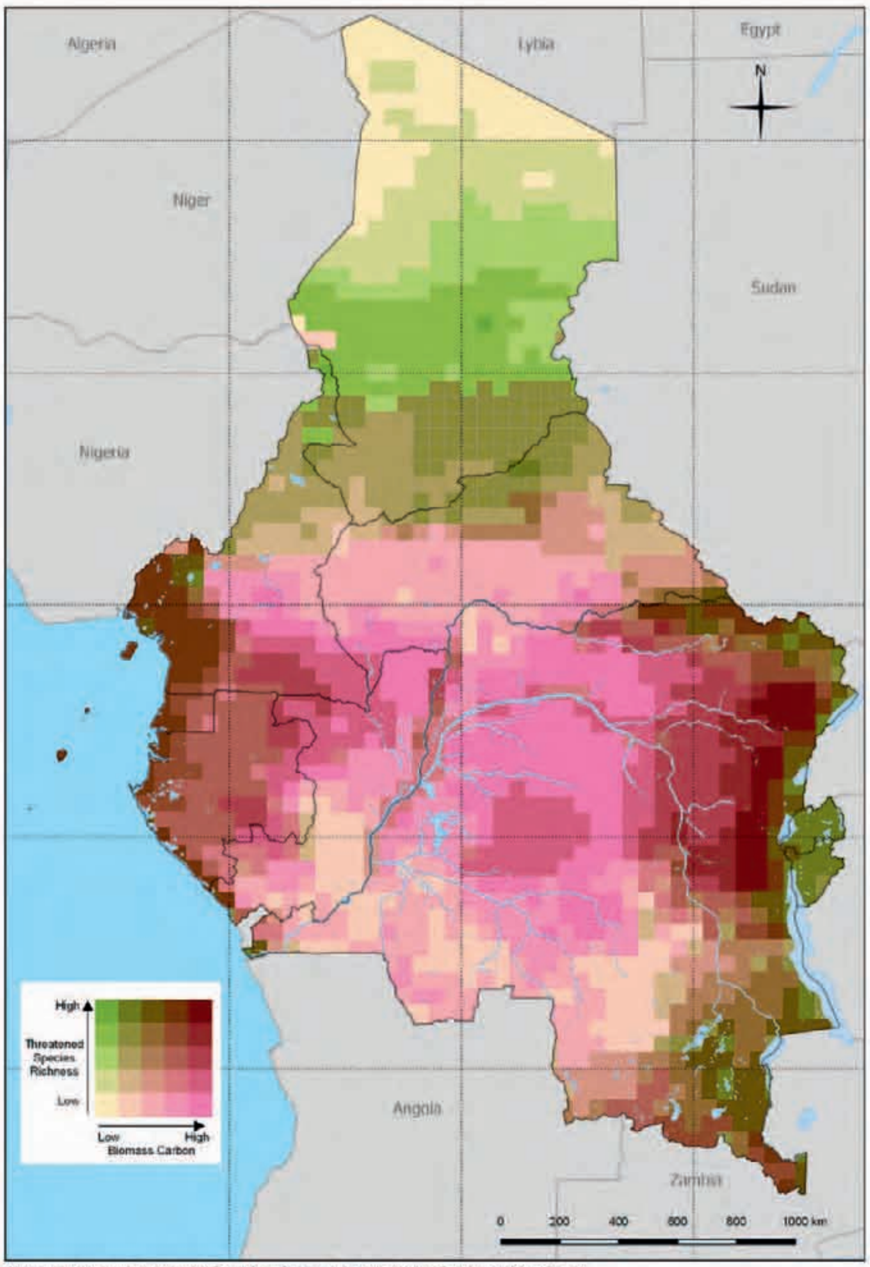
Large zones can be characterized according to various interests:

- pink: zones with high carbon. If it can be proven that they are at risk of future pressure (REDD+ scenario), they offer opportunities for decreasing emissions from deforestation and degradation, through conservation (effectiveness and expansion of the protected area network) as well as sustainable management of logging areas;

- dark red: zones that are both rich in carbon and in endangerd species. Possible actions on ecosystems must be envisaged in synergy with conservation;

- beige: zones that are low in carbon and present low biodiversity value. They offer few opportunities to reduce emissions from deforestation. They could be suitable for actions aiming at increasing carbon stocks such as afforestation or forest rehabilitation or even agricultural development;

- green: zones with low carbon content but including some high biodiversity value. They could be used for afforestation although this could jeopardize the species living there (notably in case of planting of exotic and fast growing species).



Map projection: Lambert Azimuthal Equal Area Projection, latitude of origin 5 and central meridian 19
Map prepared by UNEP-WCMC

Figure 1.6: Spatial variation of carbon density and potential specific richness of endangered species

Source: map made by UNEP-WCMC (IUCN, 2013; Baccini et al., 2012)

6. Possible future evolution of the forest cover (under constant climate characteristics)

The elaboration of policies which would allow both economic development and forest protection in the next few decades is a major challenge for Central African countries. Developing a better understanding of future anthropogenic pressure is an important step in this process as well as the impact of climate change.

The population in Central Africa is going to increase strongly. According to forecasts from the United Nations the population density in the COMIFAC zone will be multiplied by 1.6 by 2030 and by 2 by 2050. DRC, where dense rainforest accounts for 70 % of the territory (Potapov *et al.*, 2012), shall become the 11th most populated country in the worl by 2050 (ONU, 2013). Taking into account that countries in Central Africa are lagging behind in development, their forthcoming needs of a fast growing and increasingly richer population will be considerable.

The bulk of the populace in Central Africa will live in towns and cities : except for Burundi and Chad, over 40 % of the population in 2030 will live in towns and cities in the countries of the COMIFAC zone and over half of inhabitants will be urban dwellers by 2050 (ONU, 2013). Urbanization alters livelihood style. The share of cereals, rice and products including wheat, oil as well as dairy products and meat tends to become more important in food intake of urban households. However, a radical western diet does not always take over in Central African cities. The impacts on forests from increasing demand for agricultural products will depend not only on the production areas but also on the production modes : countries in the Congo Basin are currently lagging behind in agricultural productivity.


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Photo 1.10 : Artisanal wood exploitation at the border of terrace (Rwanda)

Most farmers cultivate less than one hectare with very few tools and very little or no input. Deforested areas detected through satellite images between 2000 and 2010 in DRC averaged to 1.4 ha in area, which is likely to relate to clearing for subsistence cultivation, as opposed to Brazil or to Indonesia where commercial agriculture is the major driver of deforestation (Potapov *et al.*, 2012). Most studies indicate that yields could easily double if improved seeds, fertilizers and adequate pest treatments were used (Gockowski and Sonwa, 2011). Productivity gains could increase production while controlling the expansion of farmland, knowing that farmland expansion may goes together with increased deforestation in the absence of stringent zoning (Mosnier *et al.*, 2014 ; Byerlee *et al.*, 2014). Moreover the expansion of agro-industrial plantations is presented as a strategic priority in many development plans in the sub-region (as addressed earlier). The share of palm oil in the world production of vegetable oil has more than doubled in the last twenty years and has overtaken soy oil production (OECD and FAO, 2013). The bulk of arable land suitable for cultivation are found in nine tropical countries only, with lands with high potential mainly covering some large areas in dense rainforests (Mosnier and Pirker, 2015). While available land suitable to plantations in Indonesia and Malaysia is getting scarcer and scarcer, international investors show some increasing interest in the Congo Basin where governments hope for quick positive impacts from new plantations on employment and economy (Hoyle and Levang, 2012).

Urbanization and growing demography usually go with an increase in demand for building materials and energy. While large logging companies in the sub-region export the bulk of timber to Europe and China, numerous small-scale artisanal loggers supply domestic urban markets with local timber. This wood demand from national and sub-regional markets is often less sensitive to criteria of sustainable management of forest areas as opposed to European markets and therefore it constitutes a serious threat on the future of forests in the Congo Basin.

As far as energy needs are concerned, several hydro-electric plant projects are identified in the sub-region and are under discussion. On the one hand, these infrastructures will flood some upstream forest land, but on the other hand some better access to electricity could contribute to solve the fuelwood issue which is a major driver of ecosystem degradation within an increasing radius around cities in Central Africa (Schure *et al.*, 2015). The maintenance of hydro-power plants remains crucial in the long run: Inga I and II dams in DRC work at 20 % of their capacity only. Buying electrical appliances to substitute fuelwood stoves remains difficult for many households given their low purchasing power.

International industrials, notably mining companies, could expand their activities in the sub-region over the next few decades. Countries in the Congo Basin are blessed with abundant minerals: 80 % of coltan originate from DRC; major iron ore deposit have been located in Cameroon, in Gabon, in Congo and in DRC; gold and diamond are exploited in CAR, in Congo and in DRC. While many mining permits were granted over the last few years, it is difficult to say how many will actually lead to some exploitation. Since iron price has been dropping since 2011, many projects in the Congo Basin are being reviewed. Nevertheless, in the medium and long run mining activity will likely increase in the sub-region. Direct impacts on forest cover are usually limited but indirect pressures discussed earlier can be serious.

In the scope of REDD-PAC[9] project, the CongoBIOM[10] model (see Box 1.1) has been designed to appraise impacts from increasing food and fuelwood needs on forest cover in the next few decades in the COMIFAC countries, as well as CO_2 emissions and threats over biodiversity resulting from them (Figure 1.7).

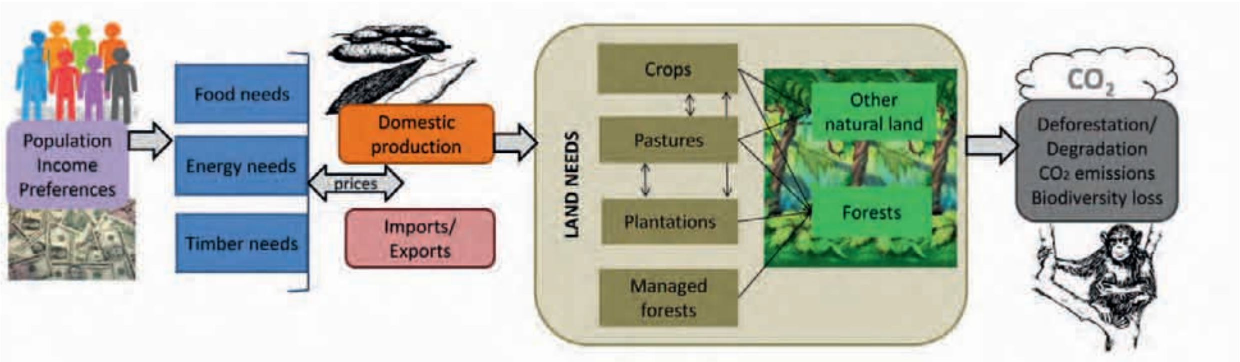

Figure 1.7: Future deforestation depends on future needs in food, in fuelwood and in energy in the CongoBIOM model

Box 1.1: *The CongoBIOM model*

The economic land use model GLOBIOM (www.globiom.org) is developed at IIASA (Havlík *et al.*, 2011) and usually works at global scale. In the scope of the REDD-PAC project, this model has been adapted to the Congo Basin ("CONGOBIOM") in order to better address local specificity and futures risks of deforestation related to the development of livestock and agriculture sectors, forestry and bioenergy. The model uses a global database which has been improved by entering national data (see www.redd-pac.org for the description of the database). In the model, land use alteration is caused by an increase (or a decrease) in local and global needs for food, wood, and bioenergies depending on the forecasts of population growth and economic growth done by other institutions (e.g. United Nations, FAO). Additional needs can be met by an increase of productive lands (e.g. deforestation), by an increase in land productivity (e.g. improvement of yields) or by an increase in imported goods. Land use alteration computed that way is combined with biomass maps or biodiversity maps to estimate carbon emissions in the atmosphere and the risk of habitat loss for some species.

[9] www.redd-pac.org

[10] The CongoBIOM model has been adapted from GLOBIOM model developped at IIASA (Havlík *et al.*, 2011) to the context of the Congo Basin (Megevand *et al.*, 2013; Mosnier *et al.*, 2014). It is an economic model (uncomplete balance) which computes the evolution of both future production and consumption of agricultural products, forestry, bioenergy and related land use alteration.

In the absence of significant productivity gains, the demand for land suitable for crop production in the COMIFAC area would increase by more than 8.5 million hectares between 2010 and 2030 in the case of casava, groundnut and maize only. The region would double its production of palm oil by 2030 as well as its exports, albeit the increase in palm oil production would mainly aim at meeting the local demand. In total, it is assumed that the mean annual deforestation related to the expansion of agricultural land for cultivation and livestock would increase by 640 thousand hectares on average and per annum between 2000 and 2010, by a bit more than 1 million hectares per annum between 2010 and 2020, and finally by 1.5 million hectares per annum between 2020 and 2030. It means a total loss of 26 million hectares of forest between 2010 and 2030 in the Congo Basin, which represent circa. 10 % of the total forest cover (see Figure 1.8 for the location of deforestation in Cameroon, Congo and in DRC). The emissions related to this deforestation could range from 8.8 to 13 billion tCO_2 over the period 2010 – 2020, when only accounting for carbone contained in the above ground biomass and forest areas completely cleared[11].

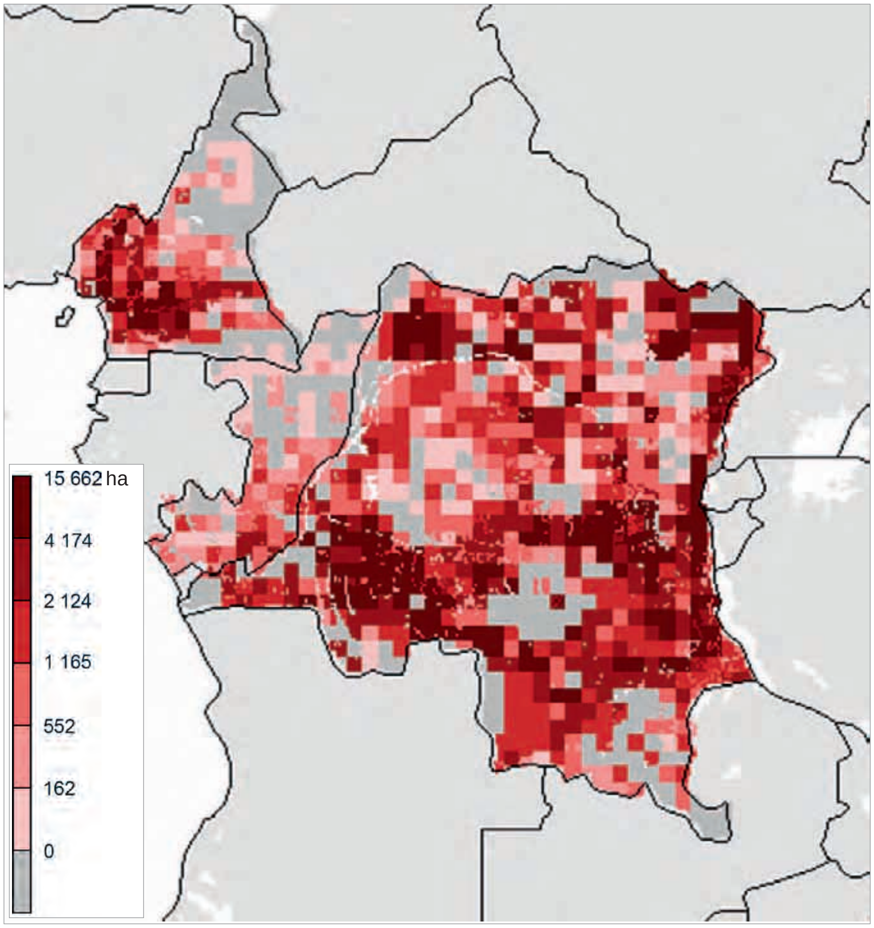

Figure 1.8 : Cumulative deforestation for the period 2010-2030 in Cameroon, Congo and DRC (findings resulting fom the CongoBIOM model)
Unit : ha per cells of 0.5 x 0.5 degrees

Moreover, results from works performed by the IIASA show the threat on protected areas in the Congo Basin. In the context of demographic growth the States usually lack sufficient means to guarantee territorial integrity and biodiversity in protected areas. According to the findings from the model, 4 % of forests in protected areas could be destroyed in the next two decades if their protection were not secured. Finally, logging areas can also be useful in fighting deforestation. Indeed, in the absence of legal land tenure status, it is assumed that an additional 280 thousand hectares of forest would be destroyed between 2010 and 2020 and this figure would reach 600 thousand hectares between 2020 and 2030. This would be particularly detrimental to forests in the Republic of Congo, in Cameroon and in CAR.

Overexploitation of logging concessions over the first few years of operations, or the lack of economic profitability, can – in theory – result to the hand over of the logging area to the State. It is thus crucial to strengthen the sustainability of forest exploitation and in the meantime to add value to forest products in order for logging areas to play a role in maintaining forest cover and biodiversity. According to this line of reasoning, European consumers aware of legal operations and sustainably managed forests can understand that using tropical timber coming from well-managed forests actually contributes to their preservation because it gives these forests some economic value and make them competitive vis-à-vis other land uses in the sub-region.

A sustainably managed forest in the Congo Basin produces continuously about 0.2 m^3/ha/year. Assuming a 25-30 year-rotation and recovery rate usually used in processing units (±30 %), any consumer buying a piece of sustainably produced timber 400 x 30 x 2 cm (0.08 m^3) helps securing economically and environmentally 0.5 hectare of forest over a period of 30 years. Extrapolating from this calculation, France – which imported 2.48 million m^3 of tropical timber in 2013 (Groutel, 2013) – could sustainably preserve about 50 million hectares of forests (FRM, 2015), i.e. a bit over the 49 million

[11] The variation of emissions depends on biomass maps one uses, here the Saatchi maps has been used (Saatchi *et al.*, 2011). Besides more than half of agriculture expansion will occur on fallows or secondary forests which could develop if fallow cycles were long enough, and this could reduce the level of total emissions computed by the model.

hectares of logging areas currently granted in the Congo Basin; provided that these forests are well managed and are not subsequently assigned to other uses (i.e. industrial agricultural plantations).

On the other hand, current research on forest and forest species tend to show that the human impact on forests in the Congo Basin has been rather widespread since the beginning of the Holocene. Important remains of human activities and fires were noticed especially during two periods, between 2500-1500 years before present (BP) and since few hundred years ago, along the Atlantic coast as well as further inland, in the Sangha river interval (Morin-Rivat *et al.*, 2014; Biwole *et al.*, 2015). It is nevertheless difficult to assess the precise impact of past human populations independently of past climate changes as they tended to occur simultaneously (see also Chapter 2). The presence of some light demanding species such as azobe (*Lophira alata*) in Southern Cameroon seems to be related to recruitment after human agriculture, a few hundred years ago (Biwole *et al.*, 2015), and forest exploitation could enable to maintain such species in the landscape, which tend to disappear in undisturbed forests. But such positive effect is also dependant on the maintenance of a minimum forest structure such as in the past with scattered small scale shifting cultivation and long fallow periods.

6.1 Land planning management issues raised by development

Territorial stakes related to the future of the Congo Basin forests are multiple: one has to face needs incurred by the development of these countries as well as the need to conserve the integrity of the forestry ecosystems for providing ecosystem services and their role in climate change mitigation. The socio-ecosystem analysis developed in the study "Horizon 2040" supported by COMIFAC is an attempt to depict territorial dynamics in the long run (Marien and Bassaler, 2013). The approach developed in this study puts forward the priority given to issues such as regional and national political stability, neo-urban demography and economic and structural development projects (roads, navigable waterways, etc.) vis-à-vis the purely technical aspects of the future dynamics of the forest cover. Strengthening governance of States and their administration to address illegal forest exploitation and ecosystems degradation resulting from other drivers of deforestation is a prerequisite to any territorial construction. In the forestry sector, the FLEGT[12] process tries to bring some answer and could become a model able to inspire other initiatives in the exploitation of natural resources and spaces.

Thus, on-going economic development in the sub-region will necessarily translate into making choices about land allocation to various sectors of activity, about management rules and potential compensation measures of possible impacts of industrial projects on forests. Land tenure conflicts, which frequently take place between various economic sectors in Central Africa, are coming back as a result of the priority given to mining or certain types of agro-industries by the States over other tenure rights of lesser immediate economic value. Table 1.4 and Figure 1.9, related to the overlap of land utilization based on legal titles, illustrate the complexity of territorial dynamics.

Table 1.4: *Overlap of main soil utilizations in some COMIFAC countries*

Countries	Overlap of mining exploration over logging areas (%)	Overlap of mining exploration over conservation[13] zones (%)	Overlap of mining exploitation over logging areas (%)	Overlap of mining exploitation over conservation[13] zones (%)
Cameroon	44.3	25.7	1.9	0.0
Congo	43.7	16.3	0.4	0.0
Gabon	54.0	17.8	0.1	0.0
CAR	0.8	0.0	1.5	0.0
DRC	6.6	12.5	0.5	1.3
COMIFAC[14]	33.8	13.2	0.6	0.7

[12] Forest Law Enforcement, Governance and Trade.

[13] any kind of protected spaces, without any distinction between status and denomination

[14] the whole group of COMIFAC countries and not only the sum of the five countries given in the table for which more data are available

Photo 1.11: Food crops in densely populated areas leave little room for trees (Rwanda)

Besides, the issue of the carbon footprint of extractive activities or agro-industrial plantations is not yet raised with all its dimensions and complexity. Various questions arise, such as to what extent could the carbon balance be positive if ecological compensation are to be implemented by stakeholders at each phase of the exploitation cycle in the mine/plantation?

Land-use planning goes now beyond the scope of the sole development issues and meets today the stakes around climate change mitigation and adaptation. Land planning and exhaustive national cadasters seem to be the most favoured solution to development planning and to the resolution of associated problems and conflicts. Some initiatives about land planning schemes exist in various countries in the Congo Basin, but they are only indicative and bear no legal rights, being widely unknown and seldom implemented by land use and development planners.

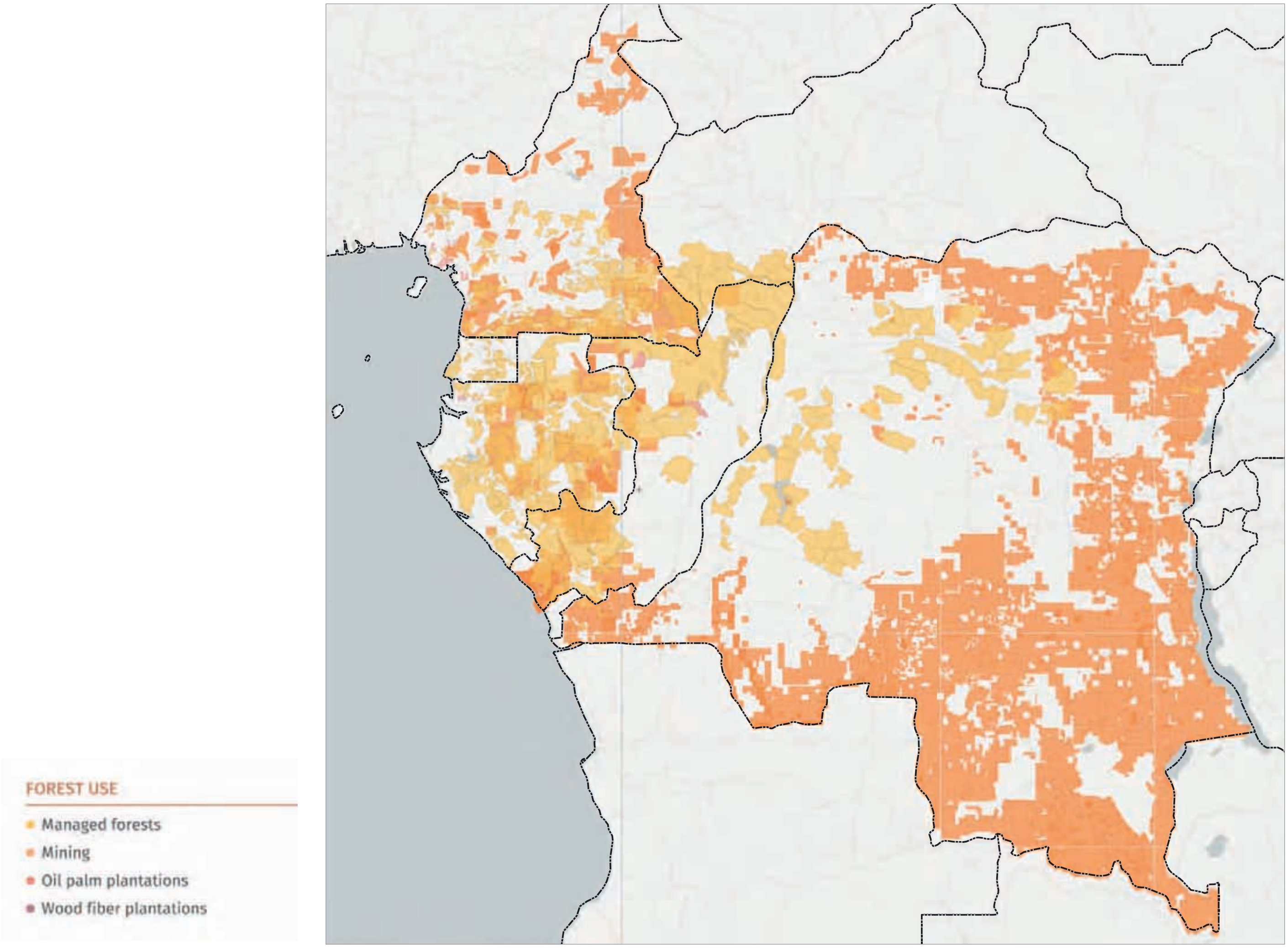

Figure 1.9: Overlaying of various land uses in some COMIFAC countries

Source: www.globalforestwatch.org/map/

CHAPTER 2

Climate of Central Africa: past, present and future

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1. Introduction

Albeit some improvements, climates and paleoclimates in Central Africa are still unsufficiently known. This uncomplete knowledge results from the lack of local data, the disperse networks of past and current measuring and the very few pieces of scientific work on climate in this region. Consequently, some uncertainty still prevails on how these climates may evolve in response to current climate warming. In order to understand changes that might affect these climates, it is necessary to get some solid knowledge about their current functionning, more specifically the way they fit into the global climate system and to what extent they affect climate variability and changes in the tropical zone (Camberlin, 2007). Few existing studies show that the Region presents some mild interannual rainfall variability when contrasted to other regions with similar annual rainfalls. The spatial coherence is also particularly weak. These two elements reflect some small sensitivity to interannual major forcing of tropical climate, notably to sea surface temperatures. One also may predict an increase in extreme events, disruptions in the frequency of meteorological catastrophic events, hence hazards. Consequently, it is necessary to understand how countries in the region get organized with regard to climate change challenges.

Photo 2.1: Deforestation causes climate changes at the local level, promoting the loss of water available through rising temperatures, evaporation and runoff

2. General climate context

Due to its geographic situation, Central Africa confers a variety of climate types which can be grouped into two broad types: equatorial and tropical (Figure 2.1). Some areas of limited extent are subjected to montane climate, such as the Albertine Rift (towards the East of DRC) and the Cameroon volcanic line.

Equatorial climate with four seasons stretches up to southern Cameroon and CAR, the centre of DRC, in Congo, in Gabon, in Equatorial Guinea and in Sao Tomé and Principe (Mpounza and Samba-Kimbata, 1990). Mean annual rainfall is about 1,500 to 1,800 mm with some extremes as high as 10,000 mm in Debundsha, in south-west of Mount Cameroon, and south of Bioko Island in Equatorial Guinea. The climate is warm and humid with temperatures ranging between 22°C and 30°C.

Tropical climate, with two seasons, presents several sub-types: Sudanese, Sahelian and Saharan. Sudanese, sudanese-sahelian and sahelian sub-types are found in North Cameroon, the south of Chad, the centre and north of CAR. The southern DRC has a more temperate climate due to an average altitude higher than other areas. Mean annual rainfall ranges from 300 mm to 1,500 mm. Shahelo-Saharan and Saharan subtypes only include north of Chad where the mean annual rainfall is below 300 mm and where maxima temperatures may reach 50°C (Godard and Tabeaud, 2009).

The equatorial and tropical climates of the Northern hemisphere are characterized by a dry and sunny main dry season (December to February), while those in the Southern hemisphere, especially to the Atlantic coast, have a cloudy dry season cover preserving very high levels of humidity (June to August). These climatic differences, on both sides of the climatic hinge separating the northern and southern climates, impact on the vegetation and their importance is too often unrecognized regarding future climate changes (Gonmadje *et al.*, 2012; Monteil *et al.*, in prep.).

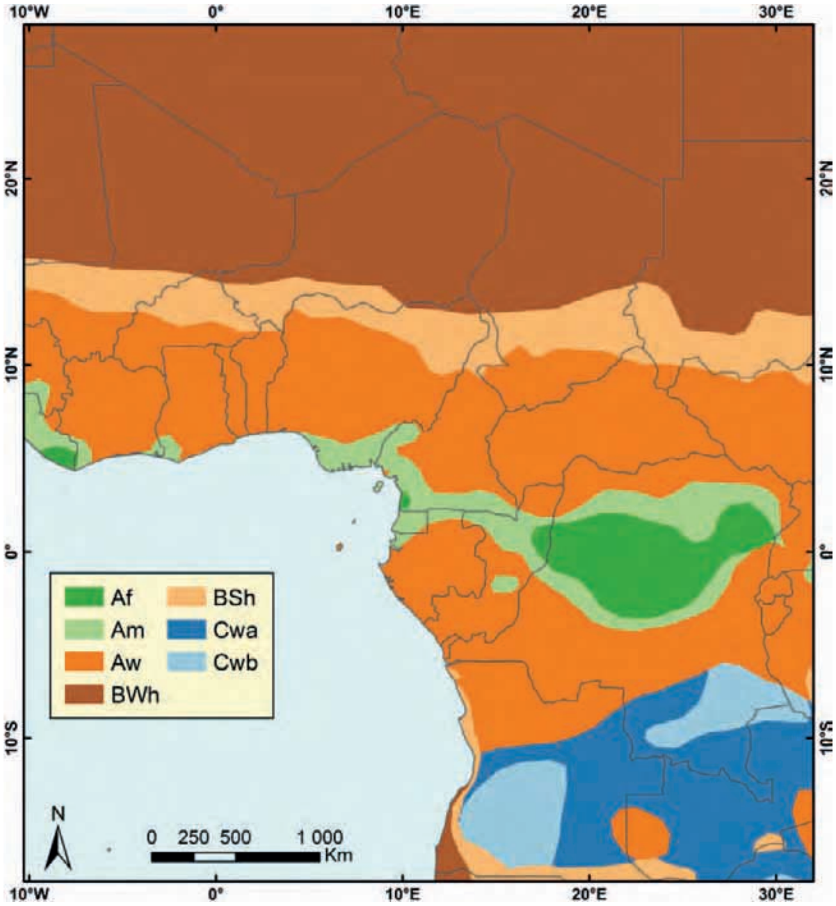

Figure 2.1: Climate classification of West and Central Africa using the Köppen-Geiger system[15] (Peel et al., 2007). Af = equatorial/humid, Am = tropical/monsoon, Aw = tropical/dry winter, BSh = semi-arid/dry, hot, BWh = arid/ hot, Cwa = hot temperate/dry winter/hot summer, and Cwb = hot temperate/dry winter/warm summer.

3. General functionning and characteristics of present climates

3.1 Dynamic of the atmosphere

Two circulation modes – the Hadley circulation and the Walker circulation – control the movements of air masses and climate in Central Africa.

3.1.1 The circulation of Hadley

The circulation named after Hadley (Figure 2.2), between the equator and the tropical latitudes (30°), commands weather types and climates in Central Africa.

The high temperatures in the equator lead to significant evapotranspiration and the formation of clouds causing heavy rainfall. While rising in the atmosphere, the air becomes progressively drier towards higher altitudes. It then moves north and south and, when cool enough, descends to the lower layers of the atmosphere (Figure 2.2). Strong updrafts winds at the equator make the effect of a pump which then attracts surface winds of tropical latitudes towards the equator. The south and north trade winds meet along a surface of discontinuity called Inter-Tropical Convergence Zone (ITCZ) or Inter-Tropical Front (ITF). The ITCZ migrates north from January to July and allows the southern trade winds, that change direction and load oceanic moisture, to dump heavy rains on the African continent. At its migration peak towards

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[15] Note: This map is a very general outline that reflects only partially the variability of climates in Central Africa. In particular, most of Gabon and Congo benefits from equatorial to subequatorial climates, intermediate between the climates Af, Am and Aw.

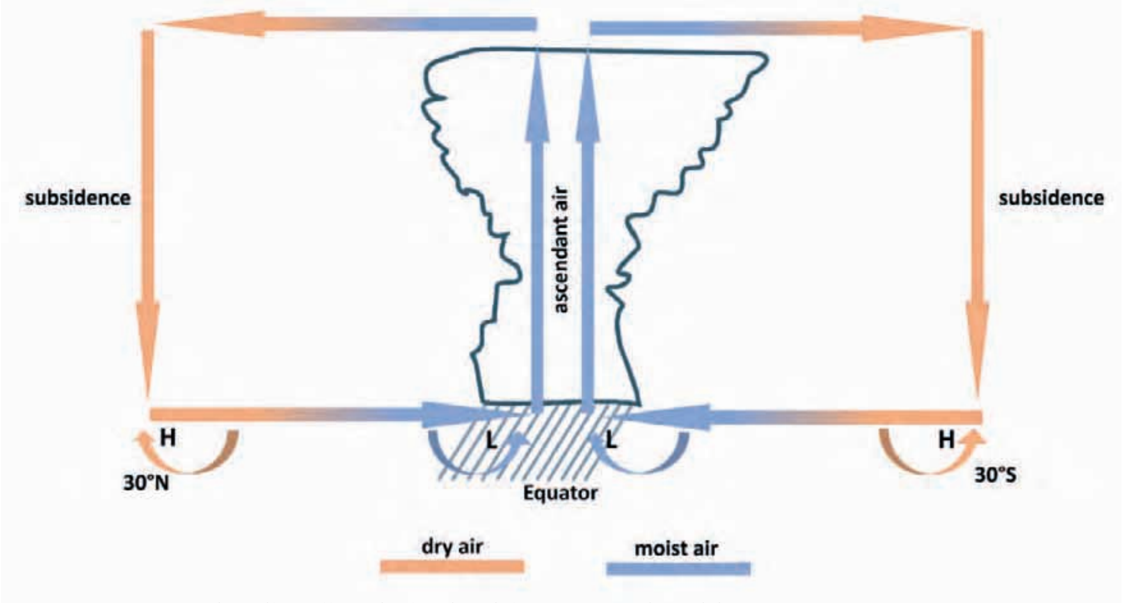

Figure 2.2 : Section of Hadley cells on both sides of the equator (adapted from Demangeot, 1992)

north, the southern trade wind is very close to the continent and causes the dry season from July to August in areas located in the southern part of the region. Starting in July, the trade winds from the north-east, also called Harmattan, deploy itself to the South thanks to the retreat of the ITCZ. It reaches its southernmost position in January, providing dry weather corresponding to the dry season in northern Central Africa.

Figure 2.3 shows the ITCZ average positions and the Interoceanic Convergence (IOC) on Africa during the year. The IOC is materializing the confluence of winds from the Atlantic and the Indian oceans. Although the impact of the IOC movements during the year is far from negligible, particularly in the east of the area we are concerned with, the migrations of ITCZ are of the utmost importance to countries impacted by them since they allow to understand the patterns of seasons and their variations among years. These migrations are influenced by the earth rotation and the rotation around the sun as well as ocean surface temperatures. Man, through his activities (afforestation, deforestation, bush fires, air pollution, etc.), may make the composition of the air masses more complex and impacts on their movements and raining capacity.


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Photo 2.2 : Small mountains along the Atlantic coast benefit from a high atmospheric moisture from the ocean which favor the development of dense evergreen forests

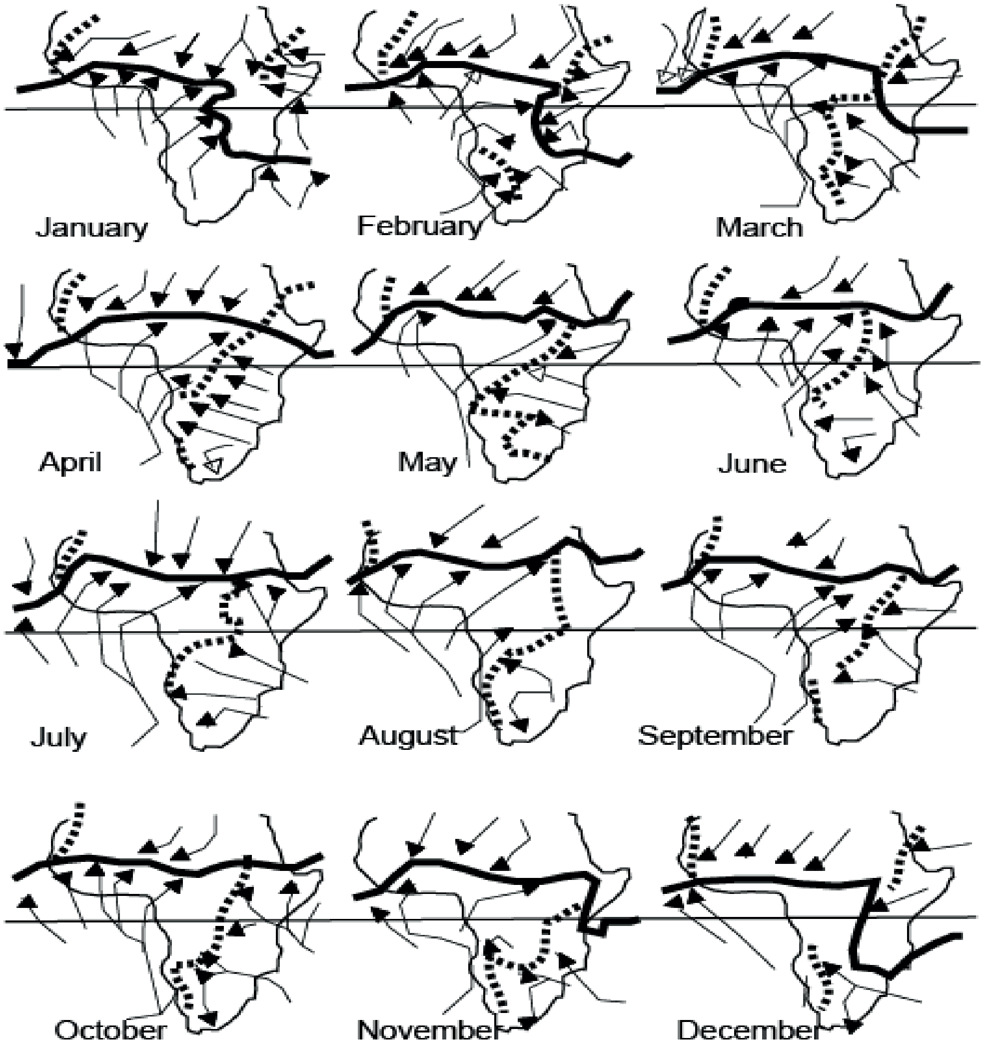

Figure 2.3 : Mean monthly position of the ITCZ (plain line) and the Inter-Oceanic Confluence (dash) across Africa (Samba-Kimbata, 1991 ; Bigot, 1997).

3.1.2 The Walker circulation

Central Africa is also subject to a cell circulation linking the climates of the entire tropical belt. Seasonnal anomalies in regions located East and West of the Congo Basin originate from this so called "Walker circulation" (Figure 2.4).

Walker and Hadley circulations combine themselves to impact seasonnal and annual climatic parameters.

3.2. Impact of the ocean circulation

The ENSO phenomenon (El Niño Southern Oscillation) seems to partly impact climates in Central Africa as well as Sea Surface Temperatures (SST). Rainfall variability seems to be linked to ENSO and the western Indian Ocean in the first months of the year, and to the Atlantic during the June-August period ; the Indian Ocean becoming again important later on (Balas *et al.*, 2007). Precipitations in Central Africa are promptly and seasonnaly impacted by the behaviour of sea surface temperatures, especialy in the Atlantic Ocean, in relation with the dynamics of the ITCZ. Years during which the Southern Atlantic Ocean is warmer than usual show a lack of rainfalls during July-September period north to 10°N latitude, and in October-December south of Cameroon then Gabon. Conversely, on the southern fringe of the

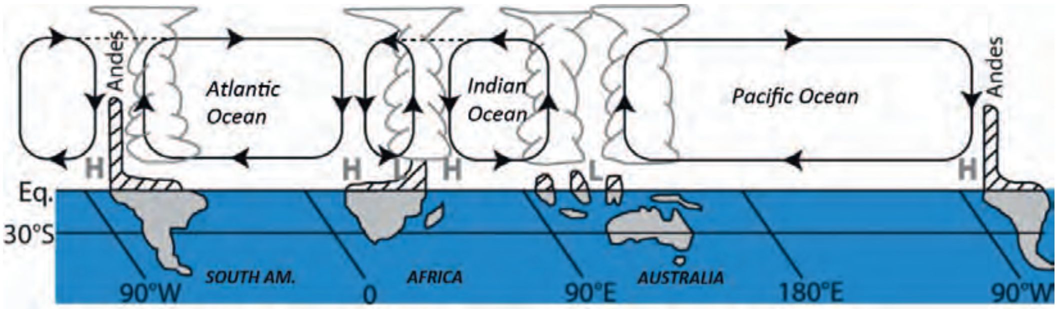

Figure 2.4 : Walker circulation

Source : Dhonneur, 1985

ITCZ, a warm central Atlantic Ocean goes with some excess of rainfalls, at least close to the ocean.

3.2.1 Space and time variability of rainfalls at a regional scale

3.2.1.1 Mean annual rainfalls

Figure 2.5 shows the variations in rainfall between the early twentieth and the early twenty-first centuries (Djoufack, 2011; Djoufack and Tsalefac, 2014). All in all, one observes two areas of high precipitations (P>2,500 mm) : the one above and below the equator (equator stripe) and the coastal area of the Gulf of Guinea. Elsewhere, total annual rainfalls do not exceed 1,500 mm. North of 15th parallel, Saharan and Sahelian areas get less than 500 mm per annum.

The bottom of the Gulf of Guinea and, in general, the Atlantic Central Africa is under the influence of the African monsoon and experience heavy rainfall. This ocean influence combines with other influences (relief, vegetation, etc.) to create the diversity of local climates. Therefore the high pluviometry on the coastal area from Cameroon to Gabon is directly or indirectly related to the presence of highlands such as Mount

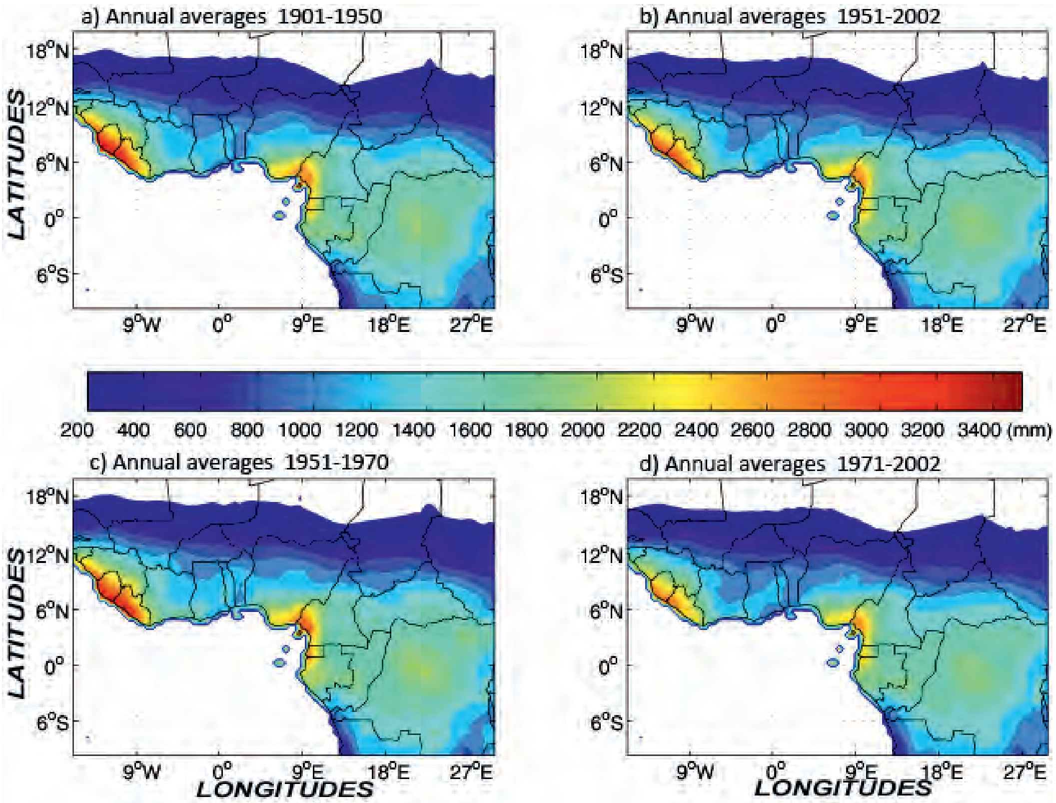

Figure 2.5 : : Changes in annual rainfall (mm) between 1900 and 2000 at the regional level; a) average 1901-1950 ; b) average 1951-2002 ; c) average 1951-1970, d) average 1971-2002.


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Photo 2.3: If the climate dries up, rare ecosystems of high ecological value such as the swampy clearings could disappear

Cameroon or the small mountains bordering this atlantic coast.

The Congo Basin also has its heavy rainfall, less from the influence of the ocean than from the evapotranspiration of its forest and marshy cover (Bigot, 1997).

3.2.1.2 Precipitation trends

Figure 2.6 suggests that rainfalls remained relatively abundant during the last century, although they seem to have decreased since the 1950s and especially since the 1970s. Thus, one has noticed a downward trend of total precipitations of 31 mm/decade between 1955 and 2006 (Aguilar *et al.*, 2009). The biggest fall of precipitation levels were seen during the decade 1968 – 1980 (Mahé, 1993) and were not of even intensity across the region. In the south of Cameroon and in Congo, the fall in precipitation has occurred until 1990. Besides, in Gabon and CAR, one has observed a rise after 1980 and 1985 respectively (Mahé, 1993).

Some discrepancies were also noticed at a local scale (Tsalefac *et al.*, 2007; Tsalefac, 2013). While the pluviometry in the north of the Republic of Congo is marked by a fall, it remains stable in the south of the country (Samba-Kimbata, 1991). Similarly, one has noticed a decrease in the number of rainy days with precipitations >1 mm, as well as a decrease of the number of days with precipitations >10 mm (Aguilar *et al.*, 2009).

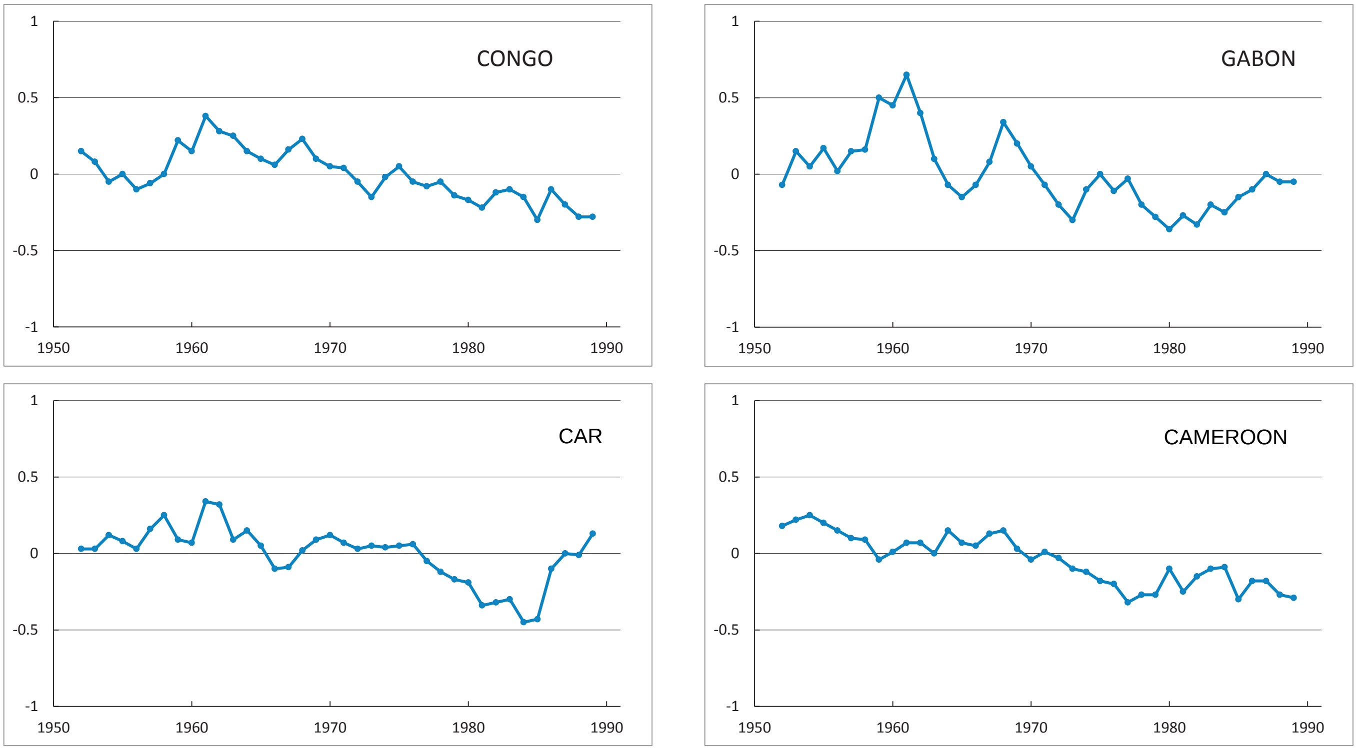

Figure 2.6: Evolution of annual precipitations since 1950 in different regions of Central Africa (Mahé, 1993)

3.2.1.3 Trend in temperatures

Conversely, temperatures show an upward trend. In the Republic of Congo, over a period of time from 1950 until 1998, temperatures have increased by 0.5°C up to 1°C during the decades 1980s and 1990s (Samba-Kimbata, 1991). Regarding changes of temperature in the long run observed in the region, data available from local weather stations, although limited, tend to show some warming at a statistically significant level (GIEC, 2007). This trend is accompanied by an increase in extreme temperatures (for example, the temperature of the hottest day seems to increase by 0.25°C every new decade) while period of time with cooler weather have become less frequent (Aguilar *et al.*, 2009). Nevertheless, given the scarcity of data from field stations, it seems very difficult to draw definitive conclusions on the evolution of current climates.

4. Past climate of Central Africa

Paleoclimates in Central Africa are relatively well known over the period of time spreading over the Upper Pleistocene and Holocene for which the chronology of climatic events has considerably evolved, mainly due to C^{14} dating. Palynology and sedimentology studies in lakeside and sea sediments allow a relatively coherent scheme of paleo-climates (Table 2.1).

Around 4,000 years BP, the sea surface temperature decreased and precipitation lowered. At that time, erosion and alluvial deposits, however, remained moderate. This phase of relative drying changed suddenly around 2,500 years BP with a change in the seasonal distribution of rainfall. Despite higher sea surface temperatures and rainfall probably more sustained than previously, the length of the dry season seemed to increase, causing negative effects on forest cover. At that time, erosion and alluvial deposits intensified, showing the existence of a more tropical climate with contrasting seasons.

From 2,000 years BP, a wet phase resettles to the current days, interspersed with drier periods such as the one that took place between 500 and 200 years BP (from the XVth to the XVIIIth century), corresponding to the small Ice Age in Europe.


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Photo 2.4: Mangroves will undoubtedly suffer from future sea level changes

Table 2.1: *Overall evolution of past climates in Central Africa according to palynological and sedimentological data*

Chronology	Climate	Indicators
-22,000 à -16,000 years BP(*) (Kanemian)	Cool and dry climate	Presence of aeolian sediments and dunes along the banks
-16,000 to -8,000-7,000 years BP (Bossumian, Pleistocene transition)	Humid phase	Sealing of fairways and mangrove development; development of rainforests
-7,000 to -4,000 years BP	Persistence and peak of the humid phase	Maximum development of forests towards -6,000 years BP and then beginning of fragmentation on the forest margins
-3,000 to -2,000 years BP	Sudden dry phase	Sudden shrinkage and opening of forests, deepening of fairways, strengthening of Benguela Current (Giresse, 1984)
-2,000 to -1,800 years BP	Sudden come back of humid phase	Expansion of forests on land not used by men

(*) BP = before present.

5. Predicted climate of Central Africa

5.1. Global and regional assessments of climate changes

Assessments on how precipitation and near surface temperature, the most important climate parameters, might change over the course of the 21st century have been made by several COMIFAC countries in the framework of their national communications to the UNFCCC. These assessments were based on projections of Global Circulation Models (GCM) and display a limited accuracy due to their coarse spatial resolution (up to 500 km). As Appendix 1 shows, their projections differ substantially between the countries.

At regional level, climate projection studies are available that cover the Congo Basin completely or at least to a large portion, even though the region was not always the focus of these studies (Sonwa *et al.*, 2014). Most of these studies go only up to the middle of the 21st century and use the input of only one GCM run for one specific scenario. But recently, a comprehensive regional climate change assessment was conducted over the Congo Basin region from 2010 to 2012 (CSC, 2013). In this assessment, 77 existing and additionally compiled global and regional climate change projections were analyzed for high and low GHG emission scenarios respectively. This study allowed not only to estimate the potential magnitudes of projected climate change signals but also enabled to judge on the reliability of the projected changes. Furthermore, a representative subset of the climate change projections has been used as input for subsequent impact assessments and the formulation of adaptation options.

5.2 Near surface air temperature

The aforementioned Climate Change Scenarios study (CSC, 2013) revealed that for near surface air temperature all models, independent from season and emission scenario, show a warming of at least 1°C towards the end of the 21st century. The frequency of cold/hot days and nights, will decrease/increase respectively, again independently from season and emission scenario (Table 2.2). Since all models are projecting changes in the same direction, the likelihood of these changes to occur is very high. However, the full range of possible changes is large and mainly caused by a few outlier model projections.

Therefore a sub range (the central 66 % of projections) defining changes being likely to occur was defined. For near surface annual mean temperature the likely changes towards the end of the century, are between +3.5°C and +6°C for a high emission scenario and between +1.5°C and +3°C for a low emission scenario (Haensler *et al.*, 2013). In general, projected temperature increase is slightly above average in the northern parts of the region, North of the climatic hinge, and slightly below average in the central parts.

Table 2.2: *"Likely range" (centered on the median) of projected changes (in %) for the frequency of cold/hot days/nights averaged over the entire Congo Basin region.*

Projected Changes	Low emission scenario		High emission scenario	
	2036 – 2065	2071 – 2100	2036 – 2065	2071 – 2100
Cold nights (in %)	-9 to -7	-10 to -7	-9 to -8	-10
Cold days (in %)	-8 to -5	-9 to -6	-9 to -6	-10 to -9
Hot nights (in %)	+27 to +43	+29 to +56	+38 to +53	+64 to +75
Hot days (in %)	+12 to +21	+13 to +29	+16 to +28	+31 to +54

Source: Haensler et al. (2013).

5.3 Total precipitation

According to Haensler *et al.* (2013), for total precipitation, the results of the different projections are not as robust as for near surface air temperature. Some models project an increase of annual total precipitation in most parts of the Congo Basin region, whereas other models project a decrease over the same areas. However, the same authors are projecting towards the end of the 21st century a general tendency for a slight increase in future annual total precipitation for most parts of the Basin. Largest increase in annual total precipitation is projected over the generally dryer northern part, which is mainly related to the northward expansion of the ITCZ and to the fact that total precipitation amounts are rather small over this region. The range likely to occur for changes in total annual precipitation is between -10 to +10 % in the more humid zone and between -15 to +30 % in the more arid zone. It thus seems rather unlikely that drastic changes in annual total rainfall will occur in the future.

In contrast, the rainfall characteristics are projected to undergo some substantial changes. The intensity of heavy rainfall events is likely to increase in the future (likely range for most parts positive, up to +30 %). Also the frequency of dry spells during the rainy season is for most parts of the domain projected to substantially increase in the future, indicating a more sporadic rainfall distribution.

Photo 2.5: Transport of logs floating on the Mfimi river (Bandundu -DRC)

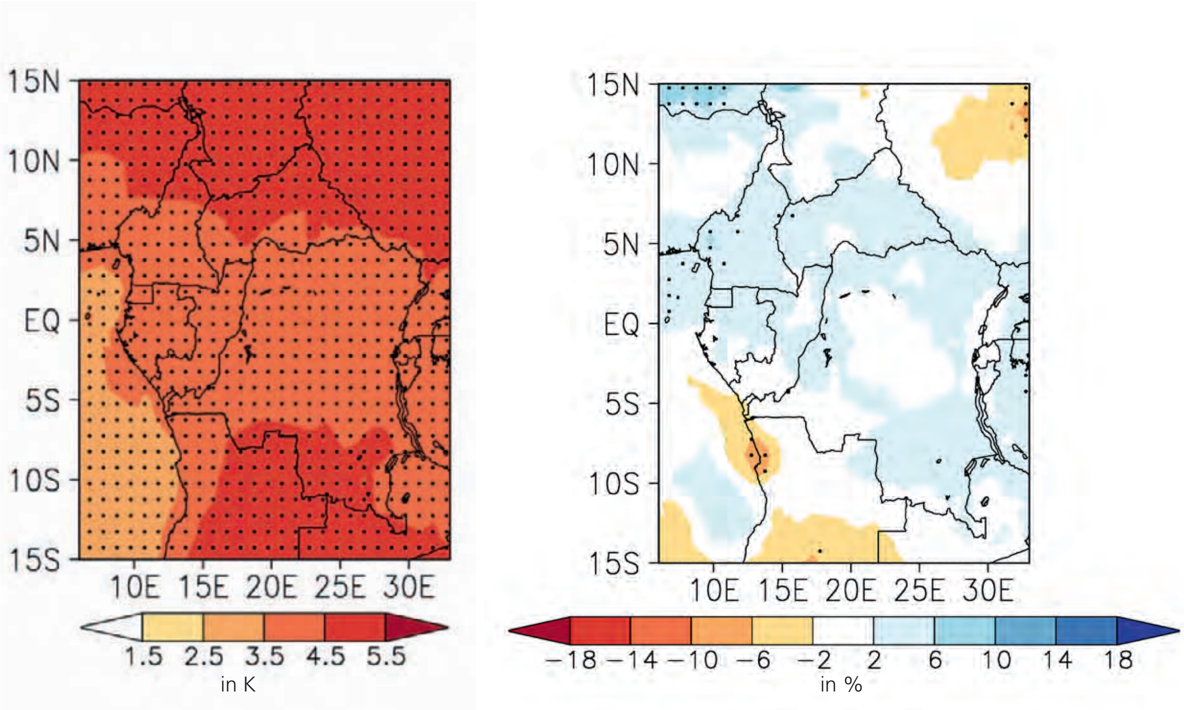

Figure 2.7: Projected change in annual mean temperature (left) and annual total precipitation (right) until the end of the 21st century (2071 to 2100) for a high emission scenario.

Source: CSC (2013)

The depicted change in figure 2.7 is the median change from a set of 31 different climate change projections from global and regional climate models. The black stipples highlight regions where the majority of the models agree in the direction of change. Changes in these regions are therefore more robust than over regions without stipples.

6. Current climatic delineation and water regime trends

Abrupt climate change occurred over Africa several decades ago with different impacts on river regimes (Laraque *et al.*, 2001 ; Mahé *et al.*, 2013). These changes on river regimes are related both to climate change and to human activities. Central Africa seems much less impacted by human activities as it is the case in other African areas, due to less population density and less agricultural development.

In Central Africa, hydrologists have studied the hydrological regime of many rivers for decades since the 1950s. Data are gathered in the SIEREM information system (Boyer *et al.*, 2006); (http ://www.hydrosciences.org/sierem/) and in the Hybam observatory for the Congo catchment (http ://www.ore-hybam.org). These data are used to study the variability of the river regimes, which can be linked to rainfall changes.

6.1 Global trends of hydrological regimes of large watershed in Central Africa

Long time series of annual discharges standard values for several large river basins of West and Central Africa have been studied within large regions (Mahé *et al.*, 2013). They show differences in the interannual variability according to the region. Common periods of low flows and high flows can be observed (during the 1910's, 40's, 60's, 70's). But some periods show discrepancies in the evolution (50's and 80's). Equatorial rivers do not show any interannual trend, while tropical rivers follow a decrease since the 70's, and Sahelian river discharges increase since the 80's.

6.2 Case study of the impacts of climate change on the hydrological regime of the Congo River watershed

Beyene *et al.* (2013) made an assessment of impact of projected climate change on the hydrologic regime and climate extremes of the Congo River basin. This specific river basin, despite its huge importance and implications to the regional hydrological cycle, has the least number of climate change impact studies in Africa to date. Land surface hydrologic modeling, used bias-corrected and spatially downscaled climate data from three GCMs (CNCM3, IPSL, and ECHAM5) and two emissions scenarios (A2-High and B1-Low), to simulate historical and future hydrologic regimes. The reference historical observations from the newly available global WATCH (http ://www.waterandclimatechange.eu/) and the forcing dataset (henceforth referred to as WFD ; Haddeland *et al.*, 2011) were used to simulate the current

Photo 2.6 : Herd of cattle entering the Faro National Park in the dry season (Cameroon)

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status of the hydrologic regime of the Congo River basin. The current and future hydrologic regime change in the Congo River basin was simulated using the Variable Infiltration Capacity model (VIC), and then assessed (Beyene *et al.*, 2013). The following results were found on key hydrological parameters.

6.2.1 Evaporation

According to Beyene *et al* (2013) the model simulation outcomes indicated that climate change will result in increased evaporation throughout the basin. The change is quite evenly distributed throughout the basin but the increase in evaporation will be slightly higher towards the edges compared to the central Congo Basin. On average, the increase in evaporation by the end of the century will be about 10 % for the A2 emission scenario and 8 % for the B1 scenario (Table 2.3). The different climate models gave similar results and for all six scenarios the evaporation increased.

Increased evaporation as a result of climate change is reported in many other studies, especially if the rainfall is increasing (Beyene *et al.*, 2013). It is important to note here that the Variable Infiltration Capacity (VIC) modeling framework used for this assessment does not include the direct impact of CO_2 enrichment on plant transpiration. Higher CO_2 concentrations reduce plant transpiration because the leaf stomata, through which transpiration takes place, have to open less in order to take up the same amount of CO_2 for photosynthesis (Lambers *et al.*, 1998). It is thus possible that VIC over estimates the impact of climate change on total evapotranspiration.

Table 2.3: *Summary of changes in precipitation, evapotranspiration and runoff across the Congo River basin using climate change scenarios (30-year average changes not weighted) for the 2050s and 2080s, for SRES A2 (high) and B1 (low) emissions scenarios expressed as percentage change of the historical base simulation (1960 – 2000)*

GCM	Precipitation				Evapotranspiration				Runoff			
	A2		B1		A2		B1		A2		B1	
	2050	2080	2050	2080	2050	2080	2050	2080	2050	2080	2050	2080
CNCM3	+8	+12	+10	+6	+8	+11	+8	+9	+12	+15	+10	+9
ECHAM5	+6	+21	+8	+15	+13	+17	+3	+5	+16	+60	+24	+42
IPSL4	+11	+9	+5	+13	+9	+12	+9	+11	+19	+6	-3	+20
Multi-model average	+8	+14	+8	+11	+10	+10	+7	+8	+15	+27	+10	+23

Source: Beyene et al. (2013).

Box 2.1: *Runoff and discharge*

Runoff, in hydrology, is the quantity of water discharged in surface streams. Runoff includes not only the waters that travel over the land surface and through channels to reach a stream but also interflow, the water that infiltrates the soil surface and travels by means of gravity toward a stream channel (always above the main groundwater level) and eventually empties into the channel. Runoff also includes groundwater that is discharged into a stream; streamflow that is composed entirely of groundwater is termed base flow, or fair-weather runoff, and it occurs where a stream channel intersects the water table (from Encyclopaedia Britannica).

Discharge, in hydrology, is the volume rate of water flow, including any suspended solids (e.g. sediment), dissolved chemicals (e.g. $CaCO_{3(aq)}$), or biologic material (e.g. diatoms), which is transported through a given cross-sectional area (from Wikipedia).

Photo 2.7: The erosion settles gradually on the abandoned logging roads

6.2.2 Runoff

Beyene *et al.* (2013) found that in most scenarios the runoff is increasing (Table 2.3). The increase in runoff is not evenly distributed throughout the Basin. Runoff is especially increasing in central and western DRC and in the Republic of Congo. Also the Cameroon and part of the Congo Basin shows a relatively high increase in runoff. On the Northern, Southern and Western edges of the Basin, the results are considerably different. Here the increases are marginal and sometimes the runoff decreases. On average, over the whole Congo Basin, runoff is projected to increase by 15 % by mid-century for the A2 scenario and 10 % for the B1 scenario (Table 2.3). By the end of the century, runoff is projected to increase with 27 % for the A2 scenario and 23 % for the B1 scenario.

The changes in runoff also depend on the season. For all three climate models the difference in runoff between dry and wet season are increasing indicating a more variable future hydrologic regime. Also on spatial scale the variability is increasing. Especially in the wetter central and western part of the Basin, the runoff is increasing while at the drier edges the runoff is slightly increasing in some scenarios and decreasing in others. Other previous studies on the impact of climate change on hydrologic characteristics of the Congo River basin show diverse results (Beyene *et al.*, 2013). Arnell (2003) showed a possible decrease in average changes in runoff over the Congo River basin by 2050, using a different set of climate models. Aerts *et al.* (2006) documented an increase in runoff of 12 % in the Congo River basin by 2050 compared to the historical simulations.

Table 2.4 : *Projected relative changes in annual average Congo river flow at Kinshasa for two future periods expressed as percent change compared to the historical time period (1960-2000). Three different climate models were used in combination with a high emission scenario (A2) and a low emission scenario (B1).*

Climate Model	2036-2065		2071-2100	
	A2	B1	A2	B1
CNCM3	20 %	5 %	27 %	17 %
ECHAM5	23 %	28 %	73 %	46 %
IPSL4	8 %	1 %	14 %	18 %
Multi-model average	17 %	11 %	38 %	27 %

Source : Beyene *et al.* (2013).

6.2.3 Discharges

Consistent with projected runoff changes, Beyene *et al.* (2013) found that multi-model average annual flows at Kinshasa gauging station were projected to increase between 11 and 17 % by 2050 depending on the emission scenario and by 27 to 38 % by 2080, compared to the historical period (1960-2000 ; Table 2.4). There was a large difference between the climate models in projected changes in discharge.

Increased changes in discharge are especially observed in the wet season. In October, November and December all analyzed scenarios show an increase in discharge. In the dry season, however, both the CNCM3 and IPSL4 models indicate a reduction in discharge for the 21st century. Especially, the IPSL4 model shows a significant reduction in discharge from June until October. These results indicate that during the wet season river flows are likely to increase. During the dry season however results are more uncertain and flows could both increase and decrease. So while total water availability is likely to increase in the future this does not mean that droughts or low flow frequency will reduce in the future. For all scenarios the difference in discharge between the dry and wet season are increasing, indicating that both wet and dry extremes could increase in the future, towards a more seasonal and tropical type climate.

Based on field measurements, Mahé *et al.* (1990), Lienou *et al.* (2008) and Laraque *et al.* (2001, 2013) presented recent changes of river regimes of Central African rivers. According to these studies, the annual discharge time series of these rivers do not show any long term trend like in West Africa. However, a significant drop in the interannual Congo and Oubangui discharges was reported in relation to the average of century's recordings (Laraque *et al.*, 2013). These authors also mentioned that since 1995 discharges of the Congo have been returning to normal, whereas those of the Oubangui and Sangha, despite some recovery, remained drastically below normal levels (Figure 2.8). In 2010 and 2011, the lowest levels in 65 years were observed in Brazzaville, and the Oubangui reached its lowest level in one hundred years in 2012. According to the authors, these changes seem to highlight climatic disturbances that affect more specifically northern regions of the Congo Basin (Oubangui and Sangha basins), north of the climatic hinge, already marked by climatic deterioration.


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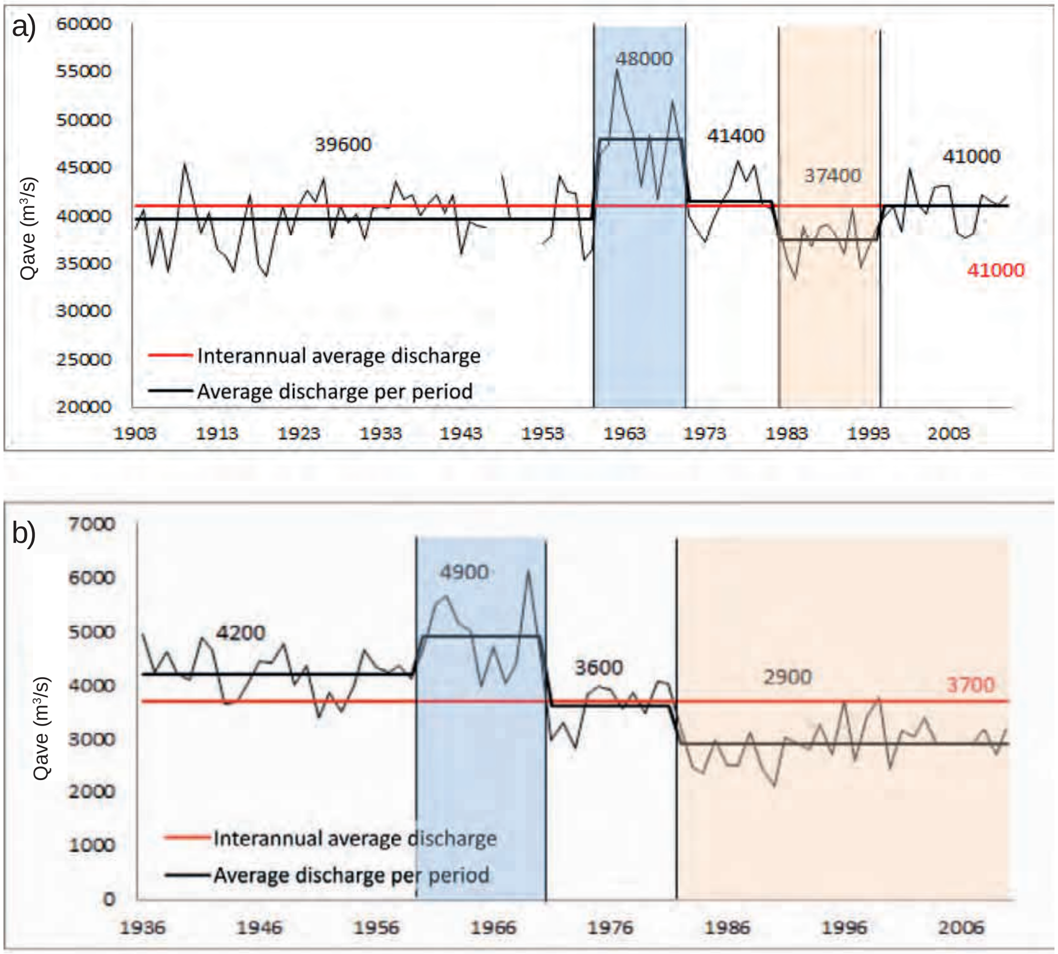
Photo 2.8: The Ogooué river in the dry season at Okanda (Gabon)



Blue = humid period; Orange = dry period; White = normal period

Figure 2.8.: Sequencing of annual discharges of a) the Congo river in Brazzaville from 1903 to 2010 and b) the Oubangui river in Bangui from 1936 to 2010

Source: Laraque et al. (2013).

In addition, significant changes in seasonal discharges have been noticed (Figure 2.9). For the Ogooué and the Kouilou rivers, and part of the South Cameroonian rivers, the March-June flood decreased steadily over the 1970s and the 80s, when the October-December flood showed no change or a slight increase. Even for the huge Congo River, spring flood is also severely reduced compared to the autumn flood. The flood peak is also observed in April during the recent observation period (years 2001 to 2007), rather than in May before, which is, despite its size, along the same trend than for the Ogooué.

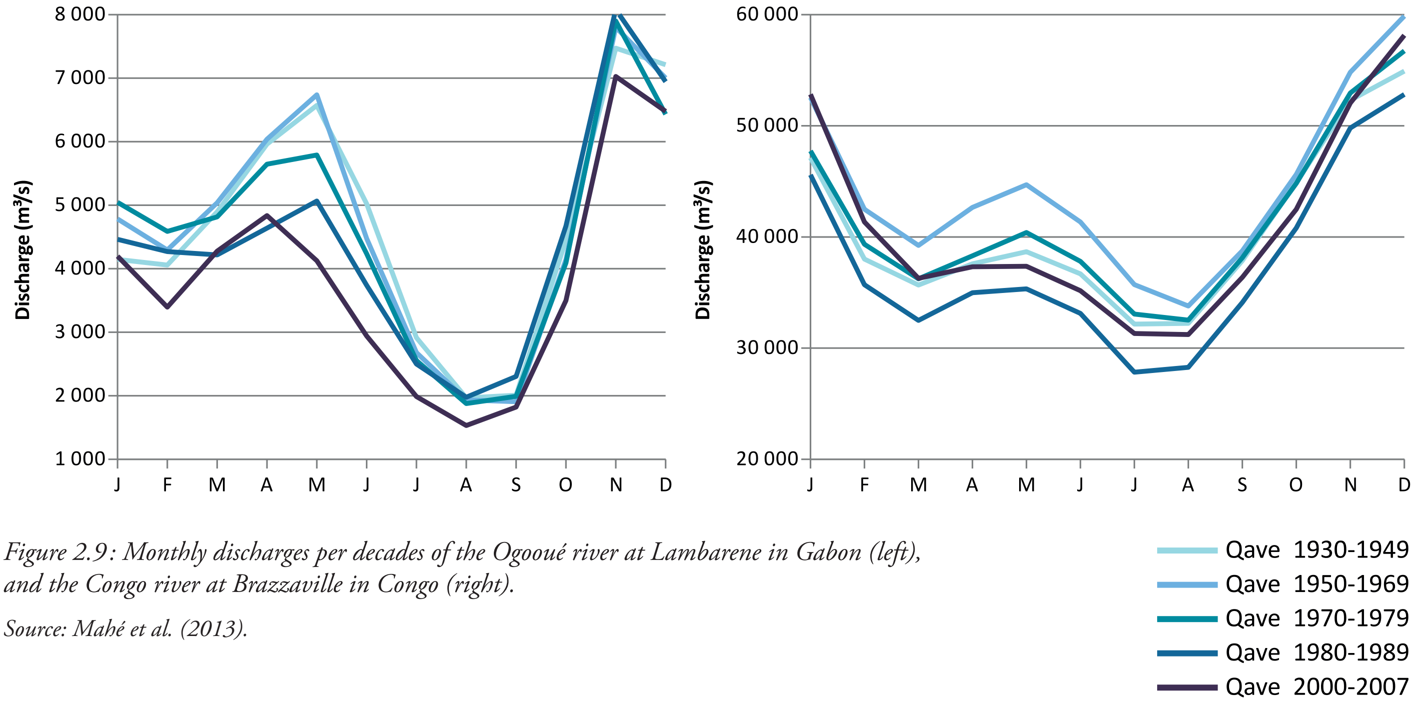


Figure 2.9 : Monthly discharges per decades of the Ogooué river at Lambarene in Gabon (left), and the Congo river at Brazzaville in Congo (right).

Source: Mahé et al. (2013).

7. Issues on climate evolution monitoring in Central Africa

7.1 Climate observation in Central Africa

In 2000, the Global Climate Observing System (GCOS), the World Meteorological Organization (WMO) and the national hydrological and meteorological services made several assessments of the climate observation systems in different parts of the world. The result of this assessment showed that the density and quality of meteorological stations of Africa are the weakest of the world. From 2001 and 2005 regional consultations were then undertaken to develop regional action plans for Africa. Especially, the AU-NEPAD action plan for environment and regional strategy on hazards reduction have underlined the need to improve the availability and the use of climatic data as mean to enhance economic development of Africa. But so far nothing has effectively been done to improve the situation.

Sonwa *et al.* (2014) reported that there are 419 meteorological stations and 230 hydrological stations in the ten COMIFAC countries. Some stations have produced data for well over a century. Regular climate measurements began in 1885 and 1889 at the Douala and Yaoundé stations in Cameroon (Nicholson *et al.*, 2012). According to these authors, the majority of the stations, however, only began their observations in the 1950s and 1960s. Since the 1980s, several stations have unfortunately stopped functioning regularly, and time series are often interrupted, limiting the number of stations with reliable and complete time series data.

To compensate for the lack of field observed climate data, the use of estimates derived from geostationary satellite is becoming widespread. Recent satellite-based studies have been conducted to test some calibration methods (Munzimi *et al.*, 2015 ; Washington *et al.,* 2013). These studies have tended to adopt proxies such as streamflow to represent rainfall quantities or satellite altimetry to evaluate water resources and climate.

7.2 Strategies developed by countries and regional bodies to improve availability of climate data

7.2.1 Climate for development program (ClimDev-Afrique)

ClimDev-Afrique is a common initiative between the African Development Bank (AfDB), the African Union and the African Economic Community (BAD, 2009). Its aim is to facilitate the involvement of climate data producers, especially meteorological and hydrological services and research organizations in development projects in order to create direct links between climatic services and development priorities. ClimDev will enable a continuous flow of climatic data between data producers and users. The AfDB has been mandated to host and manage a special fund for the program, namely the Africa ClimDev Special Fund (FSCD).

Photo 2.9: In many parts of Central Africa, river transport remains of great importance - Kindu beach, DRC

7.2.2 Regional Meteorological Telecommunication Network (RMTN) in West and Central Africa

Central Africa countries are members of the Regional Meteorological Telecommunication Network (RMTN) and ASECNA (*Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar*). ASECNA is actually coordinating the satellite telecommunication network called SATCOM, which covers Western and Central Africa including Madagascar, and provides communications for civil aviation programs. The SATCOM network has sufficient capacity to also ensure the improved GTS (Global Telecommunication Systems of the WMO) links, which are being implemented for ASECNA members. The SATCOM network offers a unique opportunity to modernize the RMTN in West and Central Africa. Discussions among member countries have been conducted on operational modalities of the SATCOM network to improve the RMTN in ASECNA countries.


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Photo 2.10: During particularly pronounced dry seasons, some small rivers may dry completely

CHAPTER 3

INTERACTIONS BETWEEN CLIMATE CHARACTERISTICS AND FORESTS

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With the contribution of: Andreas Haensler, Fulco Ludwig and Paul Scholte

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1. Introduction

A large knowledge about climate and vegetation interactions is indispensable for estimating human implications in climate and land cover changes.

Highlighting the forest system's contribution to the regional climate leads naturally to a concern about the possible impacts of the forest cover loss which is the current trend, along with the increased density of agricultural production and the acceleration of land clearing activities etc. Nevertheless, the impact of such actions is extremely difficult to evaluate because the cause and effect links between the forest and climate are not yet clearly understood (Brou Yao, 1997).

Indeed, numerous uncertainties still remain about the knowledge of vegetation-climate relationships under tropical latitudes and about the part of the anthropogenic forcing on the current climatic evolution at the global scale. Nevertheless, the human impact on local surface conditions is obvious at least at the regional scale of forest conversion, where hydrological changes are clearly connected to an increase of agricultural activities. Also, the biophysical relationship between land cover types and the local atmospheric environment is relatively well understood in principle, but the quantification of the processes still remains uncertain.

Knowledge on the current and future impact of human driven land change on climate in the Congo Basin, perhaps the most understudied tropical forest region of the world, can be improved using models, given the cost and difficulty of collecting ground-based information in the region. But we have to accept large uncertainties, especially when working at various scales.


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Photo 3.1: Tali (Erythrophleum ivorense) is a species that has a large distribution area in Central Africa and elsewhere

2. Vegetation – climate relationship

2.1 Biophysical interaction between forest and climate

The forest system, because of its great propensity for solar energy absorption and its capacity for evaporation, plays the role of an enormous energy converter. For example, forests convert water to water vapor (much like sweating) and provide shade more than other vegetation cover, which can lead to cooler surface temperatures (decreased upward longwave radiation). Indeed, the forest system absorbs the solar energy to limit heating and to vaporize water that its root system extracts from the soil (Monteny, 1987; cited by Mahé *et al.*, 2004). In the Tropical regions where horizontal temperature gradients are weak, the atmosphere is very sensitive to land and ocean surface conditions (relief, albedo, temperature, humidity, vegetation), which influence the distribution and the intensity of heat sources and heat sinks (Fontaine *et al.*, 1998a, 1998b).

The resulting exchanges of energy that forests maintain with the atmosphere influence the physical air mass parameters of the atmospheric layer closest to the earth (Monteny *et al.*, 1996).

Polcher (1994) catalogues three characteristics that determine the sensitivity of the climate to surface processes:

(i) the density of the forest system is such that the albedo (the amount of incoming solar energy reflected by a surface back to the atmosphere) is very weak compared to that of bare ground;

(ii) the high rate of evaporation, comparable to that of oceans, is one of the main characteristics of forests whose leaf density allows them to intercept and re-evaporate a large part of rainfall. The root systems of trees allow them to extract water from a greater portion of the soil than could be done in any other surface system;

(iii) the surface variation caused by the different heights of trees that make up the forest generates turbulence, which is favorable to triggering precipitation.

For Fontaine and Janicot, (1993), the two key parameters that forests influence are albedo and moisture. These parameters are closely linked, since wet ground, whether covered with vegetation or not, has a weaker albedo and greater evaporation capacity than the same ground, bare and dry.

Box 3.1: *Albedo*

The albedo (α) of a surface is the ratio between reflected and incoming solar radiation. It varies between 0 for a perfect black body that absorbs all the incoming radiation to 1 for a surface that reflects it all. It depends on the wavelength, but the general term usually refers to some appropriate average across the spectrum of visible light, or across the whole spectrum of solar radiation.

Source: http://www.elic.ucl.ac.be/textbook/glossary_a.html#albedo


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Photo 3.2: The forest and water vapor are closely linked in ecophysiological functioning

In tropical regions the dense forest is closely integrated in the water cycle.

The quantity of water precipitated on the continent comes primarily from the condensation of water vapor accumulated in the air masses as they pass over the ocean and secondly via evapotranspiration, which is the water that is transpired by vegetation as they assimilate carbon or evaporated from the surface. Whereas moisture from the ocean has a clear connection to regional and global climatic processes, evidence shows that vegetation recycles moisture primarily locally, with more recent evidence showing potential regional influences as well (Bigot, 1997; Bonell, 1998). Indeed, recent studies have shown that the Congo Basin land cover influences the rainfall in Sahara, Ethiopia, and other parts of the continent.

The concentration of water vapor in the air mass coming from the ocean and which then crosses the continent depends also on the evaporation process of the vegetation-atmosphere interface. It has been shown in central Africa (Figure 3.1) that a large part of moisture transfer into the atmosphere (evapotranspiration), contributes to the formation of cloud systems (Bigot,

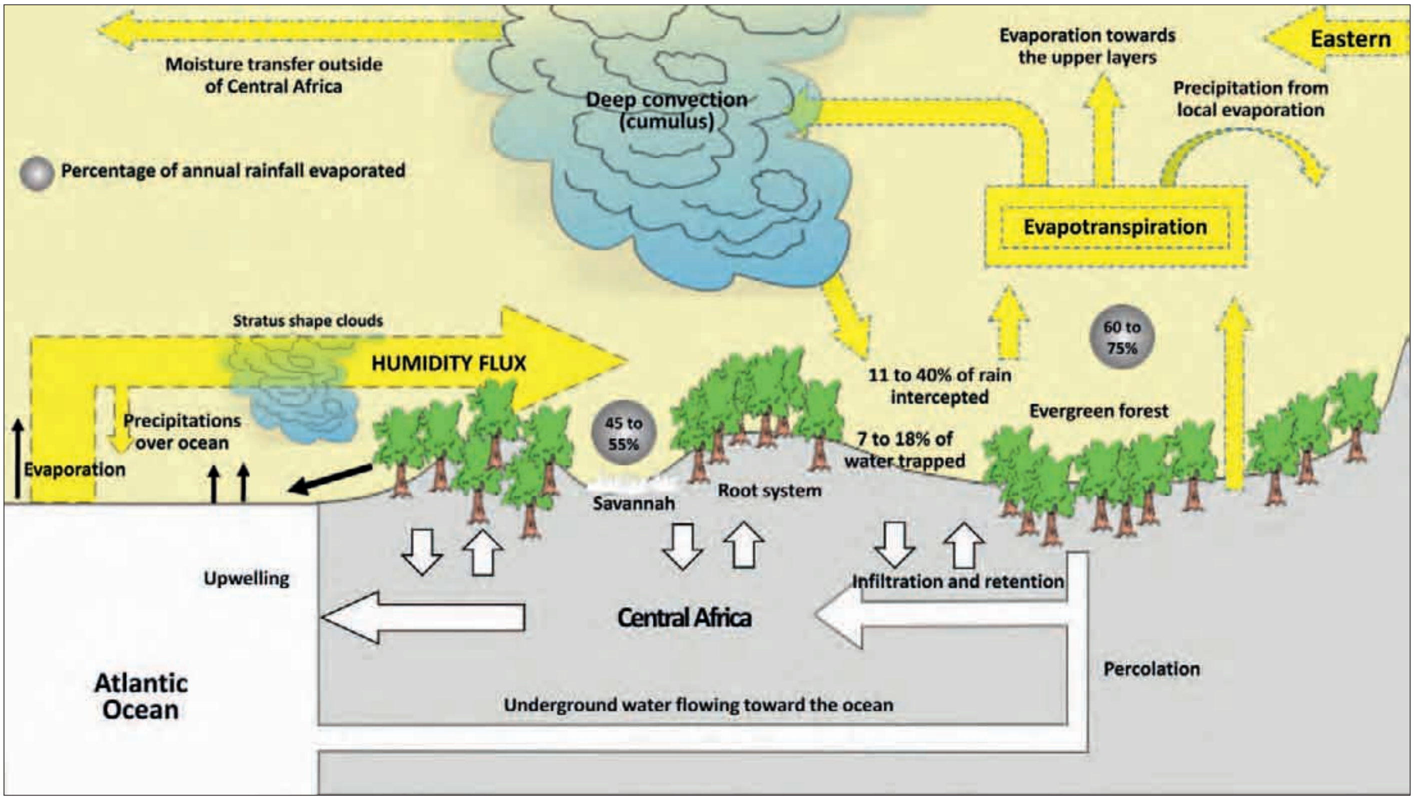

Figure 3.1 : Main interactions between water cycle and ocean-atmosphere-forest interface
Source : Bigot, 1997

1997). The rainfall associated with these convective systems depends then not only on the monsoon flow but also on the recycling of moisture by the forest (Cadet and Nnoli, 1987).

The forest system is both a receiver of precipitation (especially monsoon rains) ; and a generator of rainfall by means of evapotranspiration and fine scale processes (Bigot, 1997). It injects back in the atmosphere the equivalent of more than 50 % of the annual precipitation. Also, forests can reduce surface runoff and improve soil infiltration and fertility, which lead to increased soil moisture storage (Jose, 2009).

2.2 History of vegetation in relation to climate in a former time

This part of the text is largely inspired by the excellent publication of Mahé *et al.*, 2004.

The history of dense forests and their dynamics can be reconstituted by the study of fossils such as pollens or, much rarer, wood or carbon fossils, within specific disciplines such as palynology, paleo-botany or anthracology.

Thanks to recent advances in the area of paleo-ecology it has been shown that dense forests, such as those in Africa, have undergone profound changes in response to global climatic changes.

The end of Cretaceous, around 120 million years BP, marks a period of floristic conversion of tropical forests. Indeed, dominant gymnosperms plant forms, were replaced in favor of angiosperms plant forms. Since that time, the African dense tropical forests are almost entirely made up of angiosperms. At first, African dense forests were characterized by a great number of palm trees that became relatively rare and around 40 million years BP (upper Eocene), the floristic composition of these forests began to resemble their current state (Maley, 1996).

The irregularity of data in space and time makes it difficult to propose a very precise distribution scheme for the various types of ecosystems in forests of the past. Nevertheless, the major variations in tropical forests can be interpreted in a global context of temperature variations and in particular, of cooling phases (Maley, 1996). Not surprisingly, the forest extension phases were associated with humid period. Dryer periods had a direct impact on the vegetation which opened and dried out, resulting in forest regression and savanna expansion. Progressively, a pattern of seasonal climates alternating from dry to humid seasons emerged.

Till the beginning of the quaternary era (around 2.5 million years BP), there was a succession of contrasted dry and humid climates. These oscillations became less strong with a smoother impact on the vegetation.

Box 3.2 : *Driving factors of the forest cover during the ice age and interglacial period*

The ice ages controlled the water level of the ocean ; extension of the polar ice caps due to more frozen water at the poles results in a decrease of the sea level (for example, the sea level was lower by 120 m around the year 18,000 BP, during the last glacial maximum). This entailed a concurrent change in the amount of evaporating water surface. At the same time, global temperatures fell. This synchronous variation of lower water surface and lower temperature leads to a decrease of the quantity of water vapor in the air and therefore to a decrease of precipitation. On the continents, the resulting decrease in rainfall leads to a regression of forests and accordingly to an expansion of the savannas and open areas.

During interglacial period, the inverse phenomena, when polar ice caps melt combined with a general increase of temperature, leads to an increase of the sea level. The evaporation then increases. Combined with an increase of evapotranspiration by the vegetation, the quantity of water vapor in the air increases also and leads to more precipitation. On the continents, the resulting increase in rainfall leads to an expansion of forests and accordingly to a regression of the savannas and open areas.

For example, the maximum extension of the African forest seems to have been synchronous with a sudden rise in the sea surface temperatures of the Gulf of Guinea (Maley, 1997). Monsoons pick up moisture from the eastern Atlantic and this rise in water temperature has the effect to sharply increase the water vapor pressure and ultimately increase rainfall in the neighboring continent.

Photo 3.3 : A key factor for the development of forests, is the amount of light reaching the different strata

The period between 2.5 million and 20,000 years BP known as the ice age and interglacial periods began with an arid phase and was marked by a significant expansion of savannas. Then came a progressive increase in the magnitude of glacial variation, marked by two principle phases : the first occurred between 2.5 million and 800,000 years BP, and was characterized by ice age/interglacial cycles of about 40,000 years ; the second from 800,000 years BP to the current era and is characterized by dominant cycles of about 100,000 years.

Data shows that between 70,000 and 40,000 years BP, this region was relatively dry. At the global level, the maximum cooling period occurred between 20,000 and 15,000 years BP. As a consequence, monsoons were dramatically reduced which entailed a severe reduction of forests areas. Such reductions resulted in nothing more than a series of isolated forested areas, not far from the coast of the Gulf of Guinea and some others, near the center of the Congo Basin (riverine forests), and at the foot of the mountains of the African Rift (Maley, 1996, 1997).

From 15,000 years BP started the last expansion phase of forests that reached its optimum around 9,500 years BP of the last glaciation cycle. This corresponded to the warmest climatic phases in which ice masses of both polar ice caps were reduced. But there has been a major interruption around 2,800 years BP in southern Cameroon and western Congo (Maley and Brenac, 1998 ; Maley *et al.*, 2000 ; Vincens *et al.*, 2000). Extremely dry conditions were present in these regions between 2,800 and 2,000 years BP, facilitating the expansion of savannas and open spaces. This particular climatic phase appears to have resulted from an accentuation of the seasonality due to a shortening of the annual rainy season (Maley, 1997).

3. Impact of climate variation on vegetation

Changes of the forest cover can be related to climatic variations in the long-term (Sultan *et al.*, 2001 ; Mahé *et al.*, 2005), but at time scales that are much longer than what is observed since some decades in the regime variability of African Equatorial rivers. Climatic variability is defined as being the distribution of climatic elements around their average values calculated over 30 years ; this natural variability is an intrinsic character of climate (Janicot, 1995).

The space-time variability of climate principally depends on the interaction between the surface conditions (temperature, albedo, humidity) and the atmosphere : linkage manifested by wind pressure and sensible and latent heat flows.

3.1 Vulnerability framework

Vulnerability can be defined as “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes”. The vulnerability framework [V= f (E, S, A)] considers vulnerability (V) as a function (f) of exposure (E), sensitivity (S), and adaptation (A). The function can also be applied to the forest sector (Locatelli *et al.*, 2008, see : Figure 3.2).

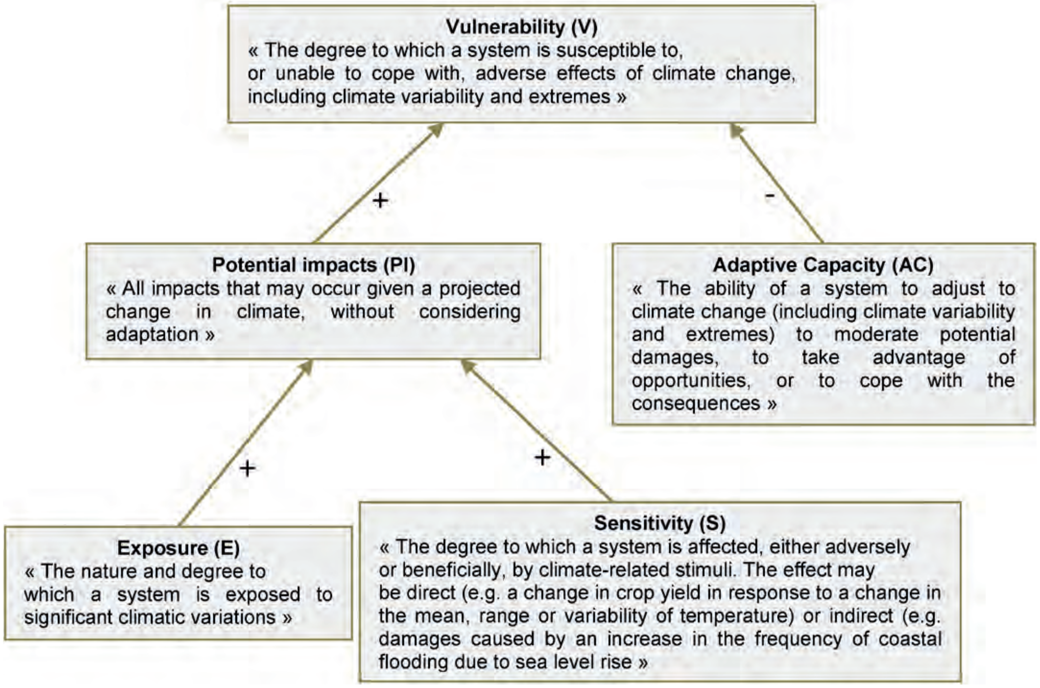

Figure 3.2: The components of vulnerability (definitions are from IPCC: McCarthy et al., 2001). The signs under the arrows mean that high exposure, high sensitivity and low adaptive capacity induce high vulnerability.

Adapted from Locatelli et al., 2008.

3.2 Direct impacts

Climate change is expected to have a range of impacts on forest ecosystems. However, the effects of CO_2 and temperature on tropical forest growth are not yet fully understood. Generally it appears that higher atmospheric CO_2 concentrations might increase forest growth and carbon capture. Higher temperatures, however, might have negative impacts on forest growth and reduce the amount of carbon in the forests (Jupp *et al.*, 2010). Also, climate change can affect the forest reproduction, and it can cause their decline.


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Photo 3.4: Unlike the forest, fossil fuel combustion is not renewable

Possible future trends in forest response to climate evolution

The impact analyses show that the Congo Basin is unlikely to see a decline in forest growth as is sometimes predicted for the Amazon Basin as a result of climate change. Instead, there could be a moderate increase in ecosystem carbon, including vegetation and soil carbon (Figure 3.3). Depending on how the climate will change, there could also be a shift in the ecosystems' land cover between forest and savanna. Based on the analysis, the most likely future scenario involves a moderate expansion of evergreen forests into savannas and grasslands to the North and the South of the current forest-savanna-transition zone. There is a large uncertainty range in the model assessments, highlighting the importance of collecting new data to further narrow the prediction ranges (e.g., biomass in the central Congo Basin and responses of forests to changing climate and CO_2 concentrations).

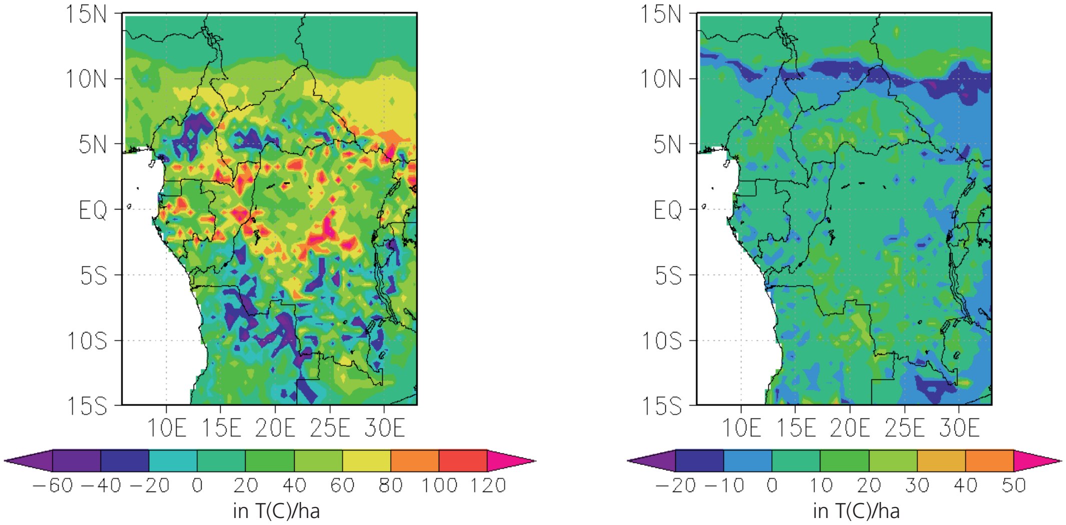

Figure 3.3 : The projection of change towards the end of this century (mean of the period 2071-2100 compared to the mean of the period 1961-1990) under a high emission scenario. In the left panel, changes in potential vegetation carbon are shown, and in the right panel, changes in potential soil carbon are shown. The sum of these two panels indicates the changes in total ecosystem carbon. Changes in potential vegetation and soil carbon are calculated using the Lund-Potsdam-Jena-managed lands (LPJ-ml) model in combination with a single climate model (ECHAM5).

Source : CSC, 2013

3.3 Indirect impacts

The effects of climate change are often indirect, for example by affecting the frequency of fires or modifying the behavior of pests and diseases. During the "El Niño" years of 1983, 1987, and 1997, fires were particularly destructive in southeastern Cameroon. The effects of climate change can accelerate biodiversity loss through the disappearance of species or by reducing the resilience of severely disrupted ecosystems. The climate can have immediate and sustained effects on hydrology (Li *et al.*, 2007), that can have itself an impact on vegetation.

The impact of climate change on water regimes has already affected vegetation. Prior to the considerable drop in water levels of Lake Chad, vegetation in the north of the Congo Basin was mainly composed of *Phragmites*, *Cyperus papyrus*, *Vossia, Typha, Potamogeton* and *Ceratophyllum.* The drop in the lake's water level led to important vegetation changes and by 1976, the bulk of the vegetation was no longer constituted of *Vossia* and *Aeschynomene sp.* (Olivry, 1986). Changes in aquatic vegetation were also observed in the Logone flood plain in northern Cameroon where flooding had declined in the

1970s following the upstream construction of a dam. Certain plant species characteristic of flood areas, such as *Vetiveria nigritana* and *Echinochloa pyramidalis,* were replaced by other species, notably *Sorghum arundinaceum* (Scholte *et al.,* 2000 ; Scholte, 2007).

4. Impact of deforestation on climate characteristics (temperature, rainfall)

Box 3.3 : *Latent and sensible heat*

Latent and sensible heat are released or absorbed in the atmosphere. Latent heat ("Latent" means "hidden") is related to changes in phase between liquids, gases, and solids. It is generally used interchangeably with its mass equivalent (evapotranspiration) in plants. Latent heat is absorbed when a substance changes from solid to liquid and from liquid to vapor, and it is released when the vapor condenses into liquid, and when the liquid freezes into solid.

Sensible heat is related to changes in temperature of a gas or object with no change in phase.

Water vapor is a greenhouse gas located in the atmosphere and a very important component of cloud formation. Clouds form when moist, warm rising air cools and expands in the atmosphere. If the air is dry, or unsaturated, clouds are not likely to form because there is minimal water vapor in the air. If the air is moist, or saturated, the water vapor will condense to form tiny water droplets which are the basis of clouds. When these gas molecules condense into liquid drops, latent heat is released into the atmosphere which warms the air surrounding the molecule. This helps to add instability in the atmosphere as the warm air surrounding the molecule decreases in density and rises. Warm air is less dense than cold air because molecules in warm air move around much faster and move further apart.

Source : https ://www.nc-climate.ncsu.edu/edu/k12/.lsheat

Photo 3.5 : Construction of a base camp of a logging company

The surface conditions, especially the plant cover of dense rainforests and the upper layer of oceans have a significant effect on the atmospheric water cycle and also on the vertical movements within the tropical atmosphere.

Deforestation can significantly alter the surface water and energy balance in multiple ways and thus affect atmospheric temperatures and moisture content, atmospheric boundary layer development, and weather and climate processes at continental scales (Niyogi *et al.*, 2009).

Forest conversion to agriculture and other land uses increases the portion of bare ground exposed to the sun's rays and therefore increases albedo which lowers incoming solar radiation absorbed by the surface and energy available for sensible and latent heat flux.

Considering these mechanisms, the role of deforestation, particularly in the Congo Basin region, has received relatively little attention in understanding African climate and climate change.

To date, research in the Congo Basin region has primarily focused on "global" drivers of climate and future change, such as warming sea surface temperatures and rising CO_2 emissions, and has ignored deforestation and other land drivers, because land-atmosphere coupling is considered a highly localized phenomenon (Koster *et al.*, 2004).

In addition, several uncertainties and bias in the models used to simulate these processes may obscure their importance (Pielke *et al.*, 2007). These uncertainties and bias include: (i) the spatial resolution at which processes are modeled is too coarse to capture the fine scale spatial structure of deforestation (Brunsell and Anderson, 2011); (ii) groundwater is typically ignored or simulated using simple "slab" soil models that do not sufficiently estimate soil saturation or its influence on moisture feedbacks (Ferguson and Maxwell, 2011); (iii) sensible heat and latent heat is difficult to partition (de Noblet-Ducoudré *et al.*, 2012); (iv) studies simulate processes using only one global climate model coupled to a land surface model instead of a multi-model ensemble; and (v) deforestation is assumed a linear or static process (Pielke *et al.*, 2011).

Thus the sensitivity of the tropical climate to forest conversion remains open to debate.

At the regional level, the deforestation impact on climate is assessed more with regards to carbon emission, temperature increase, and rainfall balance. Deforestation impact on local climate is more studied through characteristics such as flux of energy, moisture, evapotranspiration, soil properties and albedo. Currently, there is a growing body of evidence showing the impact of deforestation on local climate in the Congo Basin, while its impact on regional (African) climate is less clear and global teleconnections unknown (Lawrence and Vandecar, 2015).

4.1 Deforestation and its effects on local climate

The impact of the forest clearance on the rainfall/runoff relationships seems to be dependent on the type of climate/vegetation system.

In Sahelo-Sudanian areas, the forest clearance, associated with an increase of agricultural activities, rapidly induces a destructuration of the top layer of the soil in which infiltration decreases, and runoff coefficients increase (Mahé and Paturel, 2009; Descroix *et al.*, 2010). But in more humid tropical and equatorial areas such a correspondence is not observed.

The reduction of the forest cover has therefore a direct impact toward the increase of runoff in Sahelian basins. In Equatorial areas, although the river regimes have been well studied, we still have to study the possible link between changes of the forest cover and the intraseasonal changes of the equatorial river regimes.

ORSTOM (IRD) hydrologists have studied the river regimes of many rivers for decades since the 1950s. Data are gathered in the SIEREM information system (Boyer *et al.*, 2006) (http://www.hydrosciences.org/sierem/) and in the Hybam observatory (http://www.ore-hybam.org) for the Congo catchment. These data are used to study the variability of the river regimes, which can be linked to rainfall changes, but could also be related to changes in the forest cover. Studies about the impact of forest cut on


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Photo 3.6: If the forest succeeds to the forest in the process of charcoal production, then the carbon balance would be close to zero.

river regimes are not numerous, and often relate to very small experimental basins (Fritsch, 1990).

In equatorial humid areas the major impact of the forest conversion is to reduce the local evapotranspiration, thus reducing the total amount of available water vapour through local recycling for monsoon rainfall. Due to lack of direct measurements, it is very difficult to estimate the impacts of a massive forest conversion on the climate dynamics as well as on evapotranspiration.

The loss of forest cover triggers an increase in albedo and decrease in available energy, leading to further declines in latent heat in favor of sensible heating. Cloud cover does not change significantly, but downward longwave radiation does increase due to the warming of the atmosphere from increased sensible heating, which offsets some loss in net radiation due to albedo.

Deforestation can also decrease rainfall by weakening direct coupling, local coupling, and indirect recycling (Makarieva *et al.*, 2013).

Direct coupling is the process by which rainfall is recycled back into the air via evaporation from bare soil and transpiration through plant stomata (evapotranspiration – mass equivalent of latent heat). With fewer trees, there is less moisture available for this process.

With local coupling, deforestation decreases surface roughness, which can suppress daytime boundary-layer turbulence and instability important for cloud development (increased downward longwave radiation) and rainfall (Santanello *et al.*, 2007).

Finally, with indirect recycling, large moist air masses from the ocean, which would otherwise be buffered against drying due to evapotranspiration from forests, lose moisture necessary for storm development downwind.

4.2 Impact of deforestation at the regional level

Multiple climate and land scenarios indicate that deforestation in the region could lead to warming between 2 and 4°C due to a decrease in evapotranspiration (latent heat) and shade, combined with increased forcing from lower greenhouse gas sequestration (Figure 3.4) (Akkermans *et al.*, 2014 ; Nogherotto *et al.*, 2013). The change in temperature is less severe on the Atlantic side and eastern border of the Democratic Republic of Congo, because latent heat is considerably higher in these areas and thus less sensitive to temperature changes. Direct and local moisture coupling under the scenarios are also expected to weaken, which could lead to as much as a 5 to 10 % decrease in rainfall over much of the region (Figure 3.5).

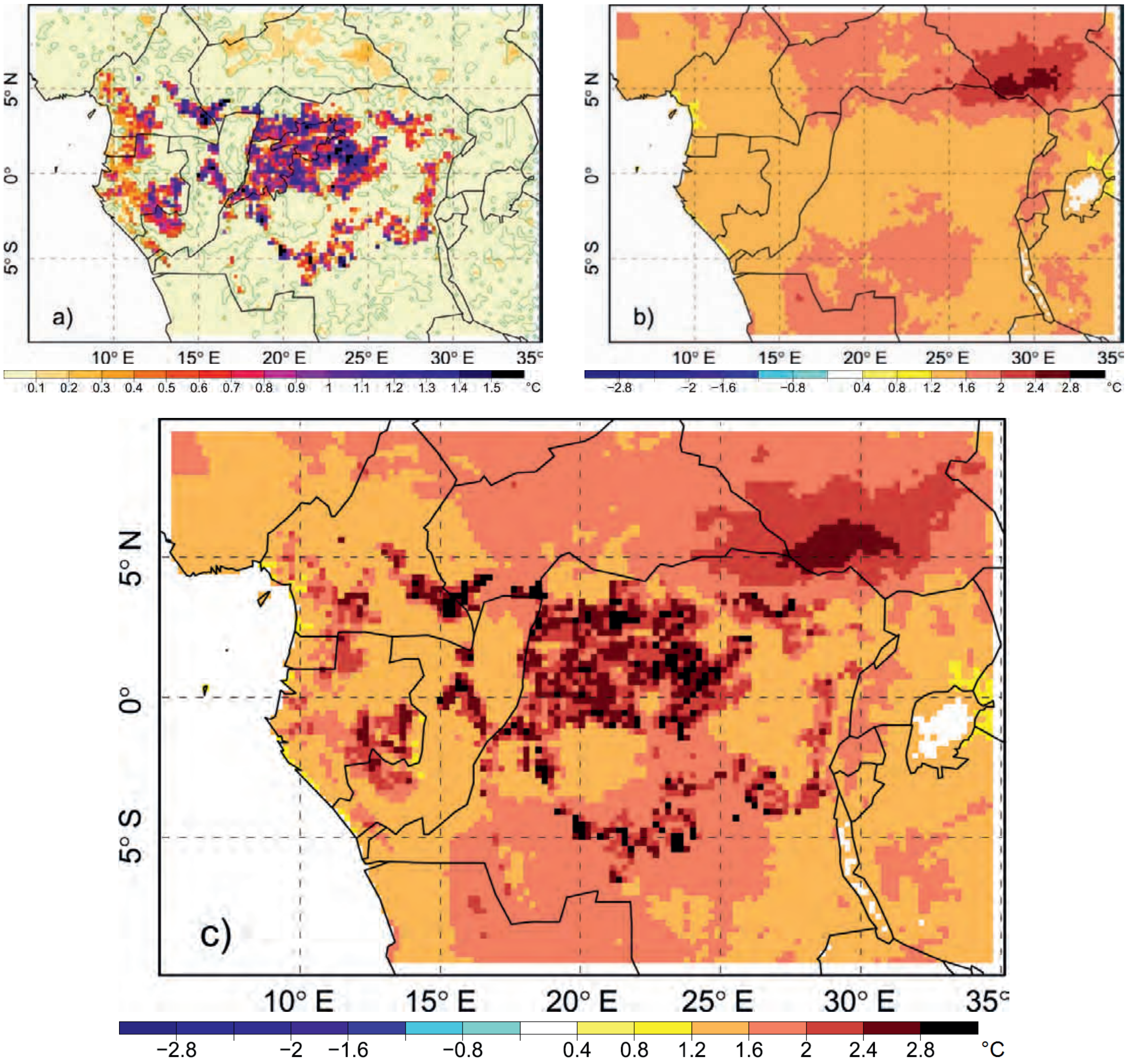

Figure 3.4 : Mean temperature change (°C) due to the succession of forests in the Congo Basin region to agriculture and other land uses from 2041-2060 directly from modifications due to the water and energy balance (a) ; indirectly from increased greenhouse gas forcing (b) ; and (a) and (b) combined. Significance on the 1% level is indicated by the green contours in (a).

Source : Akkermans et al. (2014).

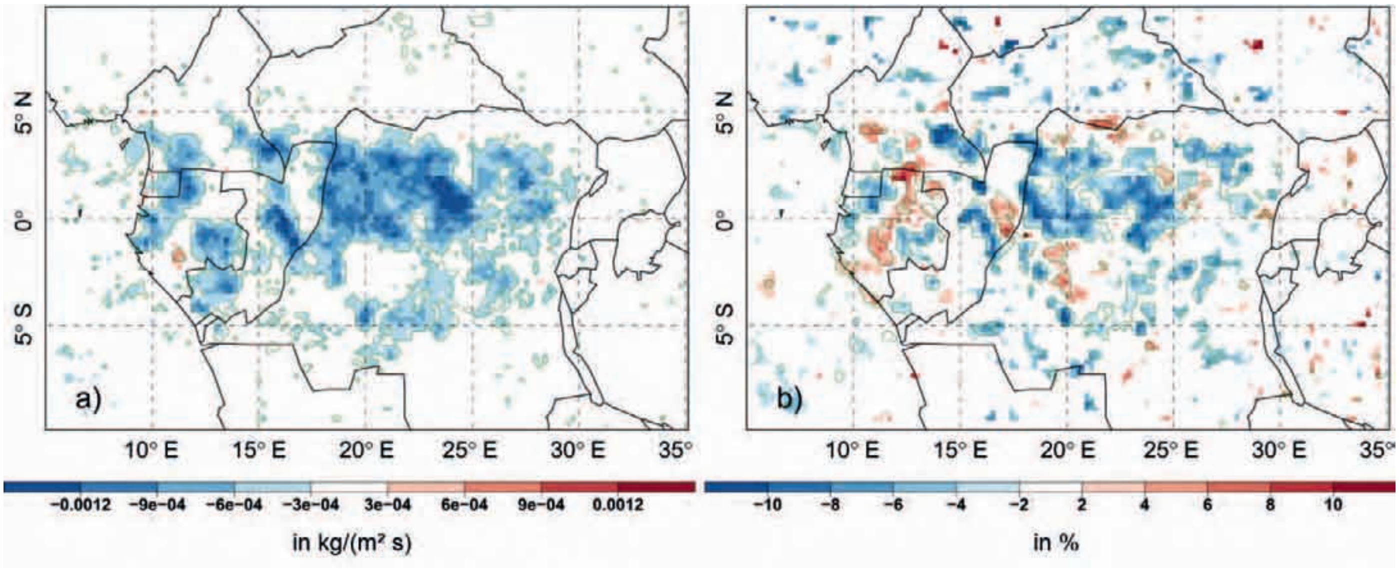

Figure 3.5 : (a) Upward convective mass flux density change at cloud-base height in absolute terms[16] *(kg* m^{-2} s^{-1}*) and (b) changes in rainfall due to the succession of forests in the Congo Basin region to agriculture and other land uses from 2041-2060 (in %).*

Source : Akkermans et al. (2014).

The increase in surface temperatures and decrease in rainfall will essentially intensify convection (low) over the Congo Basin region, but it will be warmer and less humid than now. The low is expected to intensify the West African Monsoon (WAM), which will lead to increased rainfall in more distant locations, such as the Sahel and Ethiopian Highlands (Guinea coast). However, remote sensing based rainfall (Spracklen *et al.*, 2012) and isotopic (Levin *et al.*, 2009) data provide an alternative scenario. Moisture in South Sudan and the Ethiopian highlands (and less so in the western Sahel) during the WAM originates from the Atlantic Ocean, but must pass over the Congo Basin region first. Forest cover and evapotranspiration in the region could act as a buffer against moisture loss as the warm wet air masses of WAM move onshore (indirect recycling). If the forests were not there or severely degraded, the air masses would dry out, leaving little moisture for storm development and rainfall over much of the Sahel and Ethiopian Highlands during the critical WAM rain season in the future.

[16] This unit corresponds to the displacement of a fluid, of density ρ in kg/m^3 (in this case the air) at a speed v in m/s.

CHAPTER 4

Vulnerability and adaptation of forests and communities in Central Africa

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With contributions of: Richard Sufo-Kankeu, Carlos de Wasseige and Martin Tadoum

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1. Introduction

There is growing evidence that the global climate is changing. The impacts and response to climate change will vary from one region to the other and from one country to the other due to differences in natural resource dynamics and institutional and governance capacity. It is important for central African countries to recognize the risk posed by climate change on life supporting systems in the region. This is relevant for policy design and implementation in relation to financial, governance and technical needs.

2. Vulnerability to climate change in Central Africa

2.1. Vulnerability of forest ecosystems and peoples to climate change: why adaptation matter for the region?

Many vulnerability studies focus on the arid and semi-arid regions of the African continent, paying less attention to the Central African region. However, emerging evidences show that both its forests and people are also vulnerable to climate change (CSC, 2013). The region is going to experience increase in climate variability and changes in the hydrological systems. Similarly, the differences between seasons and between years are expected to become larger. The region is going to suffer from more intense rainfall and flash floods in the wet seasons, while the dry season could become either wetter or drier. Near surface temperatures are expected to increase in the future (de Wasseige *et al.*, 2014) (see chapter 2). Like other forests, the forest ecosystems in the region are sensitive and exposed to the changing climate which will further be exacerbated by other drivers such as land use change, land fragmentation, and over exploitation of forest resources (Sonwa *et al.*, 2012b). Furthermore, the forest ecosystems might also suffer from disturbance regimes such as pests, fires and diseases.

Photo 4.1: Road construction may locally impact the surrounding forest through changes in soil condition

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Photo 4.2: Wildlife is particularly vulnerable near villages

Communities are already experiencing distortion in their livelihood systems due to changing seasons, variation in temperature and precipitation (Bele *et al.*, 2013). The livelihoods of the millions of people in the region depend on vulnerable activities and resources such as agriculture, forests for household energy, food and fiber, water supply, herbs and tree barks for health care (Sonwa *et al.*, 2012b). Crop and climate models indicate that climate variability and change are influencing the sowing dates and growing-season temperature, which have long-term effects on crop yields in some areas in the region (Tingem *et al.*, 2009). It is highlighted that a 1 mm/day increase in rainfall predicted for much of the Congo Basin by the 2050s may cause a basin wide increase in the frequency of heavy rains during the dry season. Thus causing a reduction in the size of slash and burn farmers' fields, and potentially a substantial increase in the food insecurity of poor rural families across the region (Wilkie *et al.*, 1999). Furthermore, vulnerability will be exacerbated due to changes in environmental policies related to access to forest resources (Peach-Brown *et al.*, 2010).

Central African forests play a key role from the global to the local level, but they are subject to climate variability and impacts. Paleontological studies have shown how forest have migrated, fragmented or disappeared across in the subregion due to changes in the climate regimes (see chap 2 or 3). Not only they constitute an important source for the current economy and wellbeing of populations, but also they host important genetic biodiversity that might provide responses for future threats (de Wasseige *et al.,* 2014). Furthermore, the central African population is expected to double by 2050, with the subsequent pressure on natural resources. UN projections for the continent estimate an increase from 1.1 billion to 2.4 billion by mid-century (UN, 2012). In addition, rapid urbanization will affect consumption (UN, 2015). Adaptation policies need to be mainstreamed in the region to secure stable development of its populations and global climate.

2.2. Vulnerability of economic and social sectors

As described in chapter 3, vulnerability is the combination of exposure, sensitivity and adaptive capacity. The socio-economic sectors and livelihoods of central African countries and its populations present different abilities to react to climate stimuli. Furthermore, they are highly dependent on the surrounding ecosystems that constitute a significant proportion of the gross domestic product of the countries in the region. This implies climate change might jeopardize the successful implementation of any sustainable economic and national development plans. Furthermore, climate change will constrain countries in the region to realize global targets such as the millennium development goals. At the local level, forests provide important goods for food security, local economy, housing and health (de Wasseige *et al.*, 2014).

Land use and the climate can have both immediate and sustained effects on hydrology (Li *et al.*, 2007). Furthermore, changes in hydrology can have both positive and negative impacts on economic sectors, infrastructures and agriculture, among others. It is nevertheless important to highlight that climate change impact will vary across the sub-region and across sectors.

In this context, forests could play a key role for short-term and mid-term adaptation, at smaller scales due to its potential for water provision, flood regulations and provision of medicinal plants (Sonwa *et al.*, 2012a). Ecosystem-based adaptation has been an important approach defined as having high potential for the Congo Basin region (IPCC, 2014; Somorin *et al.*, 2012; Sonwa *et al.*, 2012a).

2.2.1. Hydrology and energy

The repercussions of past climate variations on watercourses are reflected in changes in their regimes. Several studies have shown drops of a 43 % to 74 % in the Sahelian rivers from 1970 to 1990, with consequences on natural lakes. For example, the surface of Lake Chad got reduced by 4 to 12 times during the period 1955-1975 (Lemoalle *et al.*, 2012). In humid tropical Africa, the decrease reached 32 % of the flow of the rivers to the Atlantic ocean (de Wasseige *et al.*, 2014). The decline in flows has repercussions on the quantity of water filling lakes, which are natural reservoirs. On the other hand, an increase in precipitation was recorded beginning in the 1990s in certain regions of the Congo Basin, leading to an increase in the flow of certain watercourses (Conway *et al.*, 2009).

Climate projections indicate increases in flow variability, intensification of high flows and decreases in low flows. Consequently, the region could benefit from hydropower plant production. However, the increases in extreme events will require infrastructures that are more resistant. Furthermore, changes in variability will need to be overcome by combination with other power sources, electricity accumulators and reliable distribution networks (CSC, 2013).

2.2.2. Agriculture

Water and temperature regimes condition agricultural production. This is particularly true in Africa where subsistence agriculture predominates and smallholders produce about 80% of the food consumed (AGRA, 2014). As such, crop production is mostly rain-fed, and technologies to control temperature (such as greenhouses) are not yet widely applied. Projected variability across zones indicates the northern zones of the basin will be less prone to drought with increases in agricultural production. However, in the central region, increases in water might be such that they can lead to floods damaging crops. In the southern zones agricultural production will start decreasing halfway the century, due to changing evapotranspiration balances, being prone to droughts as well (CSC, 2013). In addition, changes in humidity will influence nutrient availability, and impacts of pest and diseases (de Wasseige *et al.*, 2014).

2.2.3. Health

It is recognized that climate change is a direct (insufficient access to safe water and improved sanitation, food insecurity) and indirect (limited access to health care and education) multiplier of existing health vulnerabilities (IPCC, 2014). Changing temperature and precipitation patterns will impact health due to malnutrition, diarrheal diseases, and malaria and other vector-borne diseases. Malnutrition problems could be tackled in the northern part of the Congo Basin due to increased agricultural production, but diarrheal diseases, malaria and water-borne diseases could further affect throughout the region due to increased temperatures and floods. Health is especially vulnerable in context of poor healthcare systems combined with poor governance and lack of infrastructure.

2.2.4. Urbanization

Many of the interacting social, demographic, and economic drivers of observed urbanization and migration in Africa are sensitive to climate change impacts. Climate change is triggering rural-urban migration. In addition, rapid urbanization is mostly unplanned, with infrastructure and distribution plans not adapted to projected floods and extreme events. Furthermore, urbanization is leading to transformation of the food systems with increase in purchased food in urban areas. Production, processing, transport, storage and preparation will need to be adapted to future threats (IPCC, 2014).

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Photo 4.3 : Terraced crops dominate the landscape of Rwanda

Photo 4.4 : Agriculture and timber industry are now the main economic activities of the former mining town Makabana (Congo)

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***Box 4.1 :** CCAFS projections on crop yields*

Vulnerability varies not only across zones, but also different crops are affected differently. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) has produced scenarios for crop suitability across Africa. In Central Africa the areas suitable for pearl millet, Sorghum, and tubers such as cassava and yam are stables or show either little area loss or even gains whereas crops such as banana, maize and beans will be affected negatively.

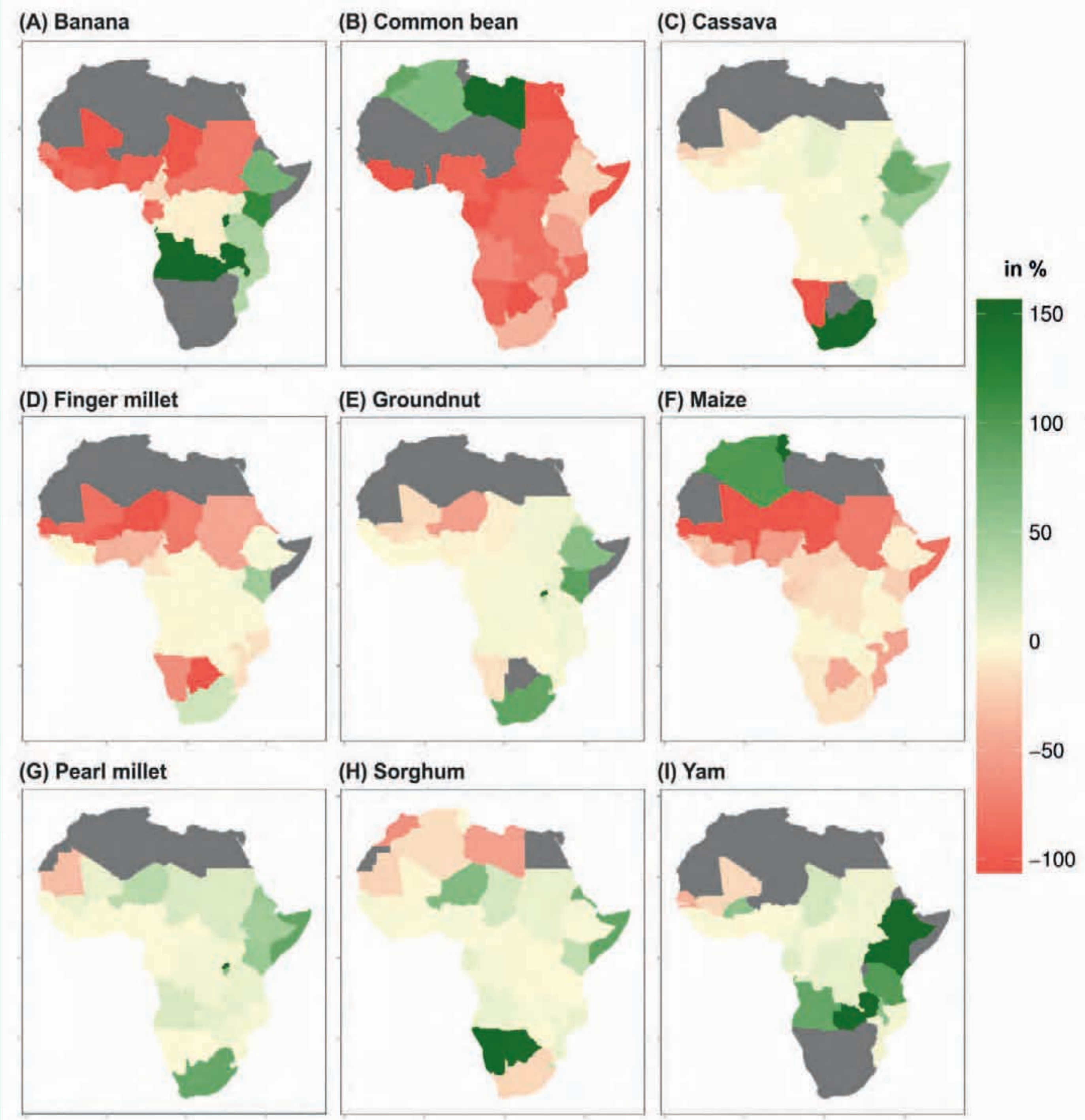

Figure 4.1: Maps showing scenarios for crop suitability in the context of climate change across Africa.
Source: Ramirez-Villegas and Thornton (2015).

3. Adaptation of forest and forest peoples to climate change

Adaptation measures for forest ecosystems ("adaptation of forest") are required to guarantee the health of forest ecosystems and the continuous provision of ecosystem goods and services, which are indispensable for economic growth and the adaptation of forest peoples ("forest for adaptation") (Figure 4.2). Adaptation strategies are twofold. First, adaptation requires political and technical measures (Figure 4.2). Second, adaptations requires the enhancement of the adaptive capacity of forest communities on one hand through ecosystem services, and on the other hand through improved tenure, improved infrastructure and technology, capacity building of diverse local institutions and improve relationships between local and national-level adaptation planning efforts. Local and national adaptation plans need to target poverty reduction, food security, water availability and biodiversity conservation (Peach-Brown and Sonwa, 2015 ; Sonwa *et al.*, 2012b). Adaptation strategies need to be continuously mainstreamed into decision making whereby strategies are assessed in terms of the degree to which they are effective ; their technical feasibility, cost and benefits are evaluated ; feasible and economically justified options are implemented ; the performance of adaptation is monitored and evaluated ; and adaptation strategies are modified if necessary (Bele *et al.*, 2015).

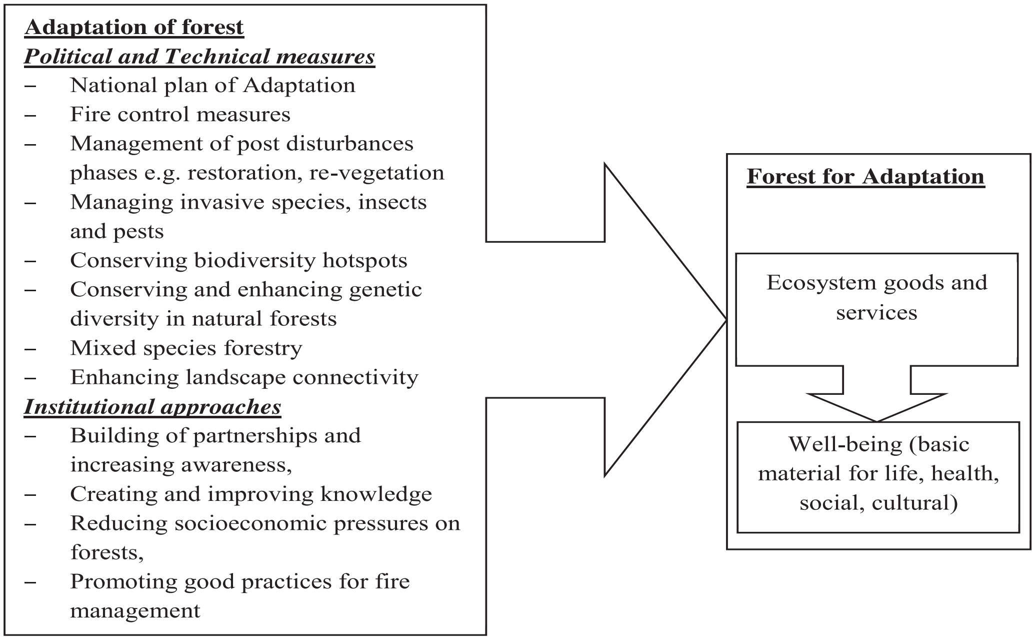

Figure 4.2 : Adaptation strategies for forests and forest for adaptation.

Source : Guariguata et al., 2008 ; Locatelli et al., 2008 ; Ravindranath, 2007.

3.1. Policy and institutional responses to climate change vulnerability

3.1.1. Adaptation policy and institutional dynamics in Central Africa

The adaptation of forests and peoples in Central Africa depends on existing and future regional and national policy and institutional efforts and orientations. The climate change adaptation policy process entails the different courses of action responsible for crafting strategies that enhance adaptation. Through this process, new approaches are expected to be designed and/or integrated/mainstreamed into existing forest and development policies. Institutions provide cross-cutting forces and arrangements (Young, 2002), which are relevant for negotiating and facilitating the design and implementation of adaptation strategies at the local level (Agrawal, 2010) ; and at the national and regional levels (Koch *et al.*, 2007). All the countries of the Central Africa (CA) region are parties to the UNFCCC, which underscores their interest to provide policy response to combat climate change.

Photo 4.5 : Performed sparingly, collecting firewood can be sustainable (Burundi)

Their efforts are demonstrated through the UNFCCCs National Communications (NCs) and the National Adaptation Program of Action (NAPA) initiatives. NCs highlight vulnerable sectors and potential measures to facilitate adaptation to climate change. The NAPA initiative tailored for Least Developed Countries (LDCs) is relevant for some countries of the CA region (Table 4.2), where they have made attempts to identify priority areas and activities that respond to their urgent needs related to climate change adaptation. Despite these efforts, the policy and institutional processes are still characterized by limited coordination, weak institutional linkages and lack of coherence between sectoral policies (Kengoum, 2013; Dkamela, 2011). There is a need to build capacities, strengthen institutional networks both at the level of policy-making as well as at the level of implementation of adaptation strategies (Peach-Brown *et al.*, 2013).

The forest ecosystems of the Congo Basin provide ecosystem goods and services which are safety nets and relevant for the adaptation of forest-dependent peoples (Nkem *et al.*, 2010). Notwithstanding, the existing policy frameworks are still to, seriously consider the role of forest resources in climate change adaptation planning (Bele *et al.*, 2011). In the past, climate change adaptation has received less attention in the policy and institutional response process due to limited information and knowledge on adaptation (Somorin *et al.*, 2012). Clear-cut information on the cost, benefits, options and the impacts of possible adaptation choices which are relevant for decision makers is lacking for the region. At the regional level, the COMIFAC, with support from national and international governmental organizations, national and international non-governmental and research institutions, is making attempts to propel the adaptation agenda and climate change response in general. In its recent 10 years (2015-2025) convergence plan, the fight against climate change is included as one of the priority areas. However, technical, financial and institutional support will be required for the Commission and member countries to operationalize the different strategies accompanying the priority areas of the convergence plan. In the context of the Central Africa region, the challenges for adaptation in the climate change policy process might be easier to overcome due to the strong links between climate vulnerability and poverty and development strategies. Development and poverty reduction are priority areas for countries in the COMIFAC space. Thus, this should be used as an opportunity for adaptation, by integrating adaptation strategies into current development plans and poverty reduction strategies (Sonwa *et al.*, 2012b).

In the advent of climate change responses, institutions involved in policy development and implementation need to revise, change and take on new roles to be in a position to facilitate and enforce new policies, become flexible and able to learn and adapt to the changing human-environmental system which is characterized by uncertainty (Locatelli *et al.*, 2008). First, state agencies should be responsible for mainstreaming adaptation into national policies, sourcing financial resources and influencing and coordinating the course of action at the international, national and local levels. Second, non-state agencies which include national and international NGOs and research organizations should provide support related to awareness raising, mobilization of efforts, promotion of inter-ministerial dialogue, collaboration, networking, knowledge generation and capacity building (Chia *et al.*, 2014).

3.1.2. Financial and funding opportunities in the region

Climate change adaptation is a financial burden for countries in the Central Africa region (Somorin *et al.*, 2012). It is important to note that, globally it is unclear whether sufficient funds will be available to address the adaptation needs of developing countries which threatens to surpass $50 billion per year after 2020 (Smith *et al.*, 2011). Countries of the CA region have accessed and benefited differently from the adaptation fund under the UNFCCC framework (Table 4.1). Many opportunities are still available, highly dependent on the countries' capacities to propose adaptation projects. Apart from the funding sources under the UNFCCC framework, other policy and funding options relevant for CA countries include multilateral and bilateral assistance through development banks and overseas Development Assistance. According to Smith et al (2011), a substantial share of present development assistance is spent on climate sensitive projects. In this context, it is argued that climate change adaptation should be factored in all development assistance that are climate sensitive (Huq and Burton, 2003). Thus, coordinating the two funding streams at the national and international levels may provide more effective support for both sustainable development goals and climate change adaptation. This approach is crucial for COMIFAC countries.

Table 4.1 : *National level funding opportunities for adaptation in Central Africa.*

Operational since	Currently operational	Fund name	Administrative body	Eligible COMIFAC countries	COMIFAC countries benefited to date ($ million)
1993	Yes	Global Environmental Facility Trust fund (GEF) – Climate Change and Land Degradation focal areas	GEF	All	Burundi (7.24), Cameroon (9.23), CAR (0.35), Chad (2.62), Congo Brazzaville (2.36), DRC (3.63) Equatorial Guinea (3.50), Gabon (0.77), Rwanda (4.83), Sao Tomé & Principe (0.35)
2002	Yes	Least Developed Countries Fund (LDCF)	GEF-WB	Burundi, Central African Republic (CAR), Chad, Democratic Republic of Congo (DRC), Equatorial Guinea, Rwanda, Sao Tome and Principe	Burundi (13.19), CAR (11.17), Chad (13.00), DRC (20.67), Rwanda (24.51), Sao Tome and Principe (16.17)
2002	Yes	Special Climate Change Fund (SCCF)	GEF-WB	All	Cameroon (4.55)
2004	No	Strategic Priority for Adaptation (SPA)	GEF	All	None
2007	Yes	Millennium Development Goals Achievement Fund – Environment and Climate Change thematic window (MDG-F)	UNDP	DRC, Equatorial Guinea, Sao Tome and Principe	None
2008	Yes	Fast-Start Financing (FSF)	Japan's Ministry of Finance	All	Burundi (2.6), DRC (31.6)
2008	Yes	International Climate Initiative (IKI)	BMU	All	COMIFAC countries (1.67), Rwanda (1.76)
2008	Yes	Global Climate Change Alliance (GCCA)	EuropeAid	Burundi, CAR, Chad, DRC, Equatorial Guinea, Rwanda, Sao Tome and Principe	CAR (6.19), Chad (4.05), DRC (5.48), Rwanda (10.27), Sao Tome and Principe (3.27)
2008	Yes	Pilot Program for Climate Resilience (PPCR)	WB	All	None
2009	Yes	Adaptation Fund (AF)	WB	All	Rwanda (3.20)
2011	Yes	International Climate Fund (ICF)	DFID	All	CBFF (35.00), contributions to other funds mentioned in the table
2012	Yes	Adaptation for Smallholder Agriculture Program (ASAP)	IFAD	All	Rwanda (7.00)
TBC	TBC	Green Climate Fund (GCF)	GCF	All	None

Sources : Adaptation Fund (2015) ; AECID (2005) ; GEF (2014) ; HBF & ODI (2015) ; MDG Achievement Fund (2013) ; PPCR (2015) ; UNFCCC (2015d).

3.1.3. Policy and institutional enabling conditions

The revising of existing policies and the creation of new policies should provide opportunities to achieve the objectives of adaptation (adaptation for forest and forest for adaptation). The design and implementation of technical measures for forest adaptation depends on a favorable institutional environment, characterized by strong networks and partnership building, knowledge generation and dissemination, and strategies for reducing socioeconomic pressure on forest resources (Locatelli *et al.*, 2008). Furthermore, regional and national institutional frameworks should create opportunities for building local level networks, collective action and social capital which are relevant for the adaptation of local forest communities (Peach-Brown *et al.*, 2014).

Photo 4.6: Artisanal exploitation and transformation in the heart of the forest

Future climate change and forest vulnerability is characterized by uncertainty and the dynamics of human-environmental systems. Thus, policy and institutional approaches should be diverse, flexible, adaptive and continuous to take advantage of knew knowledge and insights (Bele *et al.*, 2014). Building policy-science dialogue is necessary. Findings generated by rigorous research should be transformed into policy relevant language and put into the policy process. Science should inform decision makers about assessing vulnerabilities, identifying response options and designing adaptation strategies. Decision makers in the region need frequently updated information and knowledge to support regional and national positions on climate change adaptation (Tiani *et al.*, 2015).

3.2. Regional, national and sub national initiatives

Adaptation initiatives refer to initiatives whose outcome has intentions to support national adaptation policies and strategies. They include impacts and vulnerability assessments, identification of country priorities, planning for adaptation, implementing large adaptation programs, monitoring and evaluating adaptation interventions, and capacity building (Pavageau and Tiani, 2014). At the international level, adaptation initiatives are demonstrated through NCs, NAPAs and NAPs. Almost all COMIFAC countries have submitted the first and second NCs and NAPAS, with Gabon to be the first to complete the Intended Nationally Determined Contribution (INDC) including a chapter on adaptation (Table 4.2). Eligible COMIFAC LDCs countries have submitted a total of about 70 projects cutting across different sectors and levels. A limited number of these projects (9 %) explicitly take into consideration adaptation for forest and the role of forest for the adaptation of local communities (UNFCCC, 2015d). This might be due to the fact at the time of developing NAPA priority projects, COMIFAC countries had limited information and knowledge on the vulnerability of forest ecosystems to climate change and the role of forests for adaptation.

Apart from the initiatives emanating from the international level, other regional and national level initiatives exist which originate from bilateral and multilateral arrangements (Pavageau and Tiani, 2014). The COBAM and CoFCCA projects implemented by CIFOR provided early insights on the policy and local level challenges and opportunities of climate change vulnerability and adaptation in the context of forest ecosystems use and management in the Congo Basin. However, further research is required to generate and disseminate useful information on the short and long-term climate variability. This is relevant for anticipating impacts on climate sensitive activities, sectors and development planning for the Central Africa region.

Table 4.2: Status of national adaptation strategies of COMIFAC member countries in the UNFCCC process.

Countries	1st NCs	2nd NCs	NAPAs	INDCs
Burundi	2001	2010	2007	-
Cameroon	2005	-	-	-
CAR	2003	2015	2008	-
Chad	2001	2013	2010	-
Congo-Brazzaville	2001	2009	-	-
DRC	2000	2009	2006	-
Equatorial Guinea	-	-	2013	-
Gabon	2004	2011	-	2015
Rwanda	2005	2012	2007	-
Sao Tomé and Principe	2005	2012	2007	-

Sources: UNFCCC 2015a, 2015b, 2015c.

3.3. Ecosystem-based adaptation: a potential response in Central Africa?

Ecosystem-based adaptation (EbA) is defined as "the use of ecosystems to support societal adaptation through their management, conservation, and restoration to provide services that enable people to adapt to the impacts of climate change. It aims both at increasing the resilience and reducing the vulnerability of ecosystems and people in the face of climate change" (UNEP, 2009). EbA strategies range from sustainable water management for water storage, flood regulation and coastal defenses, disaster risk reduction through tree cover, sustainable agriculture using locally available genetic resources, etc. (de Wasseige *et al.*, 2014).

The Congo Basin is characterized by a large forest cover with up to 2,874,419 km^2 of humid and dry forest altogether in 2015 (see chapter 1). Although still vulnerable to climate change, forest presents a bigger relative adaptive capacity as compared to other ecosystems due to their specific composition. This is particularly evident for tropical forests that are richer in biodiversity than temperate forests (Locatelli *et al.*, 2008).

Governments in the sub-region are still struggling to push their development strategies. Planning for adaptation involves investing in uncertainties, and maladaptation could provide counterproductive medium-term outcomes. Ecosystem-based adaptation appears as a cost-effective option with significant social, economic and environmental co-benefits (UNEP, 2009). Furthermore, in a region with high mitigation potential the donors concentrate their focus on carbon conservation, with adaptation financing focusing on arid and semi-arid regions. Finally, EbA is more accessible to the rural poor than infrastructure and engineering-based adaptation. With a 54% the total population living in rural areas in Central Africa, EbA seems as a likely alternative (UN, 2015).

Photo 4.7: Will the forest return on this cleared land ? This is one of the major issues related to REDD

4. Measuring and monitoring the impacts of adaptation measures

Adaptation to climate change in the forest sector involves measures designed for implementation at the local or project level, and policy level measures. At the project level, adaptation takes place in three sequential steps. Firstly, it requires the climate vulnerability and impact assessment of forest and forest peoples. This step consists of analyzing the context, describing current climate and forest conditions and developing scenarios of future climate change and forest conditions. Second, it requires the design and implementation of adaptation measures. Third, it requires the measuring and monitoring of the impacts of adaptation measures. Indicators on the vulnerability and impacts needs to be developed during the first step, permitting planning and targeted implementation and the measurement and monitoring of the impacts of adaptation actions. Due to the novelty of adaptation programs most of the sets of indicators developed until now belong to the first level, vulnerability. The links between climate change vulnerability and poverty have allowed borrowing from development planning and implementation approaches (Box 4.2).

Box 4.2: *Climate vulnerability indexes used in Africa.*

Over 20 groups of indicators (indexes) have been developed by scientists, governments and development organizations in order to identify vulnerable areas in Africa. Most of them follow the IPCC approach to vulnerability by considering a combination of exposure, sensitivity and adaptive capacity aspects. These indexes are constructed using cross-disciplinary indicators, covering different sectors, scales and groups of populations, based in either past climate trends or climate projections. Besides the uncontestable utility of cross-regional indexes for policy and development planning, vulnerability analyses are very dependent on the type and quality of data used and they need to be used with caution. Pavageau et al (2013) analyzed the typology of indexes to find out commonalities and approaches among them (Figure 4.3). As a result, four major groups were identified: indexes focusing on agriculture and poverty (Group 1), indexes focusing on population density (Group 2), indexes focusing on governance (Group 4), and other indexes (Group 3). Very few consider the vulnerability of forests themselves, most of them taking them into account either as a source of adaptive capacity (safety nets) or as a potential source of conflict over resource management. Country vulnerability assessments are very disparate depending on the index used. Generally, Gabon appears as resilient for most of the indexes whereas Cameroon, Chad and CAR are very dependent on the focus of the vulnerability analysis. Congo, DRC, Rwanda and Burundi are sometimes classified as highly vulnerable, whereas for other indexes there are not sufficient data available.

In the forest sector, designing indicators for monitoring and measurement could be challenging as a result of the links between the three variables of forest, climate change and forest peoples. In this context, further research is required to develop and test a comprehensive set of tools which can be adapted to different situations in the region. Whatever be the approach for evaluating adaptation measures, evaluation should be considered as a continuous process, in order to modify adaptation strategies that are not responding to objectives, and to take advantage of new information on climate change impacts on forest and forest peoples. Furthermore, there is a clear need for institutions leading data collection to obtain and centralize more locally relevant and continuous data. Several countries have expressed their interest in the creation of National Climate Change Observatories like Cameroon, Chad, Gabon, and Rwanda but they still need to be made operational. Others have delegated the responsibility to existing institutions like Burundi and Sao Tomé & Principe.

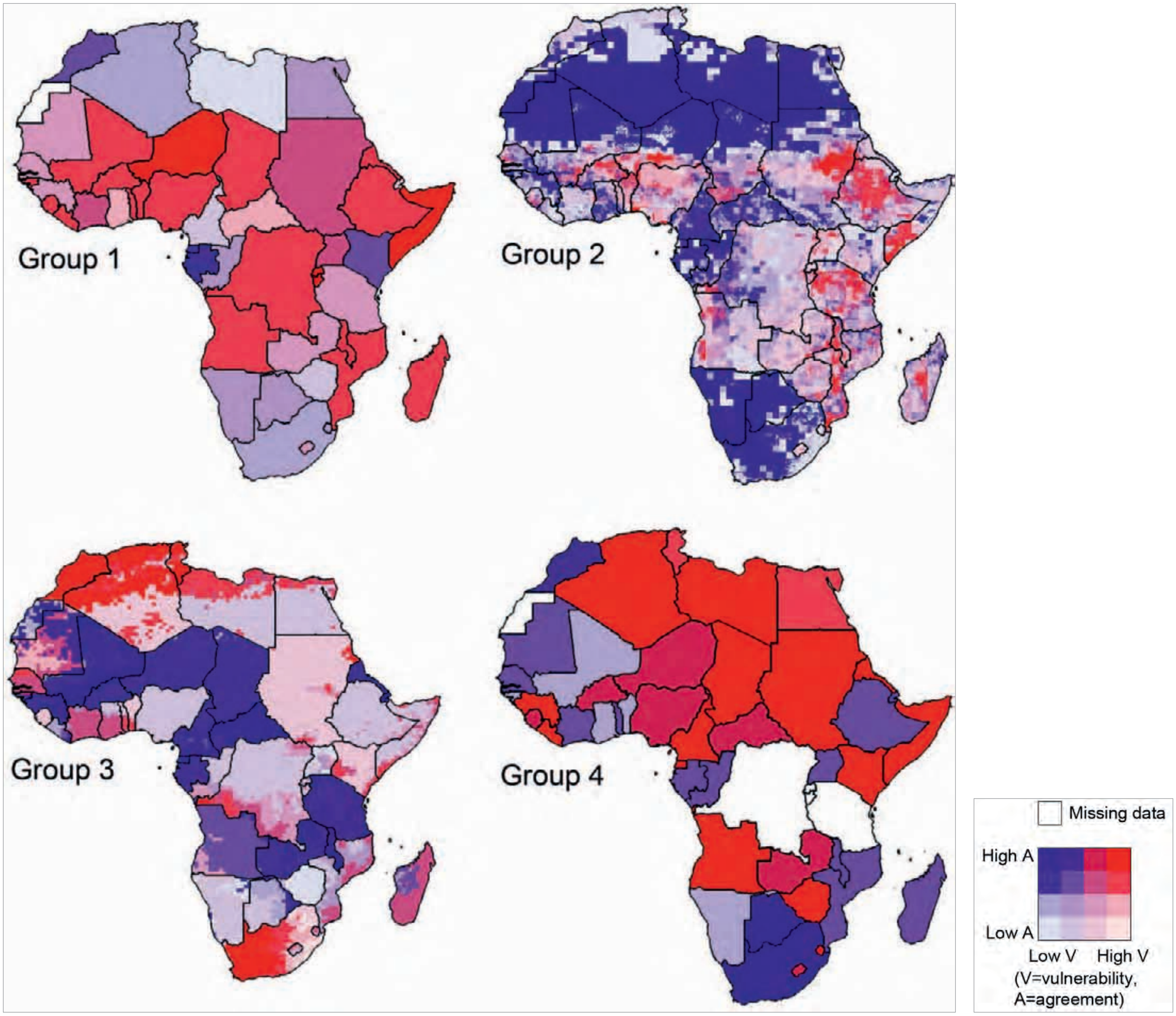

Figure 4.3 : Aggregate vulnerability maps for each group of indices across African countries
Source : Pavageau et al., 2013

5. Lesson learnt from early initiatives on adaptation

Adaptation initiatives in Central Africa and developing countries of other continents can provide useful insights for future planning in Central Africa. Ranging from governments to the grassroots, different stakeholders have fostered adaptation initiatives. NAPAs have been compiled, although not yet funded, and therefore, most observations come from international and subnational initiatives. In addition, best practices can be obtained from unintentional adaptation to past extreme events and common variability by local farmers can also help designing future programs (Füssel, 2007 ; Twomlow, 2008). Some lessons learned from initiatives on adaptation in the region are quoted as follows :

1. Adaptation measures are not rigid or definite. They involve actions that target several aspects of climate stimuli, from extreme events, variabilities to changes in means. Both natural

climate variability and anthropogenic climate change need to be considered, as the combination of both can lead to increased impacts. Combinations of coping strategies and proactive/resilience improvement can help in efficiently responding to climate change (e.g. reconstructing a building after an extreme event vs. creating climate insurance schemes that cover the costs) (Ford *et al.*, 2014 ; Füssel, 2007).

2. Adaptation planning includes managing the risk of uncertain and complex hazards. It therefore needs to remain flexible through time, as future threats might vary. Projects need then to include mechanisms of continuous monitoring and evaluation. More accurate climate projections through specialized centers will reduce the costs of adaptation projects.

3. Adaptation to climate change needs to be made context specific, because it depends on a large combination of factors. Diversifying the types of actions and scales can contribute to better adaptation. Costly adaptation measures should be thoroughly evaluated (see box 4.3) whereas no-regrets actions can be easily incorporated in policies. UNDP and UNEP have supported existing institutions at different scales across countries, by merging large and small replicable actions that are in line with national policies (Nkem *et al.*, 2011).

4. Whereas inclusiveness of different stakeholders, subnational scales and marginal groups in the design and implementation of climate change policies has proved an increase in the efficiency and effectiveness, many projects still fail to do so in Central Africa (Mai *et al.*, 2011 ; Ford *et al.*, 2014). Strengthening social networks have provided positive outputs in other African countries (IPCC, 2014). Furthermore, it can increase the sustainability of project results through increased appropriation. Adaptation planning requires contribution of climate specialists, decision-makers and practitioners. Both men and women should be actively involved in the conceptualization and implementation of adaptation actions. In many occasions, project planners have confronted transaction costs and deficient communication schemes that reduce the possibilities for public consultations (Tschakert and Dietrich, 2010).

5. Adaptation needs to be combined with mitigation, as it cannot cover all aspects of climate change due to the complexities in planning and implementation.


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Photo 4.8 : The village consultation is necessary for the success of projects in rural areas

Box 4.3 : *Choosing adaptation options*

Anticipatory adaptation if:
– climate-sensitive risks are already urgent ;
– increasing risks are projected reliably ;
– future impacts are potentially catastrophic or irreversible ;
– decisions have long-term effects ; and/or
– adaptation measures have a long lead time.

Postponing adaptation if:
– current and anticipated future risks are moderate ;
– adaptation is very costly ; and/or
– timely response options are readily available.

Source : Füssel (2007)


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Photo 4.9 : Strategy of passive self-defense. But nothing will stop the man if he wants to make use of this tree

6. Challenges and the way ahead

The major challenge for the COMIFAC countries is to develop climate change adaptation strategies for the transboundary forest system, without endangering the integrity for these forests to ensure the continuous provision of ecosystem goods and services critical for community livelihoods, national development and the economic growth of the region. At the present, there is insufficient knowledge on regional climate change patterns, unknown quality, quantity, and spatio-temporal pattern of risk occurrence and the lack of clear adaptation possibilities. There is a real need to enhance climate change information generation and its delivery through the improvement of climate change information infrastructure e.g. weather/meteorological stations and technology, and information centralization, delivery and sharing services. Notwithstanding, the dynamic ecological, economic, social and political pathways provide opportunities for COMIFAC countries to develop viable adaptation strategies.

There is a need to move from cross-continental analysis to sub-regional, since the ecological and socio-economic settings vary greatly across countries. Regional structures and platforms like COMIFAC, CBFP, CICOS, LCBC, ECCAS, and regional civil society networks need to further insist in transmitting this message. They have the potential to boost adaptation mainstreaming in national policies, through the provision of guidelines, funding and coordination (de Wasseige *et al.*, 2014). In this sense, NAPAs and adaptation provisions in NCs and INDCs are still to be operationalized. Since government cannot count solely on external funding, no-regrets adaptation is advised. Increase climate change adaptation in the national and regional policy spaces, by raising policy and public awareness on climate change, and reflecting on the need for adaptation. Harness the regions carbon potential not only for climate change mitigation, but for achieving sustainable economic growth, poverty reduction and climate change adaptation. Balance the interest of multiple stakeholders when setting priorities intended to achieve the national economic growth, environment and social sustainability objectives. Improve ecological safety nets in forests so that valued resources are more resilient to climate variability and change. Improve science- policy dialogue, with a broad public participation (Nkem *et al.*, 2008).

CHAPTER 5

THE FORESTS OF CENTRAL AFRICA: AN INCREASED CONTRIBUTION TO THE MITIGATION OF CLIMATE CHANGE

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1. Introduction

Forests continue to play important roles for the people of Central Africa, simultaneously at the local level where forests constitute the essential resources base for the livelihoods of rural communities, and at national level where they contribute to aggregate economic indicators. Because of that, the forestry sector has been a major focus of national policies as well as of international development cooperation targeting the region. Traditional forest policies were mostly oriented towards the productive functions of the forests, especially timber production, and the conservation of biodiversity. Yet, during the last 10 years increased attention has been paid to environmental services provided by these forests, especially services related to climate regulation through carbon sequestration. According to Nasi *et al.*, in de Wasseige *et al.*, (2009), an estimated 46 billion metric tons of carbon are stored in the Congo Basin. Closed evergreen lowland forests represent 60% of the carbon stored in the sub-region while only covering 35% of the area. There is a new thinking to favour traditional policies that additionally provide climate regulation services while internalizing new international initiatives such as Reducing Emissions from Deforestation and forest Degradation (REDD+).

2. Forest based policies and measures to mitigate climate change in Central Africa

Africa ranks amongst the lowest contributors to global CO_2 emissions from fossil fuels, with a 4% of total global emissions. The main relative sources, contrariwise, mainly originate from agriculture and land use change and forestry (LUCF; including deforestation) corresponding respectively to 26% and 35% of the total emissions from the continent, making LUCF-based approaches the key target for the continent.

Timber exploitation is often perceived as a direct and indirect factor of both forest degradation and deforestation. However, provided that it is conducted in a sustainable way, forest management for timber production can also contribute to fighting deforestation and forest degradation, help maintaining long term carbon stocks and reducing GHG emissions while providing livelihoods.

Mitigation of climate change has been approached by three main sets of policies and measures in Central Africa. These include the adoption of sustainable forest management techniques, the improvement of forest governance and the current engagement in the REDD+ process.


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Photo 5.1: Under the forest, there are sometimes oil, such as in Lambaréné in Gabon.

2.1. Sustainable forest management for timber production

2.1.1. Implementing sustainable forest management in Central Africa : the state of the art

The management of forest concessions for timber production in Central Africa has drastically changed since 2000. Since the first approved management plans in the late 1990s, forest concessions implementing forest management plans currently cover 19 million ha, accounting for a 40% of the total area under concessions in the subregion (Bayol *et al.*, in de Wasseige *et al.*, 2014). Nevertheless, progress towards sustainable forest management varies very widely, according not only to countries and geographical zones but also to the types of actors. Overall, it is expected that the region will experience a substantial increase in concession areas implementing forest management plans in the coming years as the Democratic Republic of Congo is finalizing its logging policy reform.

Photo 5.2 : Marking a forest track for the realization of inventories.

Additionally, forest concession managers have been increasingly adopting forest certification as a means to show that their management approaches meet international standards. At present, there are over five million ha of FSC certified production forest in the Congo Basin. Furthermore, there are more than three million ha of forest concessions covered by legality certificates granted such as « Timber Origin and Legality (OLB) » by Bureau Veritas or « Timber Legality & Traceability Verification (TLTV) » by SGS. Table 1.2 in Chapter 1, summerizes the current status of long term logging concessions in Central Africa in the light of their progress towards sustainable forest management.

2.1.2. Potentials for sustainable forest management in Central Africa to contribute to climate change mitigation

Sustainable forest management (SFM) is often overlooked in Central Africa. It may at first glance seem less efficient to reach climate change mitigation goals than classical REDD+ projects, because SFM still entails timber extraction, the building of forestry roads, and other degradation or deforestation activities. However, SFM is at present the only means to generate lasting income and employment from forest areas without converting them to other land uses. As such, properly managed forest concessions – which include protection from conversion – can be considered as contributing to avoided deforestation or reducing emissions from deforestation and forest degradation insofar as they reduce the logging impact and also prevent agricultural encroachment, illegal logging or charcoal production (see below). In addition, there are usually opportunities to improve forest management towards reducing the carbon emissions of timber harvesting practices (reduced impact logging), while extracting the same timber volume. Likewise, forest managers can set aside High Conservation Value Forests (HCVF) inside of timber concessions (which can e.g. be part of the FSC certification process) or by converting entire timber concessions into so-called 'conservation concessions' with the consequent benefits for carbon sequestration. In sum, Table 5.1 shows an array of SFM options classified according to the Verified Carbon Standard's

Table 5.1: *Activities to reduce deforestation and forest degradation in logging concessions*

Activity that help reduce emissions from deforestation and degradation	VCS project typology	Impact on annual timber production for the concessionaire as compared to the baseline scenario
Conservation concession	Improved Forest Management (IFM) - Logged to Protected Forest (LTPF)	End of logging, no volume harvested
Extended rotation age	IFM - Extension of Rotation Age (ERA)	Decreased volume logged annually
Increased DMA (minimum cutting diameter set by management plan)		
Reduced impact logging	IFM - Reduced Impact Logging (RIL)	No impact on the volume logged annually
Reducing forest conversion and unplanned forest degradation	REDD - Avoided Unplanned Deforestation and Degradation (AUDD)	Preservation of the forest estate (and thus reducing the volume logged annually)

Source: Hirsh et al., 2013

typology with positive contribution for mitigation, some of which may lead to a fall in the volumes of wood produced (or even a total cessation of logging during conservation).

Preliminary analyses of the mitigation potentials of sustainable forest management activities have been carried out in Central Africa, including the Haut Nyong, Cameroon (TEREA, 2013), and Lukenie (Hirsh *et al.*, 2013) and Mai Ndombe (Schmidt, 2014) in DRC.

In the Haut Nyong case study, emission reductions were addressed through a reduction of the annual harvest by increasing minimum girth limits for species to be harvested (IFM-ERA) in a forest concession covering an area of 342,000 ha. It was shown that by adopting a reconstitution rate of 50% for the whole stand, CO_2 emissions could be reduced by more than 600,000 tCO_{2eq} within 25 years. The 50% reconstitution rate is the common practice in forest concessions that implement forest management plans. Although the results from this pilot study cannot be generalized for the whole of the Congo Basin, they suggest that the implementation of a forest management plan over a 20 million hectare forest concession in Central Africa has the potential to reduce emissions by more than 35 million tCO_{2eq} over a period of 25 years.

In DRC, Hirsh *et al.* (2013) estimated that emission reductions through Reduced Impact Logging (RIL) could mainly be achieved by reducing the density of the forestry road network. In detail, this would entail:

- a reduction in primary and secondary road width, both for the actual road as well as for the solar strips; and
- a reduction in secondary road length. To compensate the reduced accessibility, though the length of skid trails would increase.

Schmidt (2014) analyzed the mitigation potential for a conservation concession as well as for a mix of RIL and set-aside of smaller High Conservation Value Forest (HCVF) areas and concluded that additional emission reductions could be achieved by:

- reducing the residual stand damage, e.g. through (improved) directional felling and cutting of vines; and
- reducing the proportion of abandoned timber, i.e. timber that is cut but not processed because it lacks marketable quality. This could be achieved by not cutting trees that show signs of tree rot. Tree rot can be tested relatively easily by chainsaw operators through the 'chainsaw plunge test'.


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Photo 5.3: The rivers are not a barrier to logging

No field research has been carried out to estimate the residual stand damage. However, evidence for residual stand damage can be found in the literature. Measurements e.g. by Brown *et al.* (2005) in the Republic of Congo estimate that carbon emissions from residual stand damage are 174 % of the carbon in felled merchantable biomass. A study by the FAO (2008) in the Republic of Congo finds that on average 17.7 trees in the residual stand are uprooted or at least suffer bark damage when felling one commercial tree.

A sampling analysis of forestry records as described by Schmidt (2014) shows that 5.4 % of felled merchantable timber is not forwarded for processing but remain as 'deadwood' in the forest due to either tree rot or damage to trees during the felling process (breaking of the stem).

On top of the assumed reduction in the forestry road network, if RIL is implemented at least to cover the five million hectares of certified forest concessions for which 1/30th is logged over each year (about 165,000 ha) the inherent gross emission reduction related to the implementation of RIL might be estimated around 4 million tCO_{2eq} on the annual basis. Such measures are expensive for logging enterprises that may need support from non-market funding sources that seek to encourage carbon-oriented forest management.

The above cited studies lead to the conclusion that the emission reduction potential of SFM practices is real and considerable in the Congo Basin. The actual figures obtained depend significantly on the methodology used as well as the carbon pools and emission sources included. Furthermore, particular biophysical and economic conditions within the different areas across the basin might include further variabilities. Another decisive factor with regard to financial feasibility of individual forestry concessions is the density of merchantable volume, at least when following a LtPF project approach where baseline emissions are determined on available and allowable offtake of merchantable timber stocks.

In general, it may be most beneficial, and also most realistic, to allow forestry companies a stratified or even layered baseline approach, where several baselines – unplanned deforestation, unplanned degradation and planned degradation – are combined, where this is applicable. In the DRC, forestry concessions do not only generate emissions through their timber harvesting operations but also through conversion to agricultural land, charcoal production and illegal logging. Capturing all these emissions in a baseline will provide an incentive for forestry concessionaires to (better) protect their forest resources. The Mai Ndombe REDD+ programme shows that forest concessionaires are interested in all types of forest mitigation projects, depending on the individual situations in their concessions.

The two studies conducted in the DRC show that the implementation of mitigation measures in the forestry sector can yield emission reductions at a relatively low carbon price of $ 2 to 5 per ton of CO_2. While multilateral carbon funding – e.g. through the FCPF CF in the DRC – could currently match this price (up to $ 5/tCO_2), achieving such a price in the voluntary market could be a challenge. Forest carbon prices have steadily fallen from $ 10.3 in 2011, to $ 7.7 in 2012, $ 4.8 in 2013 and $ 4.3 in 2014 (Goldstein *et al.*, 2014; Hamrick and Goldstein, 2015). However, unlike more intrinsically-driven REDD+ projects financed by NGOs or bilateral development cooperation, the long-term financial viability of a forest mitigation project is key for forestry companies. Current prices in the voluntary market are not sufficient or just borderline sufficient, but multilateral carbon funds e.g. the FCPF carbon fund or the BioCarbon Fund can currently offer better prices (though only over a short period of 5 years) and thus play an important role in triggering participation. This type of funding is however limited to forestry companies that participate in larger jurisdictional REDD+ programs such as e.g. the Mai Ndombe REDD+ Programme[17].

Another incentive for forest concessionaires to participate in a REDD+ program or develop an individual forest mitigation project is the option to combine this with FSC certification. FSC certification often entails introducing RIL and setting aside HCVF. As such, return from carbon sales could be used (partly) to offset the costs associated with FSC certification.

Finally, it must be said that emission reduction potentials calculated in the cited studies so far remain possible, but hypothetic goals. They are based on feasible assumptions with regard to adapting or changing forestry practices.

2.2 Improving forestry sector governance in Central Africa to enhance climate change mitigation

Recent development in forestry governance in Central Africa should also contribute to climate change mitigation although quantifying such contributions has not been attempted so far. Thomson *et al.* (2011) argue that REDD+ is very much a project of environmental governance. Lessons from the implementation of forest management and Payment for Forest Ecosystem Services (PFES) suggest that progress can be made towards REDD+ outcomes by supporting implementation of existing national and sub-national forest policies in ways that are consistent with the principles of good forest governance (Kanowski *et al.*, 2011). If REDD+ is to work effectively, developing countries such as the ones of the Congo Basin will need support to build capacities required for enforcing their own laws and regulations (Daviet, 2009). Analysing the interactions between FLEGT (VPA) and REDD+, Ochieng *et al.* (2012) suggested that most of these interactions potentially have a positive influence, but much depends on the future implementation of both regimes. Two recent publications provide more detail for policy implementation. Haywood *et al.* (2015) explore the “importance of viewing REDD+ in context”, i.e. addressing REDD+ governance in the context of larger, more encompassing approaches that harmonize climate, livelihood and development outcomes across the landscape. Guidance for developing national policy and legal frameworks is provided in Chapman *et al.* (2015).

For countries of the Congo Basin to benefit from REDD+ efforts, significant improvements in environmental governance is needed, and such improvement can be built in synergy with the ones already underway through the FLEGT-VPA process. In particular, effective emission reductions will require the ability to manage leakage and ensure permanence, as well as the ability to reliably account for the rate of timber extraction from forests. This in turn will require the capacity to effectively enforce domestic laws that govern forests (Daviet, 2009).

Countries of Central Africa that have embarked in improving forest governance have developed positive momentum for the reduction of forest based emissions. Nevertheless, difficulties to control the informal forestry sector remain a large challenge faced by all the countries of Central Africa.

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Photo 5.4: Timber transportation in the spotlight in an advertising campaign.

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[17] It should be considered that these considerations are based on the situation before a climate agreement has been reached in Paris in December 2015, and should this agreement materialize, the whole policy landscape around REDD+ and climate finance may shift in currently hardly predictable ways.

2.3.1 The general REDD+ architecture

The overarching aim of REDD+ is to help mitigate climate change and its effects on humans and the environment by creating incentives for developing countries to reduce emissions of greenhouse gases caused by deforestation and forest degradation. REDD+ foresees compensation for five eligible activities: (a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forests; and (e) Enhancement of forest carbon stocks. For REDD+ to realize its full mitigation potential, the drivers of deforestation and forest degradation must be addressed effectively, requiring national government to undertake reforms of their policies, practices and processes affecting forest management specifically and land management more generally (Chapman *et al.,* 2015).

The implementation of REDD+ consists of three phases (Meridian Institute, 2009). In the first "readiness" phase countries prepare a national REDD+ strategy through inclusive multi-stakeholder consultations, star building capacity in monitoring, reporting and verification (MRV), and design demonstration activities. The second phase is "more advanced readiness", but the focus is to implement policies and measures to reduce emissions. The third phase is full UNFCCC compliance during which, tropical forest countries are compensated solely for reduced emissions and enhanced carbon stocks relative to agreed reference levels (Wertz-Kanounnikoff and Angelsen, 2009).

While the earlier REDD+ debate emphasized carbon sequestration and avoided emissions from land-use change, it is now widely recognized that REDD+ (hence, the 'plus' sign) should also deliver non-carbon benefits (NCBs) related to livelihoods, biodiversity, institutional improvement; other ecosystem services (e.g. nutrient cycling, protection of watershed services, etc.).

A recurrent issue in the REDD+ debate is at which level accounting and providing incentives are to take place. There are three options: direct support to project (subnational level), direct support to countries (national level) or a "nested" approach that combines the two (Angelsen *et al.*, 2008; Pedroni *et al.*, 2009). The global preference goes to a national approach. Nevertheless many project-based REDD+ activities are already underway in response to the call for national demonstration activities to inform the design of a global REDD+ mechanism. A nested approach, the most flexible of the three approaches, allows countries to begin with subnational activities and to move gradually to a national approach (Wertz-Kanounnikoff and Angelsen, 2009). Likewise, countries are encouraged to develop their national MRV capacities in a step-wise approach to allow for an early participation with an adequate pace of capacity development (see below).

2.3.2. The status of REDD+ in Central Africa

The Congo Basin forests are the second largest area of rainforests globally, and hence potentially represent a « prime location » (Fobissié *et al.*, 2014) for implementing REDD+. A recent paper by Assembe-Mvondo *et al.* distinguishes several groups among COMIFAC member countries as far REDD+ is concerned. First, the group of COMIFAC member countries that seems to be a priority for the international community[18]. Under the joint goodwill of the World Bank (FIP), UNREDD and to some extent Norway and the African Development Bank, these four countries have adopted and validated their Readiness Preparation Proposal (R-PP). Some of them, like the DR Congo, are in the so-called investment phase after developing and adopting their REDD+ national strategies (Aquino and Guay, 2013). Second is the group of countries that are less endowed with forest potential, but also engaged in the REDD+ process through mitigation programmes and activities with the support of international cooperation[19]. This group of countries seems engaged on a voluntary basis since they were not initially targeted as countries that qualified for the REDD+ initiative. In the same vein, Burundi and Chad have officially applied to enter the Forest Carbon Programme Facility (FCPF) managed by the World Bank. Gabon had been listed as a recipient country of the Facility through its Readiness Plan Idea Note (R-PIN), its present official position on REDD+ leans toward renunciation. As for Equatorial Guinea, its attitude is simply passive toward REDD+.

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[18] These are the DRC, Cameroon, Republic of Congo, and Central African Republic (CAR).

[19] Burundi, Chad, Rwanda, and Sao Tome and Principe

The general remark is that, although countries of Central Africa are at different stages in the implementation of the REDD+ process, they all find themselves locked the first phase (readiness phase) as described in the section above.

Most advanced is the DRC, being near to the completion of phase 1, and which has put in place a number of demonstration projects. The DRC has attracted substantial funding for its REDD+ readiness needs at the level of $ 23 million funded mainly by FCPF and UN-REDD. Additionally the Congo Basin Forest Fund (CBFF) has committed itself to provide $ 35 million for the implementation of pilot REDD+ projects, while the Forest Investment Program (FIP), executed by the World Bank and the African Development Bank was committed to provide $ 60 million to fund REDD+ investment in three large Congolese cities (Kinshasa, Kisangani and Mbuji Mayi – Kananga). Result based payments for emissions reduction are still a future goal (Aquino, 2012).


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Photo 5.5: Foliage generously deployed at the top of a straight trunk, so the phenotype often met in the forests of Central Africa

3. Lessons learned from early mitigation initiatives

3.1 Lessons from sustainable forest management

SFM has made significant progress in Central Africa for the last 20 years due to a number of factors that include the following:

Political will from governments of the COMIFAC member countries that has led to the improvement of the institutional and legal frameworks within which timber production and biodiversity conservation are conducted. In fact, since the mid-1990s all timber producing countries have revised their forest legislations to include new elements setting obligations for forest concession managers to develop and implement forest management plans. Additionally the forestry legislation then adopted had provisions for better involvement of local people in sustainable forest management for their own benefits.

The Engagement of the private sector encouraged by market tools such as forest certification to meet demand from environment sensitive market of timber importing countries in Western Europe, the US and Japan. Private sector enterprises were ready to invest in long term forest management strategies that would give access to certified timber market and improve their international image. The investment made included for example: acquiring new expertise in SFM related techniques, but also financing the design and development of long term strategic forest management and establishing internal remote sensing lab within their structure. Without private sector engagement carbon-oriented forest management would be very difficult to achieve in Central Africa. However, for a better implication of the private sector, the long-term financial viability of a forest mitigation project is key for forest concessions managing companies.

The involvement of the donor community that provided support both to national government and private sector enterprises. On the one hand the international community has provided technical and financial support to government to undertake forest policy reforms. An example of the support provided by the international community to government is given by the support to the government of Cameroon provided by the World Bank (Toppa *et al.*, 2009). In 1994, the government introduced an array of forest policy reforms, both regulatory and market based. The reforms changed the rules determining who could gain access to forest resources, how access could be obtained, how those resources could be used, and who will benefit from their use. This report assesses the outcomes of reforms in forest-rich areas of Cameroon, where the influence of industrial and political elites has dominated since colonial times.

On the other hand international donors such as the French Development Agency (AFD) have financially supported credible private sector companies that intended to shift their operations towards adopting SFM technique by providing loans at low interest rates in Gabon, the Central African Republic and Cameroon.

Such multilateral and/or bilateral support to governments and private sector operators can be decisive in current attempts to promote carbon-oriented forest management in Central Africa.

3.2 Lessons from early REDD+ initiatives

Hurdles that have prevented REDD+ to progress faster in Central Africa are mostly linked to the underlying political economy of deforestation and forest degradation in a context of often weak (forest) governance, existing multilevel and multi sectorial coordination challenges, and competitive national development objectives (Martius, 2015). A study of eight subnational initiatives in Africa that included Cameroon (Sills *et al.*, 2014) finds that land tenure and finance are key challenges, but problems with scale, measurement, reporting and verification (MRV), and social safeguards are also relevant. In several initiatives, seed funding from donors ran out before REDD+ finance became viable.

The institutional obstacles can be illustrated by the case of Cameroon which has been involved in REDD+ since 2007 (Brown *et al.*, 2011). Cameroon suffers from conflicting forestry legislation (Somorin *et al.*, 2014). In view of deep-rooted cross-sectoral drivers of forest loss, enforcing REDD+ will require major policy change and reform both within and outside of the forestry sector (Epule *et al.*, 2014). The REDD+ policy process in Cameroon was found to be repeating the weaknesses of the earlier forestry law reform undertaken in 1994, as seen in the minimal ownership of REDD+ by national actor groups (Dkamela, 2011 ; Dkamela *et al.*, 2014), low inclusiveness among actors at both national and local levels, the absence of a national REDD+ coalition and a reduced ability of state agencies to make autonomous decisions about forest resources. Tackling these weaknesses and the inconsistencies between sectoral policies affecting forest resource management are important steps in achieving the policy change needed for REDD+ (Dkamela *et al.*, 2014).

Disadvantageous economics of REDD+

REDD+ will have a hard time competing with more remunerative land-use changes. While REDD+ may play an important role in stemming biodiversity loss and reducing carbon emissions from tropical deforestation in the near future, in the longer run, reliance on a system that values forests solely for their carbon retention capacities poses a serious risk. It is imperative that the institutions and policies currently being established as part of REDD+ readiness activities are adaptive to future changes in the incentive structures facing tropical forest countries due, for example, to climate policy induced demand for biofuels (Martin Persson, 2012). However, it has been demonstrated that strategic management of, for example, oil palm in Indonesia, can allow both crop yield maximization and attainment of landscape scale conservation goals (Koh and Ghazoul, 2010).

Green Economy

REDD+ contributes to the green economy and low emissions development (LED) options. Many countries around the world are developing explicit strategies to promote « green » or « bio-based » economic transitions to reduce their dependency on non-renewable resources and increase sustainability. « Green economy » (GE) and green growth visions seek to improve human well-being and social equity, while significantly reducing environmental risks and ecological scarcities, thus protecting natural capital (UNEP 2010, 2011). The GE concept specifically recognizes that we are reaching planetary limits and challenges the primacy of growth as a tenet of the current economic model (Rockström *et al.*, 2009 ; CIFOR, 2014a). In this context, LEDS (Low Emission Development Strategies also called low carbon development) describes « forward-looking national economic development plans or strategies that encompass low-emission and/ or climate-resilient economic growth » (OECD, IEA 2010, cited from UN-DESA, 2012).

There is increasing interest from governments, donors and the private sector to advance the implementation of a GE. Promoted through a global discourse focusing on environmental sustainability, this concept engages with the notion of LED. Greening of commodity supply chains and REDD+ are two broad approaches packaged within LED, and GE more broadly. This discourse filters down from global, to national and subnational levels, and is translated, contested and re-interpreted along the way by different state and business actors pursuing diverse interests and aims. A variety of concepts and approaches has become subsumed under the same umbrella. The effectiveness of such a plethora of approaches is not well understood, neither in terms of avoided deforestation and forest degradation nor in terms of improved local well-being (CIFOR, 2014b ; Obidzinski *et al.*, 2014).

Two aspects that link REDD+ to GE/LEDS are important. First, REDD+ is an important element of GE/LEDS (UNEP, 2014), because it is not only a low carbon emissions activity (i.e. it seeks to protect forests), but also potentially a source of economic growth (i.e. it creates economic incentives to protect forest), and it aims to be pro-poor. REDD+ can help to safeguard forest ecosystem services, improve forest governance and protect the rights of indigenous peoples and local communities in the transition to a global green economy. Forest management will be an important part of any GE/LEDS pathway. Second, REDD+ experiences can be particularly important to inform broader policy debates about low emissions development in and around forests. REDD+ policies and mechanisms have been tested and debated for several years now. Lessons from REDD+ highlight the challenges associated with LEDS in the forest sector, and the tradeoffs inherent to many REDD+ decisions (Phelps, 2015). It seems the right moment to reflect on the lessons from REDD+ experimentation and implementation on the ground and how this may inform movements towards GE/LEDS.

Countries should prepare for high flexibility in REDD+ finance. For example, many countries are preparing to become eligible for funding through the Green Climate Fund, which identifies REDD+ as a priority results area for funding. Similarly, efforts to move towards GE/LEDS activities need to consider the level to which they will depend on public or private funding given that market mechanisms have not yet proven to be successful in the case of REDD+.

Measurement, reporting and verification

Being able to reliably measure and monitor the extent of forests, of deforestation and of forest degradation and estimate carbon stocks is a key prerequisite to enable payments for results. As countries move through the REDD+ phases, they must develop reference levels and a national forest monitoring system that quantifies emission reductions.

Emission Level and MRV

Establishing Forest Reference Emission Levels (FRELs) /and/or Forest Reference Levels (FRLs) (see UNFCCC Decision 12/CP.17), and also systems for Measuring, Reporting and Verifying (MRV) emissions reductions and removals (14/CP.19) are therefore formal requirements for countries qualifying to establish a formally recognized REDD+ program. A stepwise or staged MRV framework (Herold *et al.*, 2012) for setting FRELs/FRLs and for measuring REDD+ emissions reductions and GHG removals (i.e. MRV) acknowledges that countries should start with the capacities they have, build on their strengths, and fill the gaps as they progress through the phases of REDD+ implementation. The process for technical assessments of FRELs/FRLs was agreed at the Conference of the Parties (CoP) 19 as a part of the Warsaw Framework for REDD+.

Targeting the drivers

As many REDD+ activities address actions and actors outside forests, monitoring should be broader than forest areas (Salvini *et al.*, 2014), and the data include more than basic environmental and ecological data. Socio-economic information is essential to understand both possible causative agencies of proximate drivers, as well as providing a baseline against which some of the co-benefits of REDD+ can be measured. This may require increased efforts in capacity building.

Countries may choose to include information on drivers of deforestation and on how effective the different activities and policies are in achieving emissions reductions in their national forest monitoring systems (UNFCCC Decision 11/CP.19). Collecting this information and making it available in those systems will be essential to understand what works and what does not under REDD+. This can be valuable information to decide on which of the REDD+ interventions best address the key drivers (Hosonuma *et al.*, 2012). While addressing these international requirements, national monitoring systems can be adapted to the different needs of national implementation, so that


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Photo 5.6 : Any project in rural areas requires consultation with the local population

REDD+ activities can be tracked by the multiple actors involved. This can then provide the basis for the distribution of REDD+ benefits and the verification of this distribution.

Data needs

Forest monitoring systems require data on activities (i.e. land use), emission/removal factors, and data on drivers of deforestation. The IPCC has outlined a framework for the first two data types that recognizes the countries' different level of capacities to assess and monitor these data (Romijn *et al.*, 2012). Countries that are developing FRELs can make adjustments for their national circumstances.

The lack of country and region specific data of sufficiently high resolution seriously limits our ability to convert area estimates of deforestation, forest degradation and land use into reliable estimations of emissions, sinks and changes in carbon stock for most tropical countries (Verchot *et al.*, 2012) including those of Central Africa. This constraint can be overcome faster if countries make coordinated, targeted investments and develop productive partnerships between the technical services in REDD+ countries, intergovernmental agencies and advanced research institutes in developed countries. Even if data on key elements of REDD+ – deforestation and forest degradation rates, mitigation potentials, aspects of benefit distribution, and safeguards – are available, they are often scattered across agencies and not translated into relevant and comprehensive information that can be used for the design of national REDD+ (Hosonuma *et al.*, 2012 ; Korhonen-Kurki *et al.*, 2013). Countries need to make better efforts for structured data generation, storage and translation into meaningful evidence, information, guidelines and tools. Critical in this international effort is compatibility between systems, not only in terms of what data is collected, but how it is collated and curated.

Capacity gaps

In a global study of the development status and trends of national MRV capacities, Romijn *et al.* (2012) integrated different global data sources to assess dynamics between 2005 and 2010 in developing countries. The results of the study emphasized that REDD+ monitoring systems need to be designed based on each country's characteristics and capacities and suggested that countries with good capacities could play a larger role in South–South cooperation on that matter. An updated study of monitoring systems has just been published (Romijn *et al.*, 2015).

Participatory MRV

While the importance of participation of indigenous peoples and local communities in monitoring and reporting has been recognized through the UNFCCC process, participatory approaches remain underdeveloped and underutilized. Involving local communities in national forest monitoring activities has the potential to increase the efficiency of monitoring, and reduce costs, while simultaneously promoting transparency and better forest management (Pratihast *et al.*, 2014), but there may be opportunity costs (e.g. work load and time needed to tend to crops and livestock). These authors could successfully validate the biomass data established through community-based MRV with biomass estimates established by professional experts. However, the ensuing processes of reporting and verification (the « R » and « V » in MRV) require much more attention to develop reliable systems. Research and a growing experience with the approach in many places can help to overcome this gap.

Benefit-sharing mechanisms

Benefit-sharing mechanisms represent a key element for national REDD+ systems to create the incentives needed to successfully reduce carbon emissions and foster joint economic and environmental outcomes (Bouyer *et al.*, 2013). Benefit-sharing mechanisms encompass all institutional means, structures and instruments for distributing finance and other net benefits from REDD+ programs.

Benefits may be monetary or non-monetary. For example, REDD+ implementation can clarify land tenure, support forest management and governance, facilitate technology transfer, and maintain or even improve ecosystem services (Di Gregorio *et al.*, 2012). Fund-based approaches, forest concession agreements, land rent fees (Assembe-Mvondo *et al.*, 2013) and market-based instruments are predominantly vertical. Horizontal approaches include community-based natural resource management and Joint Forest Management. So far, countries have tended to build upon existing models that are most familiar to their context (Pham *et al.*, 2013). This approach can reduce costs and attract political support. However, the effectiveness, efficiency and equity of these models will rely on the accountability, transparency and financial management capacity of the state (central government, often the national Forestry Department) which can be rather weak in some of the countries studied.

Legitimacy of decision-making institutions, consideration of context and attention to process are critical for stakeholders to perceive benefit sharing as fair (Luttrell *et al.*, 2013). Building this legitimacy requires attention to fair distributional outcomes, procedural equity and consensus on which institutions have the authority to make decisions.

At the local level, cash or in-kind payments are often expected. Yet, the distribution of revenues over a large number of recipients or the relatively low carbon stock in question (e.g. in dry forests) may reduce or dilute the payments. Combining REDD+ payments with additional programs, or using them at jurisdictional levels for creating development outcomes may therefore be more rewarding strategies.


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Photo 5.7: Small trees are not the only ones to give place in favor of slash and burn agriculture

Box 5.1: Benefit sharing generated by land management in Cameroon

Samuel Assembe-Mvondo

Most of Central African countries that gained independence in the early 1960s inherited from the colonial period a system of land and forest tenure characterized by a kind of conflicting coexistence between a prominent written law and a marginalized customary law. In fact, the legal reform of the postcolonial administration was not structured. It aimed to adapt the colonial regime to the new status of independent states or to perpetuate the dominance of written law over customary laws (Hesseling and Le Roy, 1990). This gradually eroded customary practices to the benefit of legal system imposed by European colonial authorities. Thus, the postcolonial land-tenure system incorporated customary land, which was considered to be vacant and unoccupied, into state land. Local communities were almost completely stripped of their ancestor lands. Customary ownership were replaced with user rights granted to local communities and indigenous people and the possibility for any economic operator to obtain a land certificate/registration. State monopoly over land was confirmed in legal systems and systematic registration. The inheritance of dual-tenure systems (statutory vs. customary) has continued into the era of independence, and to the present day. Such land tenure systems can really promote both insecure rights and deforestation, contrary of REDD+ objectives and outcomes (Sunderlin *et al.*, 2008 ; Cotula and Mayers, 2009).

After decades of centralized, authoritarian and poor land governance by postcolonial administrations, some timid measures have been adopted notably in DRC (where customary ownership is constitutional right since 2006); Republic of Congo and Central African Republic (where customary rights are recognized to the indigenous people). Likewise, Cameroon is seen as one of the pioneer country where land management can generate socioeconomic benefits to all the stakeholders. Indeed, the provisions of Decree No 76-166 of 27 April 1976 to establish the terms and conditions for the management of national lands in Cameroon, require that each national land recipient, whether held by grant or lease, must pay annual fees. This revenue is apportioned to the state, the local council and village communities. An assessment by Assembe-Mvondo *et al.* (2013) has shown that one of five agro-industries pays land royalties to: the state (40%); three local councils (40%); and eight villages communities (20%) in which its sugarcane plantations are located. In this regard, the contractual terms of emphyteutic lease concluded between the company and state of Cameroon is complied with the spirit and the letter of the 1976 land regulation. In this respect, the total amount paid as land fees in January 2012 for 15,800 ha was €155,725. The local authorities of the three local councils stated that financial revenues received as payment of annual land fees are part of their ordinary budget expenditure. The revenues contribute to the salaries of council employees at the beginning of fiscal year. For their part, some villages have invested their financial resources in school facilities through the construction and rehabilitation of classrooms and residences for school teachers. Nevertheless, others villages acknowledge that income received during the last three years have been distributed in cash to families for celebrations.

Despite those real socioeconomic opportunities provided by land fees benefit sharing in Cameroon, the mechanism does not fulfill the criteria for effectiveness, efficiency and equity required by REDD+. Indeed, the system is hampered by poor governance trend in overall country and incomplete and poorly designed. Thus, there is need to reform it based on REDD+ safeguards principles.

Safeguards

Results-based financing of REDD+ is conditional on the implementation of national Safeguard Information Systems (SIS) to address social, environmental and governance criteria that go beyond carbon. Countries are required to comply with the seven safeguards articulated in the United Nations Framework Convention on Climate Change (UNFCCC) Cancun Agreement, which focuses on doing no harm, promoting good governance and multiple benefits, and assuring emissions integrity (UNFCCC Decision 1/CP.16). Furthermore, jurisdictions and projects engaged with multi- and bilateral donors and third- party certifiers must consider additional standards for demonstrating good social and environmental performance.

Aside from the international requirement that SIS should be « transparent, consistent, comprehensive and equitable » and « build upon existing systems, as appropriate » (UNFCCC Decision 1/CP.16), countries are not given much guidance on the use of appropriate indicators, data collection methods and reporting frameworks. There is considerable variation in the capacity of countries to implement national-level SIS and monitor the social, governance and environmental impacts of REDD+, and the costs of implementing adequate systems – which extend over a wide range of sectors– may be prohibitive. The challenges of harmonization, sovereignty, capacity and costs will become even more apparent as the REDD+ safeguards dialogue moves from international discourse to action (Jagger *et al.*, 2012, 2014). Although REDD+ readiness activities of many countries of Central Africa are supported by multilateral donors and beholden to their respective safeguard policies (e.g. World Bank, UN-REDD), on-the-ground progress has been somewhat limited.

Harmonization of various (safeguard) policies is crucial to avoid overlapping and contradicting legislation while REDD+ is being embedded in broader GE/LEDS efforts. Much remains to be done between international and national levels to address these issues efficiently.

Synthesizing lessons from countries' diverse experiences in engaging with multiple international standards, could contribute greatly toward implementing a safeguarded REDD+ that goes beyond « doing no harm » to actively delivering a host of social and environmental benefits. Also, field-based evidence on the social and environmental impacts of pilot REDD+ programs and projects can help to inform our choice of indicators for respecting local rights, ensuring local participation and enhancing NCBs.

4. Challenges and the way ahead

Judging from the evidence about REDD+ in the COMIFAC countries, much remains to be done. A few countries are more advanced with their REDD+ readiness than others. But even the advanced countries are a long way from functional, operation REDD+ systems that are efficient, effective and provides equitable outcomes. Particularly in fragile States, REDD+ will not be able to exist in a 'bubble of transparency and good governance' if all other policy sectors around it are under-performing on these accounts. This is particularly true as REDD+ policies pervade many non-forestry sectors – such as those dealing with agriculture, finance, environment, social welfare – and have to be intertwined with the policies in those sectors. Hence, the question remains what to do about REDD+. REDD+ will only remain a viable option for these countries if they manage to do three things. They need to embed REDD+ in the broader context of development policies. They need to develop other, non-market based mechanisms that reduce pressure on forests and forest resources. And they need to engage in broad policy reform in all sectors, introducing rule of law, good governance and transparency, and solving pending legal impasses such as the question of rights to land and carbon (Seymour and Angelsen, 2012).

The question remains how the international community can best support the COMIFAC countries on their pathway towards these achievements. If the world is committed to reduce land-based emissions, efforts may be needed to support this goal that go far beyond the current endeavours and are much more encompassing than narrowly focusing on climate policies. However, one should also not forget the lessons from REDD+ policy analysis in Korhonen-Kurki *et al.* (2014) that goes much farther than REDD+ : If there is no strong national 'ownership' of the policy process, if such a process is mainly steered by forces outside of the countries and if there are no strong national coalitions underpinning reforms, transformational change is not likely to happen. Developing these takes time and requires national capacity development efforts that can go over decades. Forests of the Congo Basin show lower deforestation rates than those on the other continents may be a fortunate fact that could buy precious time that the policy sector can use to develop governance, infrastructure and capacity in the COMIFAC countries.

The goals underlying REDD+ should be embedded in the broader national agendas for development and poverty alleviation. This is essential if these goals are to be widely implemented and embraced by citizens at all levels of society (Martius, 2015). At the global level, REDD+ discourses emphasize carbon sequestration and avoided emissions from land-use change as the principal benefit, while forest contributions to livelihoods, biodiversity, institutional improvement; other ecosystem services (e.g. nutrient cycling, protection of watershed services, etc.) are externalized as co-benefits. The emphasis reverses at the local level. For local actors – smallholders, communities and decision-makers – the main expected benefits of REDD+ are often cash income or other livelihoods benefits (such as diversification of income source, the advent of extension services, etc.), better infrastructure and services or a palpable increase in indicators of development (e.g. better heath, reduced maternal or infant mortality). In Central Africa, rural poverty can be exceptionally high, with poverty itself being an underlying driver of deforestation and forest degradation.

Proponents of the original REDD idea as a mechanism of paying for ecosystem services (PES) expected very low opportunity costs, but these initial economic calculations have for the most part been proven incorrect. Some proponents of pilot REDD+ initiatives have emphasized financial incentives that were then slow to come, creating frustration among stakeholders (Tiani *et al.*, 2015) ; some project proponents have invested large sums to try to maintain local support while awaiting REDD+ funding (Kowler *et al.*, 2014). REDD+ lacks legitimacy in some local communities where it has not been clearly placed in the context of poverty alleviation (Kengoum and Tiani, 2013 ; Somorin *et al.*, 2014).

Mismatched expectations are shaped by power relations and have slowed the pace of progress in REDD+ negotiations and implementation. This is a powerful argument for emphasizing poverty alleviation and development goals over climate goals if REDD+ is to be implemented with reasonable expectations for success.

Photo 5.8 : Floating timber in Nioki (Bandundu - DRC)

CHAPTER 6

Forest and climate change in Central Africa: Synergy between Mitigation and Adaptation

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1.Introduction

The notion of designing and implementing climate change response policies and projects that produce simultaneous positive outcomes for mitigation and adaptation is gaining grounds in the national and international research and decision making agendas (Elias *et al.,* 2014). The Central African region is not left out in this growing quest for synergy between mitigation and adaptation. The IPCC (2007) mentions synergy as the "intersection of adaptation and mitigation so that their combined effect is greater than the sum effects if implemented separately". Literally, synergy stands for "working together", meaning that there is importance to look at processes and dimensions where opportunities can be identified for mitigation and adaptation to work together. In this case, two interrelationships could emerge between mitigation and adaptation. Firstly, a relationship in which adaptation actions has consequences (+/-) for mitigation. And secondly, a relationship in which mitigation actions has consequences for adaptation (+/-). These two relationships indicate that there is always a need to minimize negative consequences and maximize positive consequences between mitigation and adaptation.

In the Congo Basin countries, there is urgency for both mitigation and adaptation. First, the forest ecosystems of the Congo Basin are pertinent for the global carbon balance through their huge carbon sequestration and storing potential. Second, the forests and forest dependent communities are vulnerable to climate change. In this light the design and implementation of adaptation policies and projects cannot be avoided. Nonetheless, in the land use and forestry sectors, efforts to keep trees standing for carbon and the strategies to enable forests and communities to enhance their adaptive capacity might demand and compete for the same type of land use activities, and other institutional and governance arrangements and inputs. Thus, planning to design and use the same strategy and policy package for positive mitigation and adaptation outcomes is critical for the region.

Photo 6.1: Village or log-yard? In this case, the overlap in space does not allow the distinction

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Currently, it is important to note that the dynamics and evolution of synergy is being shaded by different terminologies in research and policy. Some of the terms include: integration between, links between, complementarity between, harmonizing and combining, mitigation and adaptation. Generally, synergy has been stressed from different angles depending on the ecosystem, the sector and the policy agenda (Figure 6.1) (Illman *et al.,* 2013).

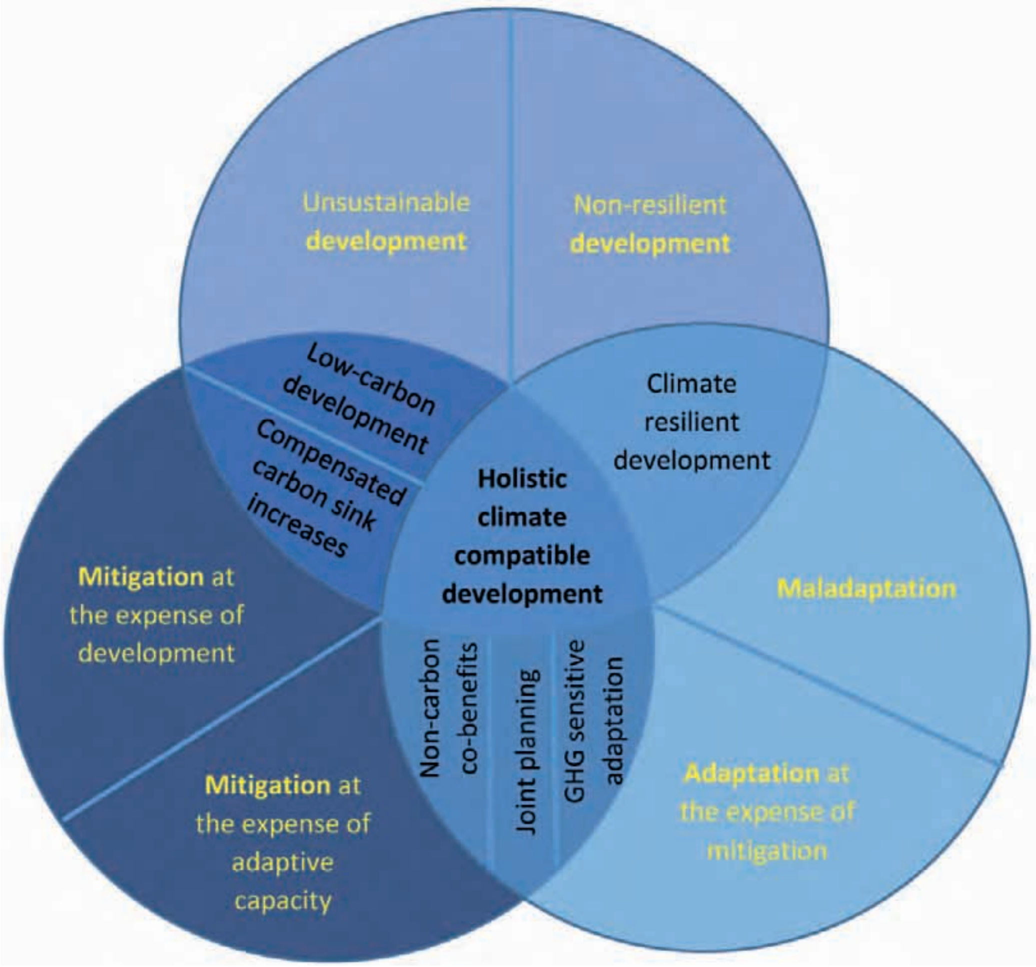

Figure 6.1 : Synergies and trade-offs between mitigation, adaptation and development interventions. Adapted from Illman et al., 2013.

2. Potential benefits of synergies between adaptation and mitigation

The climate change response process in Central Africa is progressing with mitigation through forest carbon dominating the process. Linking mitigation and adaptation has potential benefits for the development of a viable, balance, efficient and effective policy response. Climate change response in the region is experiencing limited financing, especially adaptation. In this case, by linking mitigation and adaptation in synergy, adaptation will benefit from the financial flows targeting mitigation activities. This means that adaptation projects that integrate mitigation activities may be able to benefit from carbon funding and capacity building opportunities and donors may go in for adaptation projects that produce global mitigation benefits. Technically, mitigation and adaptation activities overlap in forest landscapes in the region, and the overlap if well planned can yield benefits for adaptation and mitigation efforts. First, carbon storage through avoided deforestation and forest degradation is more likely to be permanent if it integrates the adaptation needs of communities and forest ecosystems. Second, integrating adaptation needs is an incentive and motivation for local people to accept carbon projects, thus a guarantee of sustainability. Integrated activities are likely certain to avoid duplication and waste of financial, technical and material resources, and reducing transaction cost in the design and implementation of adaptation and mitigation is vital for the countries of the region with limited financial resources (Chia *et al.,* 2014).

3. Different levels for pursuing the integrated mitigation and adaptation agenda for Central African countries

Currently, the design and implementation of climate change projects and programs at the national and local levels originate from international regimes. COMIFAC have been instrumental in shaping and providing orientation to the construction of the international climate change response regime, that take into account the needs and aspirations of the people and ecosystems of Central Africa. This section presents the different level of opportunities and context that COMIFAC countries and partners need to pursue and strengthen their position on synergy approaches.

3.1. International level policy frameworks

International policy frameworks on climate change and related issues have explicit and implicit provisions which provide foundation for exploring the opportunities for enhancing the synergy between adaptation and mitigation. Article 2 of the UNFCCC describes its ultimate objective as “stabilizing GHGs concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. The objective further states that such a level “should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner” (UNFCCC, 1992). These objectives show that both adaptation and mitigation are relevant to the international climate policy framework. Furthermore, a number of subsequent decisions made under the UNFCCC are also relevant for integrating adaptation in forest carbon mechanisms (Box 6.1).

Box 6.1 : *Mitigation and adaptation complementarity in international policy processes*

Under the UNFCCC, Decision 1/CP.16 highlights clearly that Parties must address adaptation with the same priority as mitigation. The safeguards of the Cancun agreements which were accepted by all the Parties to the UNFCCC should be protected and promoted when undertaking activities related to avoided deforestation and forest degradation. These safeguards include protecting and conserving biodiversity and ecosystem services, and enhancing other social and environmental benefits. Furthermore, Decision 9/CP.19 encourages entities financing REDD+ to provide financial resources for joint adaptation and mitigation approaches for the integral and sustainable management of forests. The Decision also recognizes the importance of promoting the delivery of non-carbon benefits which is relevant for guaranteeing the long-term sustainability of REDD+ activities. The non-carbon benefits, and the ecosystem services and the social and environmental benefits mentioned in the different decisions could be relevant for climate change adaptation.

Source : Munroe and Mant, 2014

Under the UNFCCC the only mechanism that explicitly links mitigation and adaptation is the Clean Development Mechanism (CDM). Projects in this mechanism generate carbon offsets called Certified Emission Reductions (CERs) tradable in the carbon market. A levy (share of proceed) of 2 % of CERs issued is taken to finance the Adaptation Fund. The fund is currently financing projects allowing for adaptation to climate change in developing countries. This implies, the more effective mitigation is (i.e., the CDM), the greater the funds can be expected for adaptation. An opportunity to promote the synergy between mitigation and adaptation is to oblige projects under the CDM and adaptation funds to produce both adaptation and mitigation benefits.

Photo 6.2: Competition between species is sometimes rough in the heart of tropical forests

3.2. National policy frameworks

National policies, both climatic and non-climatic can facilitate or hinder the integration of mitigation and adaptation. Currently, there is no policy framework for mitigation and adaptation synergy in the region, though actors at the national level are aware of integrated approach for mitigation and adaptation (Box 6.2). In the COMIFAC countries, mitigation and adaptation are rarely linked in national policies although in theory, national climate change mitigation policies can benefit adaptation and vice-versa. For example, under the CDM, the host country is ultimately responsible for deciding which projects are accepted. Thus, the approval of forest carbon mitigation projects with clear adaptation benefits could reduce vulnerability to climate change. Furthermore, countries in the region preparing Emission Reduction Programs for the Carbon Fund, could as well introduce the need for programs to yield adaptation benefits. On the adaptation side, national adaptation strategies could benefit mitigation through the NAPAs and Adaptation Fund projects promoting forest activities.

In terms of non-climatic policies, improving national policies regarding governance, land tenure and rights could benefit both mitigation and adaptation. For example, unclear tenure and rights indirectly contributes to deforestation (Angelsen and Kaimowitz, 1999); and at the same time tenure and rights are determinants of adaptive capacity (Adger, 2006).

Box 6.2: *Policy discourse on the links between mitigation and adaptation in the Congo Basin region.*

Integrated policy for mitigation and adaptation is one of the three main discourses on climate change in the Congo Basin. Actors in the region already had arguments for integrated strategies between adaptation and mitigation options in terms of shared meaning, ideas, interest.

Table 6.1: *Main arguments for integrated adaptation and mitigation strategies*

Discourse	Main actors	Perception
Integrated policy of adaptation and mitigation	1. Intergovernmental organizations 2. Advocacy groups 3. Civil society groups 4. Regional governments 5. Research institutes	1. Many windows of opportunity for synergy 2. Possibility of designing each to integrate the other 3. Seemingly similar institutional and legal framework for design and implementation 4. Shared policy outcome of poverty reduction, biodiversity conservation and development

Source: Somorin et al., 2012

3.3. Local/project level context

At the project level, synergy is based on the outcome of mitigation and adaptation projects where, carbon sequestration and conservation activities have potentials to produce adaptation benefits (Box 6.3), and adaptation activities also have potentials to sequestrate and guarantee the sustainability of forest carbon projects (Figure 6.2). In tropical forest countries the development of mitigation forest projects will most likely affect local communities whose livelihoods depend on forest goods and services. These mitigation activities can thus have positive (such as diversified incomes and economic activities, increased infrastructure or social services, strengthened local governance and institutions) and/or negative impacts (such as land or right deprivation, dependence on external funding) on the sustainable development of the rural poor and thus on their capacity to adapt to climate change (Murdiyarso *et al.,* 2005; Lawlord *et al.,* 2009).

The forest ecosystems in Central Africa has huge potentials for Ecosystem based Adaptation (EbA); and through EbA adaptation, projects can also directly benefit climate change mitigation, through either increasing or maintaining forests carbon stocks (Munang *et al.,* 2013). EbA includes the sustainable management, conservation and restoration of ecosystems that help people adapt to both current and future climate variability and change (Colls *et al.,* 2009).


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Photo 6.3: Despite the arrival of electricity in villages the traditional cooking is perpetuated on firewood

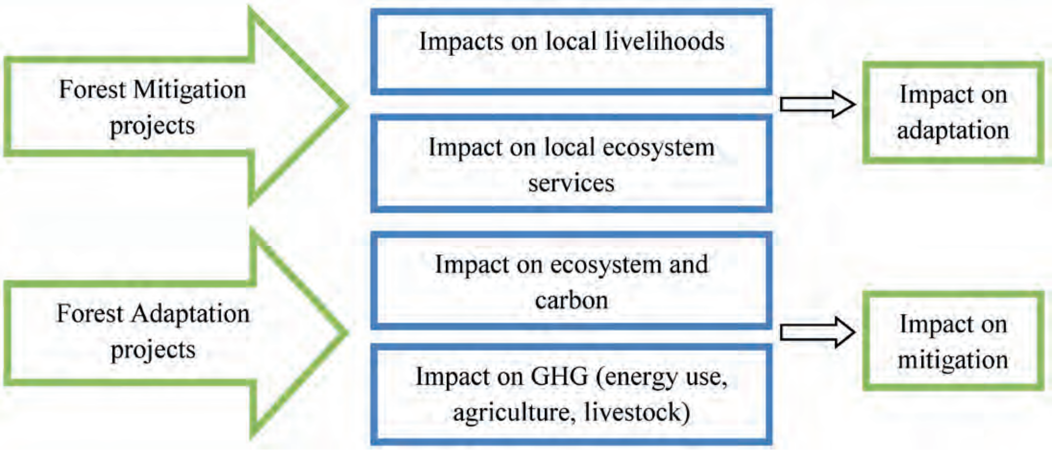

Figure 6.2: Links between mitigation and adaptation in projects

Box 6.3: *The potentials of mitigation and adaptation outcomes in Carbon Payments for Ecosystem Services (PES) projects – Case study of two community forests in Cameroon.*

The community forests, located in the Nomedjoh (Eastern Cameroon) and Nkolenyeng (Southern Cameroon) were part of a PES scheme facilitated by the Center for Environment and Development (CED). The project had as objective to generate Plan Vivo carbon certificates for the voluntary carbon markets. Although unintended, they also had potentials to provide adaptation benefits as shown in the table below.

The forests area was experiencing both deforestation and climate variability risks. Main drivers of deforestation in the project areas included the cutting down of forest to establish mixed agriculture fields for subsistence and commercial purposes. In addition, households in the project areas were also experiencing temperature changes, rainfall variability and changes in seasonal patterns.

The table 6.2 below shows how the activities and practices in project areas were evaluated in terms of their potential to enhance both carbon offsets and adaptation to climate change.

Table 6.2: *the potential of various activities and practices for adaptation and mitigation*

Activities and practices	Adaptation potential	Mitigation potential
Forest protection and regeneration - Forest reserve zoning - Patrolling and monitoring	++	++
Sustainable forest management - Increasing tree cover and enrichment planting in new, old fallows and fields - Reduced tree felling	++	++
Sustainable agriculture - Agriculture intensification; crop mixtures, new crop varieties, green manure, improve tillage and plantain propagation - Improve cocoa production; improve drying and storing techniques, introducing high yielding and disease resistant species - Improve agro-forestry; fruit trees, nitrogen fixers, community nursery for citrus and forest trees	+++	++
Alternative income and livelihood activities - Beekeeping - Livestock - Fish farming - Mushroom growing - Improve collection and marketing of NTFPs	+++	+
Knowledge and capacity building - Beekeeping and hive construction training - Training in the marketing of NTFPs - Training in sustainable agriculture practices - Training in fire management - Community awareness and training in forest protection - Knowledge in local climate variability	+++	+++
Improve governance process and institutional building - Tenure rights - Equity in access to resources - Equity in benefit sharing - Equity in decision making procedures	++	+++
Key: +: Low importance/relevance ++: Medium importance/relevance +++: High importance/relevance		

Source: Chia et al., 2014

4. Political and institutional prerequisites for synergy in Central Africa

In Central Africa, it is prudent for countries of the region to lay down ground works to take advantage of integrated mitigation and adaptation opportunities that will emerge in the near future. In this context, there is need to build institutional setups, financial mechanisms and programs and projects that will simultaneously deliver positive outcomes for mitigation and adaptation. This should consider the cross-sectorial and multi-level nature of adaptation and mitigation strategies. However, analyzing the ways to realize synergy outcomes at the policy level is about making decisions under great uncertainties (Polasky *et al.,* 2011). Kengoum *et al.* (2015) highlighted factors that support this complex uncertainty (Figure 6.3).

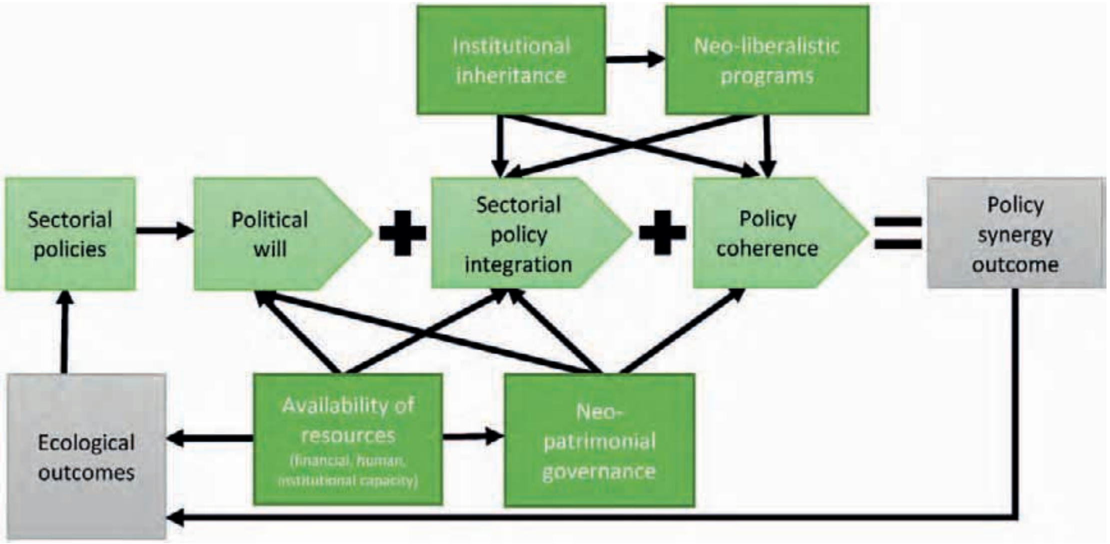

Figure 6.3 : Dependency relations among key factors and conditions in the policy process to realize synergy policy outcomes

Source : Kengoum et al., 2015

According to the dependency relations highlighted in Figure 6.3, ecological outcomes are, or need to be implemented via specific sectorial policies within the overall development framework. Assessing how integration and coherence of these sectorial policies and the role of political will contributes in overcoming structural and conjectural problems. This is of vital importance to determine the factors that hinder or enable the achievement of synergy policy outcomes, and the design of appropriate pathways for overcoming these problems (Kengoum *et al.,* 2015).

4.1. Looking beyond the forest sector for adaptation and mitigation synergy

Many policy sectors are involved as far as mitigation and adaptation are concerned. Two perspectives can be used to identify those policy sectors. The first is to take into account all the sectors contributing to GHG emissions and vulnerable to climate change. The second is to consider all the sectors that cover activities that can contribute in reducing vulnerability to climate change. Designing integrated mitigation and adaptation policies requires coordination of actions and equitable and efficient redistribution of resources among actors from the national to the local levels (Howden *et al.,* 2007 ; Challinor *et al.,* 2007). However, sufficient finance and an environment free cognitive bias due to structural or conjecture reasons is required to cover

Photo 6.4: In Burundi the natural forest, forest plantations and agriculture, often mingle

all aspects of the policy (Moser, 2012). Achieving synergy between mitigation and adaptation also requires the integration and coherence of climate policies with development policies, before attempts to delivering integrated mitigation and adaptation policy outcomes.

As far as coordination is concerned, Congo Basin countries show three patterns of politico-administrative models. First, the technical expertise principally remains within the responsibilities of governmental specialized bodies. Secondly, public and private sectors still remain separated, with no or weak collaboration. Thirdly, each aspect of the administrative machinery is exclusively attached to a specific body of the government or administration. Furthermore, overlapping mandates and multiplicity of actors across sectors and scales hamper coordination (Dkamela, 2011).

The Congo Basin countries are implementing strategies to be emergent in the short, medium and long term. Cameroon targets 2035; DRC 2030; Burundi, CAR, Chad, Republic of Congo, Gabon and Sao Tomé & Principe 2025; Equatorial Guinea and Rwanda in 2020. The strategic documents related to these development visions build on specific development sectors such as agriculture, logging, development of the mining sector, road infrastructures and hydroenergy to help promote the national economy and market development. These mostly target spaces located in forested areas, mainly the non-permanent forest estate, and could translate into shifts in land use and more GHG emissions if not managed sustainably. Thus, ongoing development paradigms place pressure on forest, and require significant policy reforms including the use of incentives such as the REDD+ mechanism.

The absence of a consistent climate change policy framework in the Congo Basin countries explains the difficulty to integrate them into the existing development frameworks of these countries as a prerequisite for synergy between mitigation and adaptation within climate policies themselves (Kengoum *et al.,* 2015). However, in the DRC climate change issues have been integrated into the national agricultural programs (PNIA). And another document drafted by both the national REDD+ committee and the ministry of agriculture provides guidance on how to reduce the impact of agriculture on forested areas. The rationale behind integration of climate concerns into agriculture policies vary from one country to another. While it is new in many of the countries in the region and mostly in relation to ongoing climate change negotiations, it is an old concern in other countries such as Cameroon where policies for a climate resilient agriculture started as early as in the 1970s, though in the non-humid forest region of the country.

4.2. Role of actors in planning and promoting synergy between mitigation and adaptation in Central Africa

Group of actors in the different countries in Central Africa have particular roles to play in order to respond to the broad policy initiative which is required for better anticipation, planning and coordination of synergy intentions. State actors are responsible for developing the government's agenda on climate change response. They have to ensure the mainstreaming and integration of mitigation and adaptation into national policies. They have to lead and increase the mobilization of financial resources to support integrated mitigation and adaptation initiatives. In addition, governments of the region through COMIFAC need to continue to influence the course of action at the international level by ensuring that negotiations stress the importance and practical approaches for integrating adaptation and mitigation.

Development partners, international and national NGOs and research institutions are actively involved in forest management in the Congo Basin forest region. They provide support to the policy process in relation to research, capacity building, advocacy, and financial assistance. With the emerging complex relationship between forest and climate change, these institutions would need to multiply their efforts. Their interventions and support could include: awareness and mobilization of efforts within the decision and policy making circle and the promotion of inter-ministerial dialogue, collaboration and networking.

Photo 6.5: The sale of charcoal is an additional income to agriculture (Rwanda)

Forest activities related to adaptation and mitigation takes place at the local level with communities as dominant players. Communities should be given the opportunity to participate in project design and implementation. This permits the identification of project activities that minimize trade-offs and enhance positive outcomes for adaptation and mitigation.

5. Emerging opportunities for Central Africa to promote mitigation and adaptation synergies within the UNFCCC

Despite the fact that current submissions to the SBSTA are not showing direct, clear and enough experience related to synergy between mitigation and adaptation, and with negotiations continuing, it is important to highlight possible entry points for mitigation and adaptation synergy, which ties with the context in Central Africa. They include the Non-Carbon Benefits and the Joint Mitigation and Adaptation Mechanism for the Integral and Sustainable Management of Forests. These two options fit into the synergy context because both mitigation and adaptation are planned and taken into consideration at the level of project and program conception, design and implementation.

5.1. Non-Carbon Benefits (NCBs)

Draft decisions for consideration and adoption by COP21 on NCBs have been recommended by SBSTA 42. Prior to the recommendation, submissions by parties and observers including the COMIFAC group of countries underscored the delivery of NCBs as important to the sustainability of REDD+ initiatives. NCBs refer to benefits which are considered part of the outcomes of REDD+ activities and associated costs and are specifically included in REDD+ design and implementation phases. Climate change adaptation has been highlighted as one of the categories of NCBs (Katerere *et al.,* 2015). This implies REDD+ projects and programs defining climate change adaptation as an NCB has to make plans for the adaptation of communities and forest ecosystems to climate risks. COMIFAC group of countries in one of their submissions proposed the need to develop a composite approach to REDD+ payments that integrates NCBs payments (Elias *et al.,* 2014). In the composite approach, NCBs (e.g. adaptation) are fully integrated into the conceptualization, design and implementation of REDD+ rather than treating them as co-benefits. It is a bottom-up approach and also falls within the UNFCCC obligations. Additional payments for NCBs are expected to be made as part of the combined results that include carbon emission reductions. MRV and payment for performance are therefore considered not only for carbon but also for non-carbon objectives and outcomes. Carbon and non-carbon objectives are treated equally at all the 3 stages of the REDD+ process. This method of making payments and incentivizing NCBs could benefit from the financial mechanisms within the UNFCCC such as the Green Climate Fund (Katerere *et al.,* 2015). It should be noted that identification and definition of NCBs might be regional and country specific and with the gap related to methodologies, COMIFAC countries need to swiftly prepare to lead in developing and proposing simple methodological guidelines and indicators of priority NCBs specific to their context.

Photo 6.6: Tali is a species widely exploited in the forests of Central Africa

5.2. Joint Mitigation and Adaptation (JMA) Mechanism for the Integral and Sustainable Management of Forests

It is an approach which is being proposed as an alternative (non-market based) to REDD+. This approach opposes the current UNFCCC framework which handles mitigation and adaptation separately, without fully considering the possibilities to embrace the integral management of forests as systems of life in order to generate sustainable conditions for the climate, people and the forests (Box 6.4). The proponent (the Plurinational State of Bolivia) of this approach argues that supporting joint mitigation and adaptation can make contributions to foster the evolution of developing countries towards pathways of social and environmental sound rural development by strengthening local resource use and management practices of forests and other land uses in forests landscapes (such as in community forests management, agroforestry, forest gardens, smallholder tree planting, etc) without compromising the role of the forest in the provision of multiple ecosystem services and livelihood support for forest-dependent communities.

This approach is appealing for Central Africa because it builds on the principles of Sustainable Forest Management (SFM), which is a management system already being practiced in forests and land use in Central Africa.

Box 6.4: *Looking at mitigation and adaptation as inseparable through JMA*

JMA is argued to lead to the following. First, it will strengthen forest governance; improve integrated management of forest and biodiversity, sustainable use of forests, agriculture and livestock production systems. Second, it will create conditions to minimize risk and the vulnerability of ecosystems and peoples to take advantage of opportunities with implications for adaptation. Third, the JMA approach is oriented to maintain environmental functions of forests which include carbon emission reductions, which can only be generated in a sustainable manner through the adaptation of forests and peoples living in forests. In this light, mitigation and adaptation are seen as integrated efforts resulting from the integral and sustainable management of forests.

Source: UNFCCC, 2015a.

The JMA implementation framework takes into consideration the following steps. Firstly, it considers the preparation of national proposals which includes the potential role of forests for mitigation and the assessment of vulnerability at the forest sector and territorial levels. And the identification of financial needs to address adaptation options in the JMA process. Secondly, it proposes *ex ante* financial agreements, which is an agreement between the UNFCCC through the Green Climate F und, and the national body in charge of operationalizing the JMA regarding the objectives to be achieved for both adaptation and mitigation. Thirdly, at the level of implementation proper, the JMA proposes the financing of multiple activities related to SFM. Lastly, the framework proposes monitoring and evaluation of mitigation and adaptation, in which the monitoring of mitigation is undertaken considering proxies for assessing tons of carbon absorbed or emitted by forest and adaptation is monitored using existing vulnerability assessment methods (UNFCCC, 2015b).

Photo 6.7: Order prevails in the logyard of the company SIFCO Congo

Conceptually the JMA appears alluring, though extra effort might be required to develop a detailed clear and technical framework in relation to the operationalization, coordination and financing at the international and national levels. Progress in these aspects should consider the national strategies, priorities and capacities of developing countries.

6. Challenges and way forward for synergy between adaptation and mitigation in Central Africa

There is a growing interest of the international community to support joint mitigation and adaptation efforts. There are also a growing number of actors, encouraging and promoting mitigation and adaptation efforts in the Congo Basin in different contexts. For example, the African Development Bank (AfDB), the COMIFAC via the PACEBCo, research institutions such as CIFOR via the COBAM and GCS projects, and others such as the African Network of Model Forests (RAFM), UEFA in DRC, the ROSE in Cameroon, ARECO in Rwanda, and INDEFOR in Equatorial Guinea. However, despite initiating activities that promote joint mitigation and adaptation outcomes, these projects do not always fit into clear national climate policy frameworks.

Challenges in integrating mitigation and adaptation policies in the Congo Basin are mostly governance based. Climate and forest matters are cross-sectorial and this is in contrast with the ongoing sectorial approach in their governance as observed in Cameroon and DRC. In the current state of governance fragmentation, integrating mitigation and adaptation is more challenging and resource intensive, than just implementing both mechanisms separately (Kengoum *et al.*, 2015). However, resource wise, mitigation and adaptation are mostly financed by international organizations, with a very low contribution from local governments and there seem to be no existing finance for producing joint mitigation and adaptation policy outcomes despite the urgent need.

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Photo 6.8: The umbrella trees are scattered along the forest road between Enyelé and Bétou in Congo

Congo Basin countries are still experiencing neo-patrimonial governance that hinders coordination across sectorial ministries could be a stumbling block for climate change response. Furthermore, the cumbersome nature of governmental procedures observed in some countries in the Congo Basin could also be a challenge for progress in climate response e.g. in Cameroon and DRC (Kengoum *et al.,* 2015).

As an opportunity for COMIFAC countries, options for exploring the synergy between adaptation and mitigation need to be explicitly introduced into ongoing and future market and non-market climate change mechanisms. In this light, present and post 2015 negotiations should continuously give space for dialogue on how best synergy options can be pursued. There is need to speed-up efforts in terms of governance, methodological and technical issues, to fill the gap of the current lack of experience on integrated mitigation and adaptation activities. Sourcing finance and funding holistic and sustainable pilot initiatives in the region may be useful to experience and generate lessons learned.

CONCLUSIONS

The forests of Central Africa: abundant resources, uncertain future

An abundant and diverse resource base to contribute to global climate regulation

Central Africa is covered by more than 2,870,000 km^2 of forests, including humid and dry forests altogether. The dense humid forests stretch from the Gulf of Guinea to the Rift Valley, on more than 1,700,000 km^2. These forests are uneven and include various forest types which present specific issues in terms of exploitation and conservation. The most diverse and the ones with the higher levels endemism are the forests bordering the Gulf of Guinea and the ones of the Albertine Rift.

Forests in Sub-Saharan Africa account for 10 to 20 % of global plant carbon stock and about 46 billion metric tons of carbon are stored in the Congo Basin countries (Nasi *et al.*, in de Wasseige *et al.* (2009). Dense evergreen lowland forests represent 60 % of this amount while only covering 35 % of the area. Biomass studies at the scale of the whole Congo Basin are on-going (Shapiro and Saatchi, 2014) and will specify previous analyses performed at a global scale (Saatchi *et al.*, 2011).

Forests as a life support system in Central Africa

Forests offer many functions beyond carbon sink and storage, or timber production, what is usually referred to as "ecosystem services" such as production of Non Timber Forest Products (NTFP), soil erosion and siltation control, water quality or local climate regulation, etc. These services are of paramount importance with regard to the subsistence of certain populations and their livelihood, and bring some diverse sources of revenue at local and national level.

The forests of Central Africa provide subsistence means to 60 million people who live either inside or in the vicinity of the forests. They also fulfil social and cultural functions essential to local and indigenous populations, and contribute to feed 40 million people who live in the urban centres close to these forest areas (Nasi *et al.*, 2011; de Wasseige *et al.*, 2014). In the case of Cameroon, for example, bush meat represents an economic value estimated at 80 billion CFA (about 122 million Euros) per annum (Lescuyer, 2014). In addition to their contributions to community livelihoods, forests of Central Africa contribute substantially to national economies of countries in the sub-regions. In Gabon for example, the timber sector is the second most important provider of employments after the State. In the Republic of Congo it is often the unique source of salaried jobs in remote rural areas and, in Cameroon, it is estimated that the forestry sector contributes at 4 % to the Gross Domestic Product (Eba'a Atyi *et al.*, 2014).

Threats to the forests of Central Africa

Forests of the region have so far been relatively well protected thanks to low demographic pressure reinforced by rural exodus, difficult access, absence of transport and communication infrastructure, and a business climate very little conducive to long term investments (Burgess *et al.*, 2006; Megevand *et al.*, 2013). Available studies give an annual net deforestation rate of 0.14 % for the humid dense forest of Central Africa between 2000 and 2010, with a higher rate for dry forests during the same time period (about 0.40 %).

However, current policy programmes defined by Central Africa States aim at economic emergence between 2025 and 2035. These programmes are based upon the continuation of natural resources exploitation (wood, oil, and minerals), agricultural production for domestic needs and exports, as well as the strengthening of industrial processing activities. Social and political stability prevailing over the last decade in certain countries of the sub-region has allowed the development of large-scale road infrastructure, power supply in the main urban areas and counties, and an improvement in the business climate. Added to this context, the rise in the price of minerals and agricultural products in the international market place in the early 2000s have acted like investment incentives.

At present, small-scale agriculture and to a lesser extent the harvest of fuelwood are considered the main drivers of deforestation in the Congo Basin (Defourny *et al.*, 2011) but projects for large scale agribusiness plants are developing in various countries and may become more and more important in the future.

An emerging threat to the forest of Central Africa consists of mining. Many mining exploration permits have been granted by the Central African countries and such permits concern large areas of rainforests already granted to logging companies, to communities or simply reserved as conservation areas, favouring the emergence of land use and resource use conflicts.

Additionally, logging still represents a noticeable driver of deforestation and forest degradation in the Congo Basin. Currently, 49 million hectares of forests have been allocated as forest concessions in the area. If those concessions should be sustainably managed, they are not under the threat of deforestation but remain under the threat of forest degradation. However, one must admit that the bulk of forest exploitation in the Congo Basin countries is not conducted according to sustainable management rules as of today. In the whole region, 40 % of concessions are under management plans but it is necessary to reach 100 % in the medium run.

In obvious contrast to the trend towards sustainable forest management, the whole forest is, at various levels, prone to illegal logging which, depending on the country, can cause some degradation or even deforestation of greater magnitude when compared with legal exploitation.

Vulnerability of human communities and forest ecosystems

The socio-economic sectors and livelihoods of central African countries and its populations present different abilities to react to climate stimuli. Furthermore, they are highly dependent on the surrounding ecosystems that constitute a significant proportion of the gross domestic product of the countries. This implies that, depending on the health and the resilience capacity of the ecosystems, climate change might jeopardize the successful implementation of any sustainable economic and national development plans. Furthermore, climate change may constrain countries in the region to realize global targets such as the Sustainable Development Goals (SDGs).

Projections towards the 21st century show that temperatures, evapotranspiration and precipitation might slightly increase on the whole region, but also that various parts of Central Africa might react differently. Studies on climate and hydrology have shown that, since the 70s and 80s, water discharge of equatorial rivers do not show any clear trend while tropical rivers seem to decrease and Sahelian river discharges tend to increase. The impacts of climate change will also be very different according to the magnitude of human activities, namely deforestation and ecosystems degradation or pollution.

Water and temperature regimes condition agricultural production. This is particularly important in Africa where subsistence agriculture predominates and smallholders produce about 80 % of the food consumed (AGRA, 2014). As such, crop production is mostly rain-fed, and technologies to control temperature (such as greenhouses) are not yet widely applied. Projected variability across zones indicates that the northern sahelian zone will be less prone to drought with increases in agricultural production. However, in the central region, increases in water might be such that they can lead to floods damaging crops. In the southern zones agricultural production will start decreasing halfway the century, due to changing evapotranspiration balances, being prone to droughts as well (CSC, 2013). In addition, changes in humidity will influence nutrient availability, and impacts of pest and diseases (de Wasseige *et al*., 2014).

Another important sector that might be affected is health. It is recognized that climate change is a direct (insufficient access to safe water and improved sanitation, food insecurity) and indirect (limited access to health care and education) multiplier of existing health vulnerabilities (IPCC, 2014). Changing temperature and precipitation patterns will impact health due to malnutrition, diarrheal diseases, and malaria and other vector-borne diseases. Malnutrition problems could be tackled in the northern part of the region due to increased agricultural production, but diarrheal diseases, malaria and water-borne diseases could further affect throughout the region due to increased temperatures and floods. Health is especially vulnerable in context of poor healthcare systems combined with poor governance and lack of infrastructure.

Policy and management responses to threats

The importance of tropical forests of the Congo Basin has gradually given these ecosystems the value of a world common asset and many multilateral agreements address today the management and conservation of these ecosystems in partnerships with the states of the region.

Adapting to climate change

All the countries of the Central Africa region are parties to the UNFCCC, which underscores their interest to provide policy response to combat climate change. Their efforts are stated through the UNFCCCs National Communications (NCs) and the National Adaptation Program of Action (NAPA) initiatives. NCs highlight vulnerable sectors and potential measures to facilitate adaptation to climate change. The NAPA initiative tailored for Least Developed Countries (LDCs) is relevant for some countries of the Central African region, where they have made attempts to identify priority areas and activities that respond to their urgent needs related to climate change adaptation.

At the regional level, the COMIFAC, with support from national and international governmental organizations, national and international non-governmental and research institutions, is making attempts to propel the adaptation agenda and climate change response in general. In its recent 10-year (2015-2025), convergence plan, the fight against climate change is included as one of the priority areas.

Almost all COMIFAC countries have submitted the first and second NCs and NAPAS, with Gabon to be the first to complete the Intended Nationally Determined Contribution (INDC) including a chapter on adaptation. Eligible COMIFAC LDCs countries have submitted a total of about 70 projects cutting across different sectors and levels. A limited number of these projects (9 %) explicitly take into consideration adaptation for forest and the role of forest for the adaptation of local communities (UNFCCC, 2015d). This might be due to the fact at the time of developing NAPA priority projects, COMIFAC countries had limited information and knowledge on the vulnerability of forest ecosystems to climate change and the role of forests for adaptation.

Contributing to climate change mitigation

Mitigation of climate change has been approached by three main sets of policies and measures in Central Africa. These include, the adoption of sustainable forest management techniques, the improvement of forest governance and the current engagement in the REDD+ process.

Sustainable forest management (SFM) may at first glance not have the same climate change mitigation potential as classical REDD+ projects (because SFM still entails timber extraction, building of forestry roads, etc.) and it is often overlooked in Central Africa. Nevertheless, preliminary analyses conducted in some countries suggest that the implementation of SFM over 20 million hectares of forest concessions has the potential to reduce emissions by more than 35 million tCO_2eq over a period of 25 years. Furthermore, the implementation of Reduced Impact Logging (RIL) might reduce gross carbon emissions from logging concessions by 1.3 million tCO_2eq/year.

Recent development **in forestry governance** should also contribute to climate change mitigation although there exist no available attempts to quantify such contributions. Fighting illegal deforestation – as defined by the developing country's own laws – can be seen as a key part of any carbon emission reduction strategy from the forestry sector. Therefore countries of Central Africa that have embarked in improving forest governance have put themselves in a positive momentum for the reduction of forest based emissions. Nevertheless, difficulties to control the informal forestry sector are still big challenges for all countries.

The Congo Basin forests are the second largest area of rainforests globally, and hence potentially represent a "prime location" **for implementing REDD+**. Although countries of Central Africa are at different stages in the implementation of the REDD+ process, about all of them find themselves locked in the first phase (readiness phase) as described in Chapter 5 above. The most advanced is certainly the DRC that is between the completion of phase 1 (readiness) and the beginning of phase 2 (investment) and has put in place a number of demonstration projects.

Pending challenges

Obstacles that have prevented effective and efficient climate policies implementation in Central Africa are mostly linked to the underlying political economy of deforestation and forest degradation in a context of often weak (forest) governance, existing multilevel and multisectoral coordination challenges, and competitive national development objectives (Martius 2015). However, problems with scale, measurement, reporting and verification (MRV), and social safeguards are also relevant.

International support

If the world is committed to reduce land-based emissions, efforts may be needed to support this goal that go far beyond the current endeavors and are much more encompassing than narrowly focusing on climate policies. At the global level, REDD+ discourses emphasize carbon sequestration and avoided emissions from land-use change as the principal benefit, while forest contributions to livelihoods, biodiversity, institutional improvement; other ecosystem services are externalized as co-benefits. The emphasis reverses at the local level. For local actors — smallholders, communities and decision-makers — the main expected benefits of REDD+ are often cash income or other livelihoods benefits, better infrastructure and services or a palpable increase in indicators of development. Mismatched expectations are shaped by power relations and have slowed the pace of progress in REDD+ negotiations and implementation. This is a powerful argument for emphasizing poverty alleviation and sustainable development goals over climate goals if REDD+ is to be implemented with reasonable expectations for success.

One of the most important challenges that have to face the Central African countries is to meet their development goals while taking into account the constraints climate changes and their commitments related to the global environment. This will be effective only if these countries have access to clean and efficient technologies related to carbon emissions.

Necessary financial support

Climate change adaptation is a financial burden for countries in the Central Africa region (Somorin *et al.*, 2012). It is important to note that, globally it is unclear whether sufficient funds will be available to address the adaptation needs of developing countries which threatens to surpass US$50 billion per year after 2020 (Smith *et al.*, 2011). COMIFAC States have accessed and benefited differently from the adaptation fund under the UNFCCC framework (chapter 4). Many opportunities are still available, highly dependent on the countries' capacities to propose adaptation projects. Apart from the funding sources under the UNFCCC framework, other policy and funding options relevant for Central African countries include multilateral and bilateral assistance through development banks and overseas Development Assistance (ODA).

Regional and national coordination

The major challenge for the COMIFAC countries is to develop climate change adaptation strategies for the transboundary forest system, without endangering the integrity for these forests to ensure the continuous provision of ecosystem goods and services critical for community livelihoods, national development and the economic growth of the region. A certain level of progress has been achieved concerning regional coordination of mitigation initiatives, and particularly REDD+ for which COMFAC has established a consultation mechanism for UNFCCC negotiators of member countries. In addition COMIFAC is implementing regional projects focusing on REDD+ capacity building.

At the national level of individual countries, the policy and institutional processes are still characterized by limited coordination, weak institutional linkages and lack of coherence between sectoral policies (Kengoum, 2013; Dkamela, 2011).

Mainstreaming climate change in development policies

In the context of the Central Africa region, the challenge for adaptation in the climate change policy process might be easier to overcome due to the strong links between climate vulnerability and poverty and development strategies. Development and poverty reduction are priority areas for countries in the COMIFAC space. Thus, this should be used as an opportunity for adaptation, by integrating adaptation strategies into current development plans and poverty reduction strategies (Sonwa *et al.*, 2012b).

In the other hand, REDD+ will remain a viable option for countries if they manage to do three things: 1) they need to embed REDD+ in the broader context of development policies; 2) they need to develop other, non-market based mechanisms that reduce pressure on forests and forest resources; 3) they need to engage in broad policy reform which need to take into account climate challenges in all sectors.

Need for stronger information and knowledge basis

At present, there is insufficient knowledge on regional climate change patterns, unknown quality, quantity, and spatio-temporal pattern of risk occurrence and the lack of clear adaptation possibilities. There is a real need to enhance climate change information generation and its delivery through the improvement of climate change information infrastructure e.g. weather/meteorological stations and technology, and information centralization, delivery and sharing services. There is a need to move from cross-continental analysis to sub-regional and national, since the ecological and socio-economic settings vary greatly across countries.

Capacity gaps

There is a need to build capacities and to strengthen institutional networks both at the level scientific and technical competences as well as policy-making, at the level of implementation of both mitigation and adaptation strategies. REDD+ MRV systems need to be designed based on each country's characteristics and capacities. Countries with good capacities could play a larger role through regional bodies such as COMIFAC on that matter.

On sustainable forest management

Lessons learned from early mitigation initiatives indicates that significant progress has been made on SFM in Central Africa for the last 20 years, due to a number of factors that include (i) the political will from governments of the COMIFAC member countries, (ii) the engagement of the private sector encouraged by market tools such as forest certification to meet demand from environment sensitive timber products markets and (iii) the involvement of the donor community that provided support both to national government and private sector enterprises. These efforts should be continued through the evolvement of management plans and the integration of this SFM approach into the multiple use of forests.

Looking forward

In the advent of climate change responses, institutions involved in policy development and implementation need to revise, change and take on new roles to be in a position to facilitate and enforce new policies, become flexible and able to learn and adapt to the changing human-environmental system which is characterized by uncertainty (Locatelli *et al*., 2008). First, state agencies should be responsible for mainstreaming adaptation and mitigation into national policies, sourcing financial resources and influencing and coordinating the course of action at the international, national and local levels. Second, non-state agencies which include national and international NGOs and research organizations should provide support related to awareness raising, mobilization of efforts, promotion of inter-ministerial dialogue, collaboration, networking, knowledge generation and capacity building (Chia *et al*., 2014).

In this context, it is argued that climate change adaptation should be factored in all development assistance that are climate sensitive (Huq and Burton, 2003). Thus, coordinating the two funding streams at the national and international levels may provide more effective support for both sustainable development goals and climate change adaptation. This approach is crucial for COMIFAC countries.

Future climate change and forest vulnerability is characterized by uncertainty and the dynamics of human-environmental systems. Thus, policy and institutional approaches should be diverse, flexible, adaptive and continuous to take advantage of new knowledge and insights (Bele *et al*., 2014). Building policy-science dialogue is necessary. Findings generated by rigorous research should be transformed into policy relevant language and put into the policy process. Science should inform decision makers about assessing vulnerabilities, identifying response options and designing adaptation strategies. Decision makers in the region need frequently updated information and knowledge to support regional and national positions on climate change adaptation (Tiani *et al*., 2015).

Ecosystem-based adaptation (EbA) is defined as "the use of ecosystems to support societal adaptation through their management, conservation, and restoration to provide services that enable people to adapt to the impacts of climate change. It aims both at increasing the resilience and reducing the vulnerability of ecosystems and people in the face of climate change" (UNEP, 2009). EbA strategies range from sustainable water management for water storage, flood regulation and coastal defenses, disaster risk reduction through tree cover, sustainable and ecologically intensive agriculture using locally available genetic resources, etc. (de Wasseige *et al.,* 2014). Ecosystem-based adaptation appears as a cost-effective option with significant social, economic and environmental co-benefits (UNEP, 2009). Furthermore, in a region with high mitigation potential the donors concentrate their focus on carbon conservation, with adaptation financing focusing on arid and semi-arid regions. Finally, EbA is more accessible to the rural poor than infrastructure and engineering-based adaptation. With a 54 % the total population living in rural areas in Central Africa, EbA seems as a likely alternative (UN, 2015).

Since government cannot count solely on external funding, no-regrets adaptation is advised :

- Increase climate change adaptation in the national and regional policy spaces, by raising policy and public awareness on climate change, and reflecting on the need for adaptation
- Harness the regions carbon potential not only for climate change mitigation, but for achieving sustainable economic growth, poverty reduction and climate change adaptation.
- Balance the interest of multiple stakeholders when setting priorities intended to achieve the national economic growth, environment and social sustainability objectives.
- Improve ecological safety nets in forests so that valued resources are more resilient to climate variability and change.
- Improve science-policy dialogue, with a broad public participation (Nkem *et al.*, 2008).

The notion of designing and implementing climate change response policies and projects that produce simultaneous positive outcomes for mitigation and adaptation is gaining grounds in the national and international research and decision making agendas (Elias *et al.*, 2014). In the Congo basin countries, there is urgency for both mitigation and adaptation. First, the forest ecosystems of the Congo basin are pertinent for the global carbon balance through their huge carbon sequestration and storing potential. Second, the forests and forest dependent communities could be impacted by climate change. In this light the design and implementation of adaptation policies and projects cannot be avoided. Thus, planning to design and use the same strategy and policy package for positive mitigation and adaptation outcomes is critical for the region.

There are a growing number of actors, encouraging and promoting mitigation and adaptation efforts in the Congo Basin in different contexts. For example, the African Development Bank (AfDB), the COMIFAC via the PACEBCo, research institutions such as CIFOR via the COBAM and GCS projects, and others such as the African Network of Model Forests (RAFM), UEFA in DRC, the ROSE in Cameroon, ARECO in Rwanda, and INDEFOR in Equatorial Guinea. However, despite initiating activities that promote joint mitigation and adaptation outcomes ; these projects do not always fit into clear national climate policy frameworks.

Challenges in integrating mitigation and adaptation policies in the Congo Basin are mostly governance based. Climate and forest matters are cross-sectorial and this is in contrast with the ongoing sectorial governance approach. In the current state of governance fragmentation, integrating mitigation and adaptation is more challenging and resource intensive, than just implementing both mechanisms separately (Kengoum *et al.*, 2015). However, resource wise, mitigation and adaptation are mostly financed by international organizations, with a very low contribution from local governments and there seem to be no existing finance for producing joint mitigation and adaptation policy outcomes despite the urgent need.

Congo Basin countries are still experiencing neo-patrimonial governance that hinders coordination across sectorial ministries and could be a stumbling block for climate change response. Furthermore, the cumbersome nature of governmental procedures observed in some countries could also be a challenge for progress in climate response, such as in Cameroon and DRC (Kengoum *et al.*, 2015).

As an opportunity for COMIFAC countries, options for exploring the synergy between adaptation and mitigation need to be explicitly introduced into ongoing and future market and non-market climate change mechanisms. In this light, present and post 2015 negotiations should continuously give space for dialogue on how best synergy options can be pursued. There is need to speed-up efforts in terms of governance, methodological and technical issues, to fill the gap of the current lack of experience on integrated mitigation and adaptation activities. Sourcing finance and funding holistic and sustainable pilot initiatives in the region may be useful to experience and generate lessons learned.

BIBLIOGRAPHY

Adaptation Fund. 2015. Projects and Programs. https://www.adaptation-fund.org/funded_projects/interactive.

Adger W. N., 2006. Vulnerability. Global Environmental Change, 16, 268-281.

AECID, 2005. Plan Director de la Cooperación Española 2005-2008. Madrid, España, AECID: 123 p.

Aerts J., Renssen H., Ward P. J., de Moel H., Odada E., Bouwer L. M. and Goosse H., 2006. Sensitivity of global river discharges under Holocene and future climate conditions. Geophysical Research Letters 33, L19401. doi:10.1029/2006GL027493

AGRA, 2014. Africa agriculture status report: Climate change and smallholder production in sub-Saharan Africa. Nairobi, Kenya. 218.

Agrawal A., 2010. Local institutions and adaptation to climate change. In *Social dimensions of climate change: Equity and vulnerability in a warming world. 2010.* Mearns R. and Norton A. Washington DC, USA: World Bank Publications. pp. 173-198.

Aguilar E., Barry A.A., Brunet M., Ekang L., Fernandes A., Massoukina M.,Mbah J., Mhanda A., do Nascimento D.J., Peterson T.C., Umba O., Tomou M. and Zhang X., 2009. Changes in temperature and precipitation extremes in western central Africa, Guinea Conakry, and Zimbabwe, 1955-2006. In: Journal of Geophysical Research-Atmospheres, 114, D02115, doi: 10.1029/2008JD011010.

Akkermans T., Thiery W. and Van Lipzig N.P.M., 2014. The Regional Climate Impact of a Realistic Future Deforestation Scenario in the Congo Basin. J. Clim. 27, 2714–2734.

Allen C.D., Macalady A.K., Chenchouni H., Bachelet D., McDowell N., Vennetier M., Kitzberger T., Rigling A., Breshears D.D., Hogg E.H., Gonzalez P., Fensham R., Zhang Z., Castro J., Demidova N., Lim J.-H., Allard G., Running S.W. Semerci A., Cobb N., 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 259: 660-684.

Angelsen A. and Kaimowitz D., 1999. Rethinking the causes of deforestation: lessons from economic models. The World Bank research observer, 14, 73-98.

Angelsen, A., Brockhaus M., Kanninen M., Sills E., Sunderlin W.D., Wertz-Kannounikoff S., 2009. Realising REDD+ national strategy and policy options http://www.cifor.org/online-library/browse/view-publication/publication/2871.html. Introduction, pp. 1-9

Angelsen, A., Brockhaus M., Sunderlin W.D. and Verchot L., 2012. Analysing REDD+: Challenges and choices. http://www.cifor.org/online-library/browse/view-publication/publication/3805.html.

Arnell N.W., 2003. Effects of IPCC SRES emissions scenarios on river runoff: a global perspective. Hydrology and Earth System Sciences 7, 619–641

Assembe-Mvondo S., Brockhaus M. and Lescuyer G., 2013. Assessment of the Effectiveness, Efficiency and Equity of Benefit-Sharing Schemes under Large-Scale Agriculture: Lessons from Land Fees in Cameroon. Eur J Dev Res 25, 641–656. doi:10.1057/ejdr.2013.27

Assembe-Mvondo S., Eba'a Atyi R. et Lescuyer, G. Impacts du régime REDD+ sur les politiques de gestion durable des forêts en Afrique centrale. FORAFAMA study report. CIFOR. Yaoundé. Cameroun.

Baccini AGSJ., Goetz S. J., Walker W. S, Laporte N. T., Sun M., Sulla-Menashe D., Hackler J., Beck P. S. A., Dubayah R. and Friedl M. A., 2012. Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. *Nature Climate Change*. Vol. 2, n°3, p. 182-185.

BAD, 2009. Document cadre sur l'utilisation du fonds spécial CLIMDEV-Afrique (FSCD). Département Agriculture et Agro-Industrie, 22p.

Balas N., Nicholson S.E. and Klotter D., 2007. The relationship of rainfall variability in West Central Africa to sea-surface temperature fluctuations. Int. J. Climatol. 27: 1335–1349.

Bele M. Y., Somorin O., Sonwa D. J., Nkem J. N. and Locatelli B., 2011. Forests and climate change adaptation policies in Cameroon. *Mitigation and Adaptation Strategies for Global Change*, 16(3), 369-385. DOI 10.1007/s11027-010-9264-8

Bele M. Y., Sonwa D. J. and Tiani A. M., 2013. Supporting local adaptive capacity to climate change in the Congo Basin forest of Cameroon: a participatory action research approach. *International Journal of Climate Change Strategies and Management*, 5(2), 181-197. DOI 10.1108/17568691311327587

Bele M.Y., Sonwa D.J. and Tiani A.M., 2014. Local Communities Vulnerability to Climate Change and Adaptation Strategies in Bukavu in DR Congo. *The Journal of Environment & Development* 23 : 331. DOI 10.1177/1070496514536395

Bele M. Y., Sonwa D. J. and Tiani A.M., 2015. Adapting the Congo Basin forests management to climate change : Linkages among biodiversity, forest loss, and human well-being. *Forest Policy and Economics*, **50** 1-10. DOI 10.1016/j.forpol.2014.05.010

Bernard F., De Groot R. S. and Campos J. J., 2009. Valuation of tropical forest services and mechanisms to finance their conservation and sustainable use : A case study of Tapantí National Park, Costa Rica. *Forest Policy and Economics*. Vol. 11, n°3, p. 174-183.

Beyene T., Ludwig F. and Franssen W., 2013. The potential consequences of climate change in the hydrology regime of the Congo River Basin. *In : Climate Change Scenarios for the Congo Basin.* Haensler A., Jacob D., Kabat P., Ludwig F. Climate Service Centre Report No. 11, Hamburg, Germany, ISSN : 2192-4058

Bigot S., 1997. Les précipitations et la convection profonde en Afrique centrale cycle saisonnier, variabilité interannuelle et impact sur la végétation, Dijon, Université de Bourgogne, Thèse de doctorat, 283 p.

Billand A., 2012. Biodiversité dans les forêts d'Afrique centrale : panorama des connaissances, principaux enjeux et mesures de conservation. Dans : *Les forêts du Bassin du Congo : Etat des Forêts 2010*. Luxembourg : Office des publications de l'Union européenne, 2012. 274 p. ISBN : 978-92-79-22717-2. p. 63-94.

Biwole A., Morin-Rivat J., Fayolle A., Bitondo D., Dedry L., Dainou K., Hardy O.J. and Doucet J.-L., 2015. New data on the recent history of the littoral forests of southern Cameroon : an insight into the role of historical human disturbances on the current forest composition. Plant Ecology and Evolution 148(1) : 19–28.

Bodin B., Ravilious C., Mant R. et Bastianelli C., 2014. *Les synergies entre la REDD+ et les objectifs d'Aichi pour la biodiversité en Afrique Centrale – L'apport de l'analyse spatiale pour la planification conjointe de deux engagements internationaux sur les forêts*. Cambridge : UNEP-WCMC.

Bonell M., 1998. Possible impacts of climate variability and change on tropical forest hydrology. Climatic Change, 39, 215-272.

Bouyer O., Gachanja M., Pesti B., Fach E. and Gichu A., 2013. Carbon rights and benefit-sharing for REDD+ in Kenya. Kenya REDD+ analytical series, Issue #2. UN-REDD Program and Ministry of Environment, Water and Natural Resources.

Bowen-Jones E., Brown D. and Robinson E., 2002. Assessment of the solution-orientated research needed to promote a more sustainable bushmeat trade in Central and West Africa. *DEFRA, London*. p.127.

Boyer J.F., Dieulin C., Rouché N., Crès A., Servat E., Paturel J.E. and Mahé G., 2006. SIEREM : an environmental information system for water resources. In : *Water Resource Variability : Processes, Analyses and Impacts*. Proc. of the 5th FRIEND World Conference, La Havana, Cuba, IAHS Publ. 308 ; 19-25.

Brou Yao T., 1997. Analyse et dynamique de la pluviométrie dans le sud forestier ivoirien : recherche de corrélations entre les variables climatiques et les variables liées aux actions anthropiques. Thèse de doctorat de l'Université de Cocody, 211 p.

Brown S., Pearson T., Moore N., Parveen A., Ambagis S. and Shoch D., 2005. Impact of selective logging on the carbon stocks of tropical forests : Republic of Congo as a case study. Deliverable 6 : Logging Impact on carbon stocks, Report submitted to United States Agency for International Development, Cooperative Agreement No. EEM-A-00-03-00006-00.

Brown H.C.P., Smit B., Sonwa O.A. and Nkem J., 2011. Institutional perceptions of opportunities and challenges of REDD+ in the Congo Basin. Journal of Environ-ment and Development 20 (4), 381–404.

Brummett R., Tanania C., Pandi A., Ladel J., Munzimi Y., Russell A., Stiassny M., Thieme M., White S. et Davies D., 2009. Ressources en eau et biens et services liés à l'écosystème forestier. Dans : Les *forêts du Bassin du Congo : Etat des Forêts 2008*. Luxembourg : Office des publications de l'Union européenne, 2009. 425 p. ISBN : 978-92-79-13211-7

Brunsell N.A. and Anderson M.C., 2011. Characterizing the multiscale spatial structure of remotely sensed evapotranspiration with information theory. Biogeosciences 8, 2269–2280.

Burgess N. D., Hales J. A., Ricketts T. H. and Dinerstein E., 2006. Factoring species, non-species values and threats into biodiversity prioritisation across the ecoregions of Africa and its islands. *Biological Conservation*. Vol. 127, n°4, p. 383-401.

Byerlee D., Stevenson J. and Villoria N., 2014. Does intensification slow crop land expansion or encourage deforestation ? *Global Food Security*. Vol. 3, n°2, p. 92-98.

Cadet D.L. and Nnoli N.O., 1987. Water vapour transport over Africa and the Atlantic ocean during summer 1979. Quart. J. Roy. Met. Sci., 113, 581-602.

Camberlin P., 2007. In : L'Afrique centrale, le Cameroun et les changements globaux. Presses Universitaires d'Orléans P 83-95

Challinor A.J., Wheeler T.R. and Garforth C., 2007. Assessing the vulnerability of food crop systems in Africa to climate change. Climate Change, 8, 381–399.

Chapman S., Wilder M., Millar I. and Dibley A., 2015. Implementing REDD+ Under the UNFCCC : Basic Requirements and Guidance for Developing National Policy and Legal Frameworks. CCLR (2). PP : 101-112.

Chia E.L., Somorin O.A., Sonwa D.J., Bele Y.M. and Tiani A.M., 2014. Forest–climate nexus : linking adaptation and mitigation in Cameroon's climate policy process. *Climate and Development,* 7(1) : 85-96. DOI 10.1080/17565529.2014.918867

Ciais P., Sabine C., Bala G., Bopp L., Brovkin V., Canadell J., Chhabra A., DeFries R., Galloway J. et Heimann M., 2014. Carbon and other biogeochemical cycles. Dans : *Climate Change 2013 : The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, p. 465–570.

CIFOR, 2007. *Forests in post-conflict Democratic Republic of Congo : analysis of a priority agenda*. Bogor, Indonesia : CIFOR, 82 p. ISBN : 979-24-4665-6.

CIFOR, 2014a. Climate change and low emissions development on the ground. Background Brief. Forests Asia Conference. http ://www.cifor.org/forestsasia/wp-content/uploads/files/ForestAsia_Brief-Theme3_web.pdf

CIFOR, 2014b. CIFOR Research Priorities 2015. CIFOR, Bogor, Indonesia.

Colls A., Ash N., Ikkala N. and Conservancy N., 2009. Ecosystem-based Adaptation : a natural response to climate change. Gland. Switzerland, IUCN. 16 p.

Corbeels M., de Graaff J., Ndah T. H., Penot E., Baudron F., Naudin K., Andrieu N., Chirat G., Schuler J. and Nyagumbo I., 2014. Understanding the impact and adoption of conservation agriculture in Africa : a multi-scale analysis. *Agriculture, Ecosystems & Environment*. Vol. 187, p. 155-170.

Cotula, L., and Mayers, J., 2009. Tenure in REDD – Start Point or Afterthought. London : IIED.

CSC, 2013. Climate Change Scenarios for the Congo Basin. Climate Service Centre Report No. 11. Eds, Haensler A., Jacob D., Kabat P. and Ludwig F. Hamburg, Germany. 212 p. ISSN : 2192-4058

Daviet F., 2009. Legally REDD : Building readiness for REDD by supporting developing countries in the fight against illegal logging. WRI working Paper. World Resources Institute, Washington DC.

De Noblet-Ducoudré N., Boisier J-P., Pitman A., Bonan G.B., Brovkin V., Cruz F., Delire C., Gayler V., van den Hurk B.J.J.M., Lawrence P.J., van der Molen M.K., Müller C., Reick C.H., Strengers B.J. and Voldoire A., 2012. Determining Robust Impacts of Land-Use-Induced Land Cover Changes on Surface Climate over North America and Eurasia : Results from the First Set of LUCID Experiments. J. Clim. 25, 3261–3281.

de Wasseige C., Devers D., de Marcken P., Eba'a Atyi R., Nasi R. and Mayaux Ph., 2009. The forests of the Congo Basin : State of the Forest 2008. Publications Office of the European Union. Luxembourg. 426p. ISBN 978-92-79-13210-0

de Wasseige C., de Marcken P., Bayol N., Hiol Hiol F., Mayaux Ph., Desclée B., Nasi R., Billand A., Defourny P. and Eba'a Atyi R., 2012. The forests of the Congo Basin : State of the Forest 2010. Publications Office of the European Union. Luxembourg. 276 p. ISBN : 978-92-79-22716-5

de Wasseige C., Flynn J., Louppe D., Hiol Hiol F. and Mayaux, Ph., 2014. The forests of the Congo Basin : State of the Forest 2013. Weyrich. Belgium. 328p. ISBN : 978-2-87489-299-8

Defourny P., Delhage C. et Kibambe Lubamba J-P., 2011. Analyse quantitative des causes de la déforestation et de la dégradation des forêts en République Démocratique du Congo. UCL/FAO/CN REDD, Kinshasa.

Demangeot J., 1992. Les milieux naturels du Globe, Masson, Paris, 276 p.

Desclée B., Mayaux Ph., Hansen M., Lola Amani P., Sannier C., Mertens B., Häusler T., Ngamabou Siwe R., Poilvé H., Gond V., Rahm M., Haarpaintner J. et Kimbambe Lubamba J-P., 2014. Evolution du couvert forestier du niveau national au régional et moteurs de changement. Dans : *Les forêts du Bassin du Congo : Etat des Forêts 2013*. Weyrich. Neufchâteau, Belgique. 328p, p. 21-46. ISBN : 978-2-87489-298-1

Descroix L., Mahé G., Lebel T., Favreau G., Galle S., Gautier E., Olivry J.C., Albergel J., Amogu O., Cappelaere B., Dessouassi R., Diedhiou A., Le Breton E., Mamadou I. and Sighomnou D., 2009. Spatio-Temporal variability of hydrological regimes around the boundaries between Sahelian and Sudanian areas of West Africa : a synthesis. *J. of Hydrology*, 375, 1-2, 90-102.

Dhonneur G., 1985. Traité de météorologie tropicale, Météo-France, 151 p.

Di Gregorio M., Brockhaus M., Cronin T. and Muharrom E., 2012. Politics and power in national REDD+ policy processes. In : Angelsen A., Brockhaus M., Sunderlin W. and Verchot LV., eds. Analysing REDD+ : Challenges and Choices. Bogor, Indonesia : CIFOR. 69–90.

Djoufack V., 2011. Etude multi-échelles des précipitations et de la végétation au Cameroun : Thèse Université de Yaoundé I et Université de Bourgogne, 298 P.

Djoufack V. et Tsalefac, 2014. Variabilité pluviométrique dans le bassin forestier du Congo. In Denis Sonwa et Johnson Ndi Nkem (ed.). Les forêts du bassin du Congo et l'adaptation aux changements climatiques, 232 P.

Dkamela G.P., 2011. The context of REDD+ in Cameroon : Drivers, agents and institutions. Occasional Paper No. 57, CIFOR. Bogor, Indonesia. 80p. ISBN 978-602-8693-32-5

Dkamela G.P., Brockhaus M., Kengoum Djiegni F., Schure J. and Assembe-Mvondo S., 2014. Lessons for REDD+ from Cameroon's past forestry law reform : a political economy analysis. Ecology and Society 19. doi :10.5751/ES-06839-190330

Doumenge C., Palla F., Scholte P., Hiol Hiol F. and Larzilière A., 2015. Aires protégées d'Afrique centrale – Etat 2015. OFAC, Kinshasa, République Démocratique du Congo et Yaoundé, Cameroun : 256 p.

Eba'a Atyi R., Lescuyer G., Ngouhouo Poufoun J. and Moulende Fouda (eds), 2014. Etude de l'importance économique et sociale du secteur forestier et faunique au Cameroun. CIFOR-MINFOF.

Edwards D. Sloan P.S., Weng L., Dirks P., Sayer J. and Laurance W. F., 2014. Mining and the African environment. *Conservation Letters*. Vol. 7, n°3, p. 302-311.

Elias P., Leonard S., Cando L., Fedele G., Gaveau D., Locatelli B., Martius C., Murdiyarso D., Sunderlin W. and Verchot L., 2014. Synergies across a REDD+ landscape : Non-carbon benefits, joint mitigation and adaptation, and an analysis of submissions to the SBSTA. Info Brief. No. 70, CIFOR.

Epule E.T., Peng C., Lepage L. and Chen Z., 2014. Policy options towards deforestation reduction in Cameroon : An analysis based on a systematic approach. Land Use Policy 36, 405–415. Doi :10.1016/j.landusepol.2013.09.004

FAO, 2008. Exploitation forestière dans les forêts naturelles de la République du Congo. Étude pilote sur les techniques d'exploitation forestière. Vol 7. Rome.

Feintrenie L., 2014. Agro-industrial plantations in Central Africa, risks and opportunities. *Biodiversity and conservation*. Vol. 23, n°6, p. 1577-1589.

Feintrenie L., Akoa S., Dessard H., Iyabano A.H., Karpe Ph., Levang P., Miaro L. and Ndong Ndoutoume E., 2014. Are agri-business companies responsible for land grabbing in Central Africa. In : *Annual World Bank Conference on Land and Poverty*. Washington DC : p. 25.

Feintrenie L., Gillet P., Garcia C., Boulaud A. L., Ferlay A., Codina Llavinia E., Lehnebach C. and Vermeulen C., 2015. Family farming in a changing landscape : how activities change when forest disappears. In : *Annual World Bank Conference on Land and Poverty : Linking Land Tenure and Use for Shared Prosperity*.

Ferguson I.M. and Maxwell R.M., 2011. Hydrologic and land–energy feedbacks of agricultural water management practices. Environ. Res. Lett. 6, 014006.

Floret C., Pontanier R. et Serpantié G., 1993. La jachère en Afrique tropicale. Dossier MAB 16, UNESCO, Paris : 86 p.

Fobissie K., Alemagi D. and Minang P.A., 2014. REDD+ Policy Approaches in the Congo Basin : A Comparative Analysis of Cameroon and the Democratic Republic of Congo (DRC). Forests 5, 2400–2424. doi :10.3390/f5102400

Fontaine B. et Janicot S., 1993. L'évolution des idées sur la variabilité interannuelle récente des précipitations en Afrique de l'Ouest. La Météorologie, 1, 28-53.

Fontaine B., Janicot S., Moron V., Roucou P.et Trzaska S., 1998a. Anomalies de températures de surface de la mer et précipitations tropicales. La Météorologie, 23, 14-35.

Fontaine B., Trzaska S. and Janicot S., 1998b. Evolution of the relationships between near global and atlantic sea surface temperatures modes and the rainy season in West Africa : statistical analysis and sensitivity experiment. Climate Dynamics, 14, 451-473.

Ford J.D., Berrang-Ford L., Bunce A., McKay C., Irwin M. and Pearce T., 2014. The status of climate change adaptation in Africa and Asia. *Regional Environmental Change,* **15**(5) : 801-814. DOI 10.1007/s1011301406482

Fritsch J.M., 1990. *Les effets du défrichement de la forêt amazonienne et de la mise en culture sur l'hydrologie de petits bassins versants : opération ECEREX en Guyane française*. Thèse, Université Montpellier 2, ORSTOM Ed., Coll. Etudes et Thèse.

FRM, 2015. *Lien entre consommation des bois tropicaux et protection des forêts tropicales humides – Cas de forêts sous aménagement durable.*

Füssel H.M., 2007. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustainability science,* **2**(2) : 265-275. DOI 10.1007/s11625-007-0032-y

Gally M. et Bayol N., 2013. Situation de l'aménagement et de la certification en République du Congo. Forêt Ressources Management.

Gockowski J. and Sonwa D., 2011. Cocoa Intensification Scenarios and Their Predicted Impact on CO_2 Emissions, Biodiversity Conservation, and Rural Livelihoods in the Guinea Rain Forest of West Africa. *Environmental Management*. Vol. 48, n°2, p. 307-321.

Godard A. and Tabeaud M., 2009. Les Climats : Mécanismes, variabilité et répartition. $4^{ème}$ Edition ; Paris, Armand Colin, 216 p.

Goldstein A., Gonzalez G. and Peters-Stanley M., 2014. Turning over a New Leaf : State of the Forest Carbon Markets 2014. Ecosystem Marketplace. Available online at http ://www.forest-trends.org/documents/files/doc_4770.pdf

Gond V. et Brognoli C., 2005. Télédétection et aménagement du territoire : localisation et identification des sites d'orpaillage en Guyane française. *Bois et forêts des tropiques*. n°286, p. 5-13.

Gonmadje C.F., Doumenge C., Sunderland T.C.H, Balinga M.P.B. et Sonké B., 2012. Analyse phytogéographique des forêts d'Afrique Centrale : le cas du massif de Ngovayang (Cameroun). *Plant Ecology and Evolution* 145(2)45 152-164.

Groutel E., 2013. *Evolution des marchés des bois tropicaux africains*.

Guariguata M.R., Cornelius J.P., Locatelli B., Forner C. and Sánchez-Azofeifa G.A., 2008. Mitigation needs adaptation : Tropical forestry and climate change. *Mitigation and Adaptation Strategies for Global Change*, **13**(8), 793-808. DOI 10.1007/s11027-007-9141-2

Haddeland D., Clark W., Franssen F., Ludwig F., Voß N.W., Arnell N., Bertrand M., Best S., Folwell D., Gerten S., Gomes S.N., Gosling S., Hagemann N., Hanasaki R., Harding J., Heinke P., Kabat S., Koirala T.,Oki J., Polcher T., Stacke P., Viterbo G.P., Weedo. and Yeh P., 2011. Multi-Model Estimate of the Global Water Balance : Setup and First Results. Journal of Hydrometeorology, 12, 869–884, doi : 10.1175/2011JHM1324

Haensler A., Saeed F. and Jacob D., 2013. Assessment of projected climate change signals over central Africa based on a multitude of global and regional climate projections. In : Climate Change Scenarios for the Congo Basin. [Haensler A., Jacob D., Kabat P., Ludwig F. (eds.)]. Climate Service Centre Report No. 11, Hamburg, Germany, ISSN : 2192-4058

Hammond Gond D.S.V., de Thoisy B., de Dijn B. and Forget P-M., 2007. Causes and consequences of a tropical forest gold rush in the Guiana Shield, South America. *AMBIO : A Journal of the Human Environment*. Vol. 36, n°8, p. 661-670.

Hamrick K. and Goldstein A., 2015. Ahead of the curve. State of the Voluntary Carbon Markets 2015. Forest Trends' Ecosystem Marketplace, Washington.

Hansen M.C., Potapov P.V., Moore R., Hancher M., Turubanova S.A., Tuykavina A., Thau D., Stehman S.V., Goetz S.J., Loveland T.R., Kommareddy A., Egorov A., Chini L., Justice C.O. and Townshend J.R.G., 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science*. Vol. 342, p. 850-853.

Havlík P., Schneider U.A., Schmid E., Böttcher H., Fritz S., Skalský R., Aoki K., de Cara S., Kindermann G., Kraxner F., Leduc S., McCallum I., Mosnier A., Sauer T. and Obersteiner M., 2011. Global land-use implications of first and second generation biofuel targets. *Energy Policy*. Vol. 39, n°10, p. 5690-5702.

Haywood C., Wardell A.D., Cordonier Segger M-C and Holmgren P., 2015. Legal Frameworks for Implementing REDD+ in Zambia, Mozambique and Tanzania : Opportunities for a Sustainable Landscapes Approach. CCLR (2). PP : 130-142.

HBS and ODI, 2015. Climate Funds Update. Retrieved 15 July 2015, from http ://www.climatefundsupdate.org/the-funds

Herold M., Verchot L., Angelsen A., Maniatis D. and Bauch S., 2012. A step-wise framework for setting REDD+ forest reference emission levels and forest reference levels. CIFOR, InfoBrief 52, 8pp.

Hesseling G. et Le Roy E., 1990. Le droit et ses pratiques. *Politique Africaine* No 40 : 2- 11.

Hirsh F., Jourget J.G., Feintrenie L., Bayol N. and Atyi R.E., 2013. Projet pilote REDD+ de la Lukénie. Working Paper 111. CIFOR, Bogor, Indonesia.

Hoare A.L., 2007. The use of non-timber forest products in the Congo Basin : Constraints and Opportunities. Rainforest Foundation London, UK, 56 p. ISBN : 1-906131-03-1.

Hosonuma N., Herold M., de Sy V., de Fries R.S., Brockhaus M., Verchot L., Angelsen A. and Romijn E., 2012. An assessment of deforestation and forest degradation drivers in developing countries. Environmental Research Letters 7 (4) : 4009. DOI : http ://dx.doi.org/10.1088/1748-9326/7/4/044009

Howden S.M., Soussana J.F., Tubiello F.N., Chhetri N., Dunlop M. and Meinke H., 2007. Adapting agriculture to climate change. PNAS, 104, 19691-19696.

Hoyle D. et Levang P., 2012. Le développement du palmier à huile au Cameroun. *Rapport WWF*. p. 16.

Huq S. and Burton I., 2003. Funding adaptation to climate change : what, who and how to fund. *Sustainable Development Opinion*. International Institute for Environment and Development (IIED). London, UK : 2 p.

Illman J., Halonen M., Rinne P., Huq S. and Tveitdal S., 2013. Scoping study on financing adaptation-mitigation synergy activities. Working Paper. NORDEN. 51 p.

Ingram V., 2009. The hidden costs and values of NTFP exploitation in the Congo Basin. In : *13th World Forestry Congress*. p.18-23.

Ingram V., Ndoye O., Midoko Iponga D., Chupezi Tieguhong J et Nasi R., 2012. Les produits forestiers non ligneux : contribution aux économies nationales et stratégies pour une gestion durable. Dans : *Les forêts du Bassin du Congo : Etat des Forêts 2010*. Luxembourg : Office des publications de l'Union européenne, 2012. 274 p. ISBN : 978-92-79-22717-2

IPCC, 2007. Climate Change 2007 : Impacts, Adaptation and Vulnerability. A contribution of working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom.

IPCC, 2014. Climate Change 2014 : Impacts, Adaptation, and Vulnerability. Part B : Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Eds, Barros V.R., Field C.B., Dokken D.J., Mastrandrea M.D., Mach K.J., Bilir T.E., Chatterjee M., Ebi K.L., Estrada Y.O., Genova R.C., Girma B., Kissel E.S., Levy A.N., MacCracken S., Mastrandrea P.R and White L.L. United Kingdom and New York, NY, USA : Cambridge University Press, Cambridge. p1199-1265.

IUCN, 2013. The IUCN Red List of Threatened Species. Available at : http ://www.iucnredlist.org/

Jagger P., Lawlor K., Brockhaus M., Gebara M.F., Sonwa D.J., Resosudarmo I.A.P., 2012. REDD+ safeguards in national policy discourse and pilot projects. In : Angelsen A., Brockhaus M., Sunderlin W.D. and Verchot L. Analysing REDD+ : Challenges and choices : 301-316. CIFOR, Bogor, Indonesia.

Jagger P., Brockhau M., Duchelle Amy E., Fernanda Gebara M., Lawlor K., Aju Pradnja Resosudarmo I. and Sunderlin W.D., 2014. Multi-Level Policy Dialogues, Processes, and Actions : Challenges and Opportunities for National REDD+ Safeguards Measurement, Reporting, and Verification (MRV). Forests 2014, 5(9), 2136-2162 ; doi : 10.3390/f5092136

Janicot S., 1995. Le point sur la désertification et les changements climatiques. La Météorologie, 4, 1-15.

Jose S., 2009. Agroforestry for ecosystem services and environmental benefits : an overview. Agrofor. Syst. 76, 1–10.

Jupp T.E., Cox P.M., Rammig A., Thonicke K., Lucht W. and Cramer W., 2010. Development of probability density functions for future South American rainfall. New Phytologist, 187, 682–693. doi : 10.1111/j.1469-8137.2010.03368.x.

Kanowski P.J., McDermott L. and Cashore B.W., 2011. Implementing REDD+ : lessons from analysis of forest governance. *Environmental Science & Policy* 14(111-117).

Katerere Y., Fobissie K. and Annies A., 2015. Non-carbon benefits of REDD+ : Options for assessment and incentives. A technical paper prepared for the African Group of Negotiators. CDKN and ACPC-UNECA. 42 p.

Kengoum F. and Tiani A.M., 2013. Adaptation and mitigation policies in Cameroon : pathways of synergy. Bogor, Indonesia, Center for International Forestry Research (CIFOR) : vii, 38p. ISBN 978-602-1504-38-3

Kengoum F., Tiani A.M. and Brockhaus M., 2015. Synergies between Adaptation and REDD+ in Cameroon and DRC : Shifting the Perspective ? Global Environmental Politics (Forthcoming).

Koch I C., Vogel C. and Patel Z., 2007. Institutional dynamics and climate change adaptation in South Africa. *Mitigation and Adaptation Strategies for Global Change*, **12**(8), 1323-1339. DOI 10.1007/s11027-006-9054-5

Koh L.P. and Ghazoul J., 2010. Spatially explicit scenario analysis for reconciling agricultural expansion, forest protection, and carbon conservation in Indonesia. PNAS 107 : 11140-11144

Korhonen-Kurki K., Brockhaus M., Duchelle A.E., Atmadja S., Pham T.T., Schofield L., 2013. Multiple levels and multiple challenges for measurement, reporting and verification of REDD+. International Journal of the Commons 7 (2) : 344–366.

Korhonen-Kurki K., Sehring J., Brockhaus M. and Di Gregorio M., 2014. Enabling factors for establishing REDD+ in a context of weak governance. Climate Policy 14, 167–186. doi :10.1080/14693062.2014.852022

Korhonen-Kurki K., Sehring J., Brockhau M., Di Gregorio M., 2015. Policy progress with REDD+ and the promise of performance based payments : A qualitative comparative analysis of 13 countries. Environmental Change.

Koster R.D., Dirmeyer P.A., Guo Z., Bonan G., Chan E., Cox P., Gordon C.T., Kanae S., Kowalczyk E., Lawrence D., Liu P., Lu C.-H., Malyshev S., McAvaney B., Mitchell K., Mocko D., Oki T., Oleson K., Pitman A., Sud Y.C., Taylor C.M., Verseghy D., Vasic R., Xue Y. and Yamada T., 2004. Regions of Strong Coupling Between Soil Moisture and Precipitation. Science 305, 1138–1140.

Lambers H., Chapin III F.S. and Pons T.L., 1998. Plant physiological ecology. Springer-verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo, Hong- Kong. 540 pp., ISBN 0-387-98326-0.

Laraque A., Mahé G., Orange D. and Marieu B., 2001. Spatiotemporal variations in hydrological regimes within Central Africa during the twentieth century. *Journal of Hydrology*, 245, 1-4; 104-117

Laraque A., Bellanger M., Adel G., Guebanda S., Gulemvug G., Pandi A., Paturel J.E., Rober A., Tathy J.P. and Yambele A., 2013. Evolutions récentes des débits du Congo, de l'Oubangui et de la Sangha. Recent evolution of Congo, Oubangui and Sangha rivers flows. Geo-Eco-Trop, 37, 1, 93-100.

Lawlor K, Olander L.P. and Weinthal E., 2009. Sustaining livelihoods while reducing emissions from deforestation – Options for Policymakers. Nicholas Institute for Environmental Policy Solutions, Working Paper NI WP 09-02

Lawrence D. and Vandecar K., 2015. Effects of tropical deforestation on climate and agriculture. Nat. Clim. Change 5, 27–36.

Leroux M., 1970. La dynamique des précipitations en Afrique occidentale. Thèse de doctorat de troisième cycle, Université de Dakar, 320 p.

Leroux M., 1973. Les principales discontinuités africaines : Front intertropical (FIT) et Confluence Inter-Océanique (CIO). *La structure continue de l'Équateur météorologique intertropical.* Publication de la Direction de l'Exploitation Météorologique, 29, Dakar, ASECNA : 21-36.

Lescuyer G., 2014. Evaluation économique de la chasse villageoise. *In :* Eba'a Atyi R., Lescuyer G., Ngouhouo Poufoun J. and Moulende Fouda (eds). Etude de l'importance économique et sociale du secteur forestier et faunique au Cameroun. CIFOR-MINFOF

Levin N.E., Zipser E.J. and Cerling T.E., 2009. Isotopic composition of waters from Ethiopia and Kenya : Insights into moisture sources for eastern Africa. J. Geophys. Res. Atmospheres 114, D23306.

Lewis S.L.,Brando P.M., Phillips O.L., van der Heijden G.M.F. and Nepstad D., 2011. The 2010 Amazon Drought. Science 331 : 554.

Li K., Coe M., Ramankutty N. and Jong R., 2007. Modeling the hydrological impact of land-use change in West Africa. Journal of Hydrology 337 :3-4, 258-268

Liénou G., Mahé G., Paturel J.E., Servat E., Sighomnou D., Ecodeck G.E., Dezetter A. et Dieulin C., 2008. Changements des régimes hydrologiques en région équatoriale camerounaise : un impact du changement climatique en Afrique équatoriale ? *Hydrological Sciences Journal*, 53, 4 ; 789-801.

Locatelli B., Kanninen M., Brockhaus M., Colfer C. P., Murdiyarso D. and Santoso H., 2008. Facing an uncertain future : How forests and people can adapt to climate change. Bogor, Indonesia : Center for International Forestry Research (CIFOR). 97p.

Luttrell C., Loft L., Gebara MF., Kweka D., Brockhaus M., Angelsen A and Sunderlin W., 2013. Who should benefit from REDD+ ? Rationales and realities. Ecology and Society 18(4) : 52. http ://www.ecologyandsociety.org/vol18/iss4/art52/

Mahé G., 1993. Les écoulements fluviaux sur la façade atlantique de l'Afrique de l'Ouest, Collection Etudes et thèses Orstom edit. 438 P.

Mahé G., Servat E. and Maley J., 2004. Climatic variability including ENSO events (droughts, extreme events). *In "Forests – Water – People in the Humid Tropics : past, present and future hydrological research for integrated land and water management"*. Cambridge University Press, 267-286.

Mahé G., Paturel J.E., Servat E., Conway D. and DezetterA., 2005. Impact of land use change on soil water holding capacity and river modelling of the Nakambe River in Burkina-Faso. Journal of Hydrology, 300, 33-43.

Mahé G. and Paturel J.E., 2009. 1896-2006 Sahelian rainfall variability and runoff increase of Sahelian rivers. *C.R. Geosciences*, 341, 538-546.

Mahe G., Lienou G., Descroix L., Bamba F., Paturel J.E., Laraque A., Meddi M., Habaieb H., Adeaga O., Dieulin C., Chahnez Kotti F. and Khomsi K., 2013. The rivers of Africa : witness of climate change and human impact on the environment. *Hydrological Processes*, 27, 2105–2114. DOI : 10.1002/hyp.9813.

Mai Y.H., Mwangi E. and Wan M., 2011. Gender analysis in forestry research : looking back and thinking ahead. *International Forestry Review* **13**(2) : 205-219. DOI 10.1505/146554811797406589

Makarieva A.M., Gorshkov V.G. and Li B-L., 2013. Revisiting forest impact on atmospheric water vapor transport and precipitation. Theor. Appl. Climatol. 111, 79–96.

Maley J., 1987. Fragmentation de la forêt dense humide africaine et extension des biotopes montagnards au Quaternaire récent : nouvelles données polliniques et chronologiques. Implications paléoclimatiques et biogéographiques. – *Palaeoecol. Africa,* 18,

Maley J., 1996. The African rain forest : main characteristics of changes in vegetation and climate from the Upper Cretaceous to the Quaternary. In : Alexander I.J., Swaine M.D., Watling R.. Essays. On the ecology of the Guinea-Congo rain forest. *Proceedings of the Royal Society of Edinburgh.Section* B, 1996, 104, p. 31-73.

Maley J., 1997. Middle to late Holocene changes in tropical Africa and other continents : paleomonsoon and sea surface temperature variation. NATO ASI series, 1, 611-639.

Maley J. and Brenac P., 1998. Vegetation dynamics, Paleoenvironments and Climatic Changes in the forests of Western Cameroon during the last 28 000 years B.P. Review of Paleobotany and Palynology, 99, 157-187.

Maley J., Brenac P., Bigot S. and Moron V., 2000. Variations de la végétation et des paléoenvironnements en forêt dense africaine au cours de l'Holocène. Impact de la variation des températures marines. In : Dynamique à long terme des Ecosystèmes forestiers intertropicaux, M.Servant and S.Servant-Vildary eds., Mémoire UNESCO, Paris, 205-220.

Marien J-N. et Bassaler N., 2013. *Eléments de prospective à l'horizon 2040 pour les écosystèmes forestiers d'Afrique Centrale – Rapport technique de synthèse final.*

Marien J-N., Louppe D., Dubiez E. et Larzillière A., 2013. *Quand la ville mange la forêt : les défis du bois énergie en Afrique centrale.* Editions Quae, 240 p. ISBN : 2-7592-1980-1.

Martin Persson, U., 2012. Conserve or convert ? Pan-tropical modeling of REDD–bioenergy competition. Biological Conservation 146, 81–88. Doi :10.1016/j.biocon.2011.10.038

Martius C., 2015. REDD+ in Africa : status, trends and developments. Study report. CIFOR. Bogor, Indonesia.

McCarthy J.J., 2001. Climate Change 2001 : Impacts, Adaptation, and Vulnerability : Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. 1032 p. ISBN 0 521 80768 9.

MDG. Achievement Fund, 2013. Environment and Climate Change Thematic window development results report – October 2013. *Development results series.* New York, USA, MDG Achievement Fund Secretariat monitoring and evaluation unit. 23 p.

Megevand C., Mosnier A., Hourticq J., Sanders K., Doetinchem N. and Streck C., 2013. *Deforestation Trends in the Congo Basin : Reconciling Economic Growth and Forest Protection.* The World Bank, 179 p. Disponible sur : http ://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-9742-8. ISBN : 978-0-8213-9742-8.

Meunier Q., Boldrini S., Moumbogou C., Morin A., Ibinga S. et Vermeulen C., 2014. Place de l'agriculture itinérante familiale dans la foresterie communautaire au Gabon. *Bois et Forêts des Tropiques.* Vol. 319, p. 65-69.

Monteil L., Gond V., Cornu G., Philippon N. and Doumenge C., in prep. The climatic hinge in Central Africa : cartography and links with forest distribution.

Monteny B.A., 1987. Contribution à l'étude des interactions végétation-atmosphère en milieu tropical humide. Thèse de doctorat de l'Université d'Orsay, 176 p.

Monteny B.A., Lhomme J.P., Chebhouni A., Amadou M., Troufleau D., Brunel J.P., Bessemoulin P., Sicot M., Galle S., Lloyd C., Said F., 1996. Les Interactions Surface Continentale-Atmosphère en Milieu Sahélien. Passage de l'Echelle Stationnelle à l'Echelle Régionale. In : Interactions Surface Continentale-Atmosphère : l'Expérience HAPEX-Sahel, Actes des X^{e} Journées Hydrologiques de Montpellier, 13-14 Septembre 1994, Ed. ORSTOM, Ed. Scient. : Hoepffner M., Lebel T., Monteny B., 287-303.

Morin-Rivat J., Fayolle A., Gillet J.-F., Bourland N., Gourlet-Fleury S., Oslisly R., Bremond L., Bentaleb I., Beeckman H. and Doucet J.-L., 2014. New evidence of human activities during the Holocene in the lowland forests of the Northern Congo Basin. Radiocarbon 56(1) : 209–220.

Moser S.C., 2012. Adaptation, mitigation, and their disharmonious discontents : an essay. Climatic Change 111(2) : 165-175.

Mosnier A., Havlík P., Obersteiner M., Aoki K., Schmid E., Fritz S., McCallum I. and Leduc S., 2014. Modeling Impact of Development Trajectories and a Global Agreement on Reducing Emissions from Deforestation on Congo Basin Forests by 2030. *Environmental and Resource Economics.* Vol. 57, n°4, p. 505-525.

Mosnier A. and Pirker J., 2015. *Global oil palm suitability assessment.* IIASA,

Mpounza M. and Samba-Kimbata M.J., 1990. Aperçu sur le climat de l'Afrique centrale occidentale. In : Lanfranchi R.

and Schwartz D. (eds.), Paysages quaternaires de l'Afrique centrale atlantique. ORSTOM, Paris : 31-41.

Munang R., Thiaw I., Alverson K., Mumba M., Liu J. and Rivington M., 2013. Climate change and Ecosystem-based Adaptation : a new pragmatic approach to buffering climate change impacts. Current Opinion in Environmental Sustainability, 5, 67-71.

Munroe R. and Mant R., 2014. REDD+ and adaptation : Identifying complementary responses to climate change. Infobrief. UN-REDD Programme.

Munzimi Y.A., Hansen M.C., Adusei B.D. and Senay G.B., 2015. Characterizing Congo Basin Rainfall and Climate Using Tropical Rainfall Measuring Mission (TRMM) Satellite Data and Limited Rain Gauge Ground Observations. Eds. American Meteorological Society, Journal of Applied Meteorology and Climatology, Vol 54, pp 541-555.

Murdiyarso D., Robledo C., Brown S., Coto O., Drexhage J., Forner C., Kanninen M., Lipper L., North N. and Rondon M., 2005. Linkages between mitigation and adaptation in land-use change and forestry activities. In : Robledo C., Kanninen M., Pedroni L. Tropical forests and adaptation to climate change. in : Search for synergies. CIFOR, Bogor, Indonesia. pp 122-154

Nair PK R., 1985. Classification of agroforestry systems. *Agroforestry systems*. Vol. 3, n°2, p. 97-128.

Nasi R., Billand A. and Van Vliet N., 2011. Empty forests, empty stomachs : bushmeat and livelihoods in Congo and Amazon Basins. *International Forestry Review*. p. 355-368.

Ndjogui T. E. et Levang P., 2013. Elites urbaines, elæiculture et question foncière au Cameroun. *Territoires d'Afrique*. n°5, p. 35-46.

Nicholson S.E., Dezfuli A.K. and Klotter D., 2012. A Two-Century Precipitation Dataset for the Continent of Africa. Bulletin of the American Meteorological Society, 93, 1219–1231

Niyogi D., Mahmood R. and Adegoke J.O., 2009. Land-Use/Land-Cover Change and Its Impacts on Weather and Climate. Bound.-Layer Meteorol. 133, 297–298.

Nkem J., Idinoba M. and Sendashoga C., 2008. Forests for climate change adaptation in the Congo Basin : Responding to an urgent need with sustainable practices. Environment Brief No. 2. CIFOR, Bogor, Indonesia. 6p.

Nkem J., Kalame F. B., Idinoba M., Somorin O. A., Ndoye O. and Awono A., 2010. Shaping forest safety nets with markets : Adaptation to climate change under changing roles of tropical forests in Congo Basin. *Environmental Science & Policy*, **13**(6), 498-508. DOI 10.1016/j.envsci.2010.06.004

Nkem J., Munang R. and Jallow B.P., 2011. Lessons for adaptation in sub-Saharan Africa. Nairobi, Kenya : UNON, UNDP, UNEP. 98p.

Nogherotto R., Coppola E., Giorgi F. and Mariotti L., 2013. Impact of Congo Basin deforestation on the African monsoon. Atmospheric Sci. Lett. 14, 45–51.

Obidzinski K., Dermawan A. and Hadianto A., 2014. Oil palm plantation investments in Indonesia's forest frontiers : limited economic multipliers and uncertain benefits for local communities. Environment, Development and Sustainability, 16(6), 1177-1196.

Ochieng R.M., Visseren-Hamakers and Nketiah K.S., 2012. Interaction between the FLEGT VPA and REDD+ in Ghana : recommendations for interaction management. *Forest Policy and Economics.*

OECD and FAO, 2013. *OECD-FAO Agricultural Outlook 2013-2022*. Paris : OECD Publishing : ISBN : 978-92-64-19422-9.

Olivry J.C., 1986. Fleuves et Rivières du Cameroun. Ministère de l'enseignement supérieur et de la recherche scientifique au Cameroun. 733 p. ISBN 2709908042

Olson D.M., Dinerstein E., Wikramanayake E.D., Burgess N.D., VN Powell G., Underwood E.C., D'amico J.A., Itoua I., Strand H.E. and Morrison J.C., 2001. Terrestrial Ecoregions of the World : A New Map of Life on Earth A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience*. Vol. 51, n°11, p. 933-938.

ONU, 2013. *ONU : la population mondiale devrait atteindre 9,6 milliards en 2050 | ONU DAES | Nations Unies Département des affaires économiques et sociales*. Disponible sur : http://www.un.org/fr/development/desa/news/population/un-report-world-population-projected-to-reach-9-6-billion-by-2050.html.

Oren R., Ellsworth D.S., Johnsen KLHL, Phillips N., Ewers B.E., Maier C., Schafer K.V.R., McCarthy H., Hendrey G., McNulty S.G. and Katul G.G., 2001. Soil fertility limits carbon sequestration by forest ecosystems in a CO_2-enriched atmosphere. Nature 411 : 469-472.

Pavageau C., Locatelli B., Tiani A.M. and Zida M., 2013. Cartographier la vulnérabilité aux variations climatiques : Une méta-analyse en Afrique. Document de travail 118. Bogor, Indonesia, Center for International Forestry Research (CIFOR). 48p.

Pavageau C. and Tiani A.M., 2014. Implementing REDD+ and adaptation to climate change in the Congo Basin : Review of projects, initiatives and opportunities for synergies. Working Paper 162. Bogor, Indonesia : Center for International Forestry Research (CIFOR), 52 p.

Peach-Brown H.C., Nkem J., Sonwa D. and Bele Y., 2010. Institutional adaptive capacity and climate change response in the Congo Basin forests of Cameroon. *Mitigation and Adaptation Strategies for Global Change*, **15**(3), 263-282. DOI 10.1007/s11027-010-9216-3

Peach-Brown H.C., Smit B., Somorin O.A., Sonwa D.J. and Ngana F., 2013. Institutional perceptions, adaptive capacity and climate change response in a post-conflict country : a case study from Central African Republic. *Climate and Development*, **5**(3) : 206-216. DOI 10.1080/17565529.2013.812954

Peach-Brown H.C., Smit B., Somorin O., Sonwa D. and Nkem J., 2014. Climate Change and Forest Communities : Prospects for Building Institutional Adaptive Capacity in the Congo Basin Forests. *AMBIO*, **43**(6), 759-769. DOI 10.1007/s13280-014-0493-z

Peach-Brown H.C. and Sonwa D.J., 2015. Rural local institutions and climate change adaptation in forest communities in Cameroon. *Ecology and Society*, 20(2) : 6 http ://dx.doi.org/10.5751/ES-07327-200206.

Pédelahore P., 2012. [Thèse]. *Stratégies d'accumulation des exploitants agricoles : l'exemple des cacaoculteurs du Centre Cameroun de 1910 à 2010*. Toulouse 2, France.

Peel M.C., Finlayson B.L. and McMahon T.A., 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences., 11, 1633–1644, 2007 ; www.hydrol-earth-syst-sci.net/11/1633/2007/

Pham T.T., Brockhaus M., Wong G., Dung L.N., Tjajadi J.S., Loft L., Luttrell C. and Assembe-Mvondo S., 2013. Approaches to benefit sharing : A preliminary comparative analysis of 13 REDD+ countries. Working Paper 108. Bogor, Indonesia : CIFOR.

Phelps, J., 2015. Forest carbon, biodiversity and the promise of a green economy. In Gasparatos A. and Willis K., eds. Biodiversity in the Green Economy. Routledge : London. http ://www.tandf.net/books/details/9780415723329/

Pielke R.A., Adegoke J., Beltrán-Przekurat A., Hiemstra C.A., Lin J., Nair U.S., Niyogi D. and Nobis T.E., 2007. An overview of regional land-use and land-cover impacts on rainfall. Tellus B 59, 587–601.

Pielke R.A., Pitman A., Niyogi D., Mahmood R., McAlpine C., Hossain F., Goldewijk K.K., Nair U., Betts R., Fall S., Reichstein M., Kabat P. and de Noblet N., 2011. Land use/land cover changes and climate : modeling analysis and observational evidence. Wiley Interdiscip. Rev. Clim. Change 2, 828–850.

Polasky S., Carpenter S.R., Folke C. and Keeler B., 2011. Decision-making under great uncertainty : environmental management in an era of global change. Trends in ecology & evolution, 26, 398-404.

Polcher J., 1994. Etude de la sensibilité du climat tropical à la déforestation. Thèse de doctorat de l'Université de Paris VI, 185 p.

Potapov P., Turubanova S., Hansen M., Adusei B., Broich M., Altstatt A., Mane L. and Justice C., 2012. Quantifying forest cover loss in Democratic Republic of the Congo, 2000-2010, with Landsat ETM+ data. *Remote Sensing of Environment*. p. 106-116.

Pratihast, A.K., DeVries B., Avitabile V., de Bruin S., Kooistra L., Tekle M., and Herold M., 2014. Combining Satellite Data and Community-Based Observations for Forest Monitoring. Forests. http ://www.mdpi.com/1999-4907/5/10/2464

Quétier F., De Wachter P., Gersberg M., Dessard H., Nzene Halleson D. et Ndong Ndoutoume E., 2015. La compensation volontaire : les normes de performance des institutions financières et leur application aux forêts d'Afrique centrale. Dans : *Restaurer la nature pour atténuer les impacts du développement*. QUAE, p. 320. ISBN : 978-2-7592-2290-2.

Ramirez-Villegas J. and Thornton P.K., 2015. Climate change impacts on African crop production. *Working Paper No. 119*. Copenhagen, Denmark : CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS). 27p.

Rasi R., Beuchle R., Bodart C., Vollmar M., Seliger R. and Achard F., 2013. Automatic updating of an object-based tropical forest cover classification and change assessment. *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of.* Vol. 6, n°1, p. 66-73.

Ravindranath N.H., 2007. Mitigation and adaptation synergy in forest sector. *Mitigation and Adaptation Strategies for Global Change*, **12**(5) : 843-853. DOI 10.1007/s11027-007-9102-9

Rockström J., Steffen W., Noone K., Persson Å., Chapin F.S., Lambin E.F., Lenton T.M., Scheffer M., Folke C., Schellnhuber H.J., Nykvist B., de Wit C.A., Hughes T., van der Leeuw S., Rodhe H., Sörlin S., Snyder P.K., Costanza R., Svedin U., Falkenmark M., Karlberg L., Corell R.W., Fabry V.J., Hansen J., Walker B., Liverman D., Richardson K., Crutzen P., Foley J.A., 2009. A safe operating space for humanity. Nature 461, 472–475. doi :10.1038/461472a

Romijn E., Lantican C.B., Herold M., Lindquist E., Ochieng R., Wijaya A., Murdiyarso D., Verchot L., 2015. Assessing change in national forest monitoring capacities of 99 tropical Non-Annex I countries. Forest Ecology and Management

Saatchi S.S., Harris N.L., Brown S., Lefsky M., TA Mitchard E., Salas W., Zutta B.R., Buermann W., Lewis S.L. and Hagen S., 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the National Academy of Sciences*. Vol. 108, n°24, p. 9899-9904.

Salvini G., Herold M., De Sy V., Kissinger G., Brockhaus M., Skutsch M., 2014. How countries link REDD+ interventions to drivers in their readiness plans : implications for monitoring systems. Environmental Research Letters 9, 074004. Doi :10.1088/1748-9326/9/7/074004

Samba-Kimbata M.J., 1991. Précipitations et bilans d'eau dans le Bassin forestier du Congo et ses marges. Dijon, Université de Bourgogne, Centre de Recherches de Climatologie, Thèse de doctorat, 242 p.

Santanello J.A., Friedl M.A. and Ek M.B., 2007. Convective Planetary Boundary Layer Interactions with the Land Surface at Diurnal Time Scales : Diagnostics and Feedbacks. J. Hydrometeorol. 8, 1082–1097.

Schmidt L., 2014. Assessment of Forest Management Mitigation Activities under the Emission Reduction Program of Mai Ndombe Province. A report of the project 'Development of a Carbon Storage Map & Carbon Payment Model Project for the DR Congo Forestbelt'. WWF/GFA Consulting Group, Kinshasa/Hamburg.

Scholte P., Kirda P., Adam S. and Kadiri B., 2000. Floodplain rehabilitation in North Cameroon : impact on vegetation dynamics. *Applied Vegetation Science* 3 : 33-42. http ://www.opuluspress.se/pdf.php ?id=17190

Scholte P., 2007. Maximum flood depth characterises aboveground biomass in African seasonally shallowly flooded grasslands. *Journal of Tropical Ecology* 23 : 63-72. http ://journals.cambridge.org/action/displayIssue ?jid=TRO&volumeId=23&issueId=01

Schure J., Ingram V. et Akalakou-Mayimba C., 2011. *Bois énergie en RDC – Analyse de la filière des villes de Kinshasa et de Kisangani*. CIFOR, Disponible sur : http ://projets.cirad.fr/content/download/11048/66023/file/Bois %20energie %20en %20RDC %20Analyse %20de %20la %20filiere %20des %20villes %20de %20Kinshasa %20et %20Kisangani.pdf.

Schure J., Ingram V., Arts B., Levang P. and Mvula-Mampasi E., 2015. Institutions and access to woodfuel commerce in the Democratic Republic of Congo. *Forest Policy and Economics*. Vol. 50, p. 53-61.

Seymour F. and Angelsen A., 2012. Summary and conclusions : REDD+ without regrets. In : Angelsen A., Brockhaus M., Sunderlin W. and Verchot L.V., Analysing REDD+ : Challenges and Choices. Bogor, Indonesia : CIFOR. 317-334.

Shapiro A. and Saatchi S., 2014. Mapping Biomass for REDD in the Largest Forest of Central Africa : the Democratic Republic of Congo. Dans : *EGU General Assembly Conference Abstracts*. p. 2678.

Sills E.O., Atmadja S., de Sassi C., Duchelle A.E., Kweka D., Resosudarmo I.A.P. and Sunderlin W.D., 2014. REDD+ on the ground : A case book of subnational initiatives across the globe. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Sist P., Sablayrolles P., Barthelon S., Sousa-Ota L., Kibler J-F, Ruschel A., Santos-Melo M. and Ezzine-de-Blas D., 2014. The Contribution of Multiple Use Forest Management to Small Farmers' Annual Incomes in the Eastern Amazon. *Forests*. Vol. 5, n°7, p. 1508-1531.

Smith J.B., Dickinson T., Donahue J.D., Burton I., Haites E., Klein R.J. and Patwardhan A., 2011. Development and climate change adaptation funding : coordination and integration. *Climate Policy*, **11**(3) : 987-1000. DOI 10.1080/14693062.2011.582385

Somorin O.A., Brown H., Visseren-Hamakers I.J., Sonwa D.J., Arts B. and Nkem J., 2012. The Congo Basin forests in a changing climate : Policy discourses on adaptation and mitigation (REDD+). *Global Environmental Change*, **22**(1) : 288-298. DOI 10.1016/j.gloenvcha.2011.08.001

Somorin O.A., Visseren-Hamakers I.J., Arts B., Sonwa D.J. and Tiani A.M., 2014. REDD+ policy strategy in Cameroon : Actors, institutions and governance. Environmental Science & Policy, Climate change and deforestation : the evolution of an intersecting policy domain 35, 87–97. doi :10.1016/j.envsci.2013.02.004

Sonwa D.J., Nkem J.N., Idinoba M.E., Bele M.Y. and Jum C., 2012a. Building regional priorities in forests for development and adaptation to climate change in the Congo Basin. *Mitigation and Adaptation Strategies for Global Change*, **17**(4) : 441-450. DOI 0.1007/s11027-011-9335-5

Sonwa D.J., Somorin O.A., Jum C., Bele M.Y. and Nkem J.N., 2012b. Vulnerability, forest-related sectors and climate change adaptation : The case of Cameroon. *Forest Policy and Economics*, **23**(October 2012) : 1-9. DOI 10.1016/j.forpol.2012.06.009

Sonwa D.J., Scholte P., Pokam W., Schauerte P., Tsalefac M., Bouka Biona C., Brown C.P., Haensler A., Ludwig F., Mkankam F.K, Mosnier A., Moufouma-Okia W., Ngana F. and Tiani A.M., 2014. Climate Change and Adaptation in central Africa : Past scenarios and Options for the future. *In:* The Forests of the Congo Basin – State of the Forest 2013. Eds : de Wasseige C., Flynn J., Louppe D., Hiol Hiol F., Mayaux Ph. Weyrich. Belgium. 328 p. ISBN : 978-2-87489-299-8

Spracklen D.V., Arnold S.R. and Taylor C.M., 2012. Observations of increased tropical rainfall preceded by air passage over forests. Nature 489, 282–285.

Suchel JB., 1988. Les Climats du Cameroun. Thèse de Doctorat d'Etat, Université de Saint Etienne, 1067 PP.

Sultan B., Servat E., Maley J. and Mahé G., 2001. Inter-relations entre les forêts tropicales et la variabilité climatique : une synthèse des études récentes. *Sécheresse*, 12, 4, 221-229.

Sunderlin W.D., Larson A.M. and Cronkleton P., 2009. Forest Tenure Rights and REDD+ : From Inertia to Policy Solutions. In : Angelsen A. : *Realising REDD+ : National Strategy and Policy Options*. Bogor : CIFOR, 139- 150.

Thompson M.C., Baruah M. and Carr E.R., 2011. Seeing REDD+ as a project of environmental governance. *Environmental science and policy 14 :100-110*

Tiani A.M., Bele M.Y. and Sonwa D.J., 2015. What are we talking about ? The state of perceptions and knowledge on REDD+ and adaptation to climate change in Central Africa. *Climate and Development,* **7**(4) : 1-12. DOI 10.1080/17565529.2014.953901

Tingem M., Rivington M. and Bellocchi G., 2009. Adaptation assessments for crop production in response to climate change in Cameroon. *Agronomy for sustainable development*, **29**(2) : 247-256. DOI 10.1051/agro :2008053

Topa G., Karsenty A., Mégevand C., Debroux L., 2009. The Rainforests of Cameroon : Experience and Evidence from a Decade of Reform. The World Bank (Serie : Directions in Development, Environment and Sustainable Development), WashingtonD.C.

Tsalefac M., Zaninetti J.M., Giroir G. et Ngoufo R., 2007. L'Afrique centrale, le Cameroun et les changements globaux. Presses Universitaires d'Orléans, 355 P.

Tsalefac M., 2013. L'Afrique et les pays du bassin du Congo face aux enjeux post-Kyoto. In : Louzolo-Kimbembe Louzolo. Changement Climatique. Enjeux socio-économiques et défis technologiques dans les pays du bassin du Congo. L'Harmattan, 13-33.

Tschakert P. and Dietrich K.A., 2010. Anticipatory learning for climate change adaptation and resilience. *Ecology and society 15*(2) : 11. http ://www.ecologyandsociety.org/vol15/iss2/art11/

Twomlow S., Mugabe F.T., Mwale M., Delve R., Nanja D., Carberry P. and Howden M., 2008. Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa – A new approach. *Physics and Chemistry of the Earth*, Parts A/B/C, **33**(8) : 780-787. DOI 10.1016/j.pce.2008.06.048

UICN-PACO, 2011. Agir pour la nature et les hommes. Rapport annuel PACO 2010, Ouagadougou, Burkina Faso : UICN-PACO, 44 P.

UN-DESA (United Nations, Department of Economic and Social Affairs), 2012. World Population Prospects : The 2012 Revision. http ://esa.un.org/unpd/wpp/unpp/panel_population.htm

UN-DESA (United Nations, Department of Economic and Social Affairs, Population Division), 2015. World Urbanization Prospects : The 2014 Revision, (ST/ESA/SER.A/366). New York, USA. 517p.

UNEP, 2009. Report of the second meeting of the second ad hoc technical expert group on biodiversity and climate change. UNEP/CBD/AHTEG/BD-CC-2/2/6 Convention on Biological Diversity. Helsinki, Finland. 18–22 April 2009. 35p.

UNEP, 2011. Forests in a green economy – a synthesis. United Nations Environment Programme, Nairobi, Kenya. www.unep.org/pdf/PressReleases/UNEP-ForestsGreenEco-basse_def_version_normale.pdf

UNEP, 2014. Building Natural Capital : How REDD+ can Support a Green Economy, Report of the International Resource Panel, United Nations Environment Programme, Nairobi, Kenya. http ://www.un-redd.org/portals/15/documents/IRPBuildingNaturalCapitalPolicyMakerSummaryweb.pdf

UNFCCC, 1992. United Nations Framework Convention on Climate Change. Available at : http ://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.

UNFCCC, 2010. *Les accords de Cancun : Résultats des travaux du Groupe spécial de l'action concertée à long terme au titre de la Convention (Décision CCNUCC 1/CP.16).*

UNFCCC, 2015a. INDCs as communicated by Parties. http ://www4.unfccc.int/submissions/indc/Submission %20Pages/submissions.aspx

UNFCCC, 2015b. NAPAs received by the secretariat http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4585.php

UNFCCC, 2015c. Non-Annex I national communications. http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

UNFCCC, 2015d. Status of NAPA implementation under the LDCF. http://unfccc.int/adaptation/knowledge_resources/ldc_portal/items/5632.php.

Verchot L., Kamalakumari A., Romijn E., Herold M. and Hergoualc'h K., 2012. Emissions factors: Converting land use change to CO_2 estimates. In: Angelsen A., Brockhaus M., Sunderlin W.D. and Verchot L., eds. Analysing REDD+: Challenges and choices. Bogor, Indonesia: CIFOR. 261-278.

Washington R., James R., Pearce H., Pokam W.M. and Moufouma-Okia W., 2013. Congo Basin rainfall climatology: can we believe the climate models? Phil Trans R Soc B 368: 20120296. http://dx.doi.org/10.1098/rstb.2012.0296

Weber W., 1998. *Conservation des Primates et Ecotourisme en Afrique (non publié)*. WCS.

Wilkie D.S. and Carpenter J., 1999. Can nature tourism help finance protected areas in the Congo Basin? *Oryx*. Vol. 33, n°4, p. 333-339.

Wilkie D., Morelli G., Rotberg F. and Shaw E., 1999. Wetter isn't better: global warming and food security in the Congo Basin. *Global Environmental Change*, **9**(4): 323-328. DOI 10.1016/S0959-3780(99)00021-7

Young O.R., 2002. The institutional dimensions of environmental change: fit, interplay, and scale. Cambridge, MA: The MIT press.

FURTHER READINGS

Assembe-Mvondo S. and Oyono P.R., 2004. An Assessment of Social Negotiation as a Tool of Local Management: A Case Study of the Dimako Council Forest, Cameroon. Scandinavian Journal of Forest Research 19, 78–84. doi:10.1080/14004080410034155

Assembe-Mvondo S., 2005. Decentralisation des Resssources Forestieres et Justice Environnementale: Analyse des Evidences Empiriques du Sud-Cameroun. Law Env't & Dev. J. 1, 35.

Assembe-Mvondo S., 2006. Forestry Income Management and Poverty Reduction: Empirical Findings from Kongo, Cameroon. Development in Practice 16, 68–73.

Assembe-Mvondo S., 2015. National-level corruption risks and mitigation strategies in the implementation of REDD+ in the Democratic Republic of the Congo: An overview of the current situation. Center for International Forestry Research. (CIFOR), Bogor, Indonesia.

Assembe-Mvondo S., Eba'a Atyi R., Brockhaus M. and Lescuyer L. Public Policy transfer: outline for disseminating the REDD+ international regime in Central African countries

Awono A., Somorin O.A., Eba'a Atyi R. and Levang P., 2014. Tenure and participation in local REDD+ projects: Insights from southern Cameroon. Environmental Science & Policy 35, 76–86. doi:10.1016/j.envsci.2013.01.017

Brockhaus M., DiGregorio M. and Wertz-Kannounikoff S.K., 2012. Guide for country profiles: Global Comparative Study on REDD (GCS-REDD) Component 1 on National REDD+ Policies and Processes. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Cerutti P.O., Lescuyer G., Assembe-Mvondo S. and Tacconi L., 2010. The Challenges of Redistributing Forest-Related Monetary Benefits to Local Governments: A Decade of Logging Area Fees in Cameroon. International Forestry Review 12, 130–138. doi:10.1505/ifor.12.2.130

Cerutti P.O., Tacconi L., Lescuyer G. and Nasi R., 2013. Cameroon's hidden harvest: commercial chainsaw logging, corruption, and livelihoods. Society & Natural Resources 26, 539–553.

Cuny P., Le Crom M. and Giraud A., 2013. Résumé Elaboration d'un profil pays: Pour la mesure et le suivi du carbone forestier, Cameroun. Center for International Forestry Research. (CIFOR), Bogor, Indonesia.

Duguma L.A., Minang P.A. & Van Noordwijk M., 2014. Climate change mitigation and adaptation in the land use sector: from complementarity to synergy. Environmental management, 54, 420-432.

Eba'a Atyi R., Assembe-Mvondo S., Lescuyer G. and Cerutti P., 2013. Impacts of international timber procurement policies on Central Africa's forestry sector: The case of Cameroon. Forest Policy and Economics, Emerging Forest Regimes 32, 40–48. doi:10.1016/j.forpol.2012.12.006

Hansen M.C., Potapov P.V., Moore R., Hancher M., Turubanova S.A, Tyukavina A., Thau D., Stehman S.V., Goetz S.J., Loveland T.R., Kommareddy A., Egorov A., Chini L., Justice C.O. and Townshend J.R.G., 2013. Hansen/UMD/Google/USGS/NASA Tree Cover Loss and Gain Area. University of Maryland, Google, USGS, and NASA. www.globalforestwatch.org.

Ickowitz A., Slayback D., Asanzi P. and Nasi R., 2015. Agriculture and deforestation in the Democratic Republic of the Congo: A synthesis of the current state of knowledge, CIFOR Occasional Paper. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Kengoum D.F., 2011. REDD+ politics in the media: A case study from Cameroon (51), CIFOR Working Paper. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Kengoum D.F., 2015 in prep. Le contexte de la REDD+ au Cameroun: Causes, agents et institutions. Version mise à jour. CIFOR, Bogor, Indonesia.

Loft L., Ravikumar A., Gebara M.F., Pham T.T., Resosudarmo I.A.P., Assembe S., Tovar J.G., Mwangi E. and Andersson K., 2015. Taking Stock of Carbon Rights in REDD+ Candidate Countries: Concept Meets Reality. Forests 6, 1031–1060.

Oyono P.R., Ribot J.C., Assembe Mvondo S. and Logo P.B., 2007. Improving Decentralized Forest Management in Cameroon: Options and Opportunities from Ten Years of Experience. CIFOR Governance Brief no. 33. Center for International Forestry Research (CIFOR), Bogor, Indonesia. 12p.

Sunderlin W.D., Ekaputri A.D., Sills E.O., Duchelle A.E., Kweka D., Diprose R., Doggart N., Ball S., Lima R., Enright A., Torres J., Hartanto H. and Toniolo A., 2014a. The challenge of establishing REDD+ on the ground: Insights from 23 subnational initiatives in six countries. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Sunderlin W.D., Larson A.M., Duchelle A.E., Resosudarmo I.A.P., Huynh T.B., Awono A. and Dokken T., 2014b. How are REDD+ Proponents Addressing Tenure Problems? Evidence from Brazil, Cameroon, Tanzania, Indonesia, and Vietnam. World Development, Land Tenure and Forest Carbon Management 55, 37–52. doi:10.1016/j.worlddev.2013.01.013

WWC, 2015. Calculation of the REL UNDEF and REL UNDEG for the Mai Ndombe ER-Program. Final Report submitted to the World Bank's Forest Carbon Partnership Fund. Wildlife Works Carbon, LLC.

ANNEXES

APPENDIX 1 : Overview of GCM-projections used in the National Communications to the UNFCCC for seven COMIFAC countries (adapted from GIZ/BMU 2011).

Country	Number of communications to the UNFCCC	Simulated parameters	Reference period	Simulation time horizons	Trends
Burundi	2	Precipitation, temperature	1975-1990	2010, 2020, 2030, 2040, 2050	- precipitation: increase 2010-2030 ; decrease 2030-2040, then a new increase starting in 2050 - temperatures: 1° to 3°C increase 2010-2050
Cameroon	2	Precipitation, temperature, marine level	1961-1990	2025, 2050, 2075, 2100	- precipitation: overall increase with strong variability in the Sudano-Sahelian region up to 2100 -temperatures: 3°C increase -rise in marine level
Congo	1	Precipitation, temperature	1961-1990		-precipitation: +4 to 24% in 2050 ; +6 to 27% in 2100 -temperatures: +0.6 to 1.1°C in 2050 ; +2 to 3°C in 2100
Gabon	1	Precipitation, temperature	1961-1990		-precipitation: +5 to 6% in 2050 ; +3 to 18.5% in 2100 -temperatures: +0.9°C in 2050 ; +2°C in 2100
DRC	2	Precipitation, temperature, and atmospheric pressure	1961-1990	2010, 2025, 2050, 2100	-precipitation: from +0.3% in 2010 to +11.4% in 2100 -temperatures: from +0.46°C in 2010 to +3.22°C in 2100 -atmospheric pressure: from 0.52 hPa in 2010 to -0.47 hPa in 2100
Sao Tome and Principe	1	Precipitation, temperature, marine level	1961-1990		- precipitation reducing - temperatures rising - rise in sea level
Chad	1	Precipitation, temperature	1961-1990		-precipitation: +50 to 60 % in 2023 -temperatures: +0.6 to 1.7 °C

Previous reports on the State of the Forest are available for download in .pdf format at:
http://www.observatoire-comifac.net/edf.php?l=en

State of the Forests

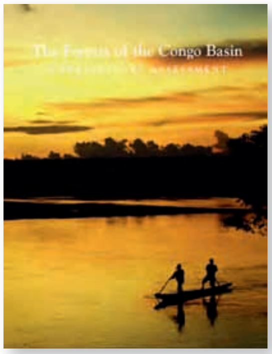
The Congo Basin forests cover 200 million hectares in the heart of Africa. They support the livelihoods of 60 million people, generate funds for States in the region through timber exploitation, absorb huge amounts of carbon, comprise a unique biodiversity and regulate the flow of the major rivers across Central Africa. Nevertheless many questions and uncertainties persist on the services the forests provide, their spatial evolution, the opportunities they represent and the threats they face.

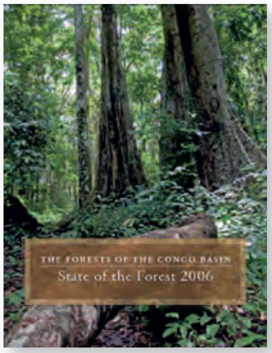
To overcome the lack of reliable information, numerous stakeholders in the region and beyond, from government departments, non-governmental organizations, the private sector and the scientific community, came together in 2005 to produce a first concise State of the Forest report at the initiative of the US-funded CARPE program, and a more comprehensive edition in 2006, with support from the European Union, the United States, France and Germany.
In 2007, the European Union backed this process with the following main objectives: (i) establish a system to monitor the natural and socio-economic environment of forest ecosystems in Central Africa based on a series of indicators; (ii) coordinate the publication every two years of a "Report on the State of the Forests", and (iii) launch the establishment of the Central African Forest Observatory (OFAC) for the benefit of COMIFAC member countries.

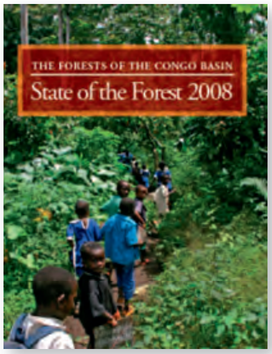
This State of the Forest report, now produced every two years by the Central African Forests Commission (COMIFAC) and the staheholders of the Congo Basin Forest Partnership, has become the gold standard for those looking for a comprehensive and detailed assessment of the status of the tropical forests of Central Africa.

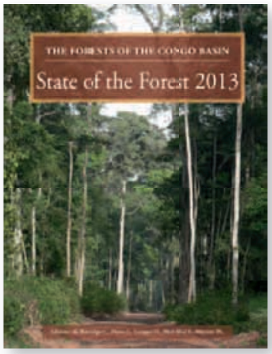
The State of the Forest 2010.

The design of the 2010 State of the Forest report does not differ fundamentally from that of the 2008 report and relies on indicators decided on collectively by about sixty

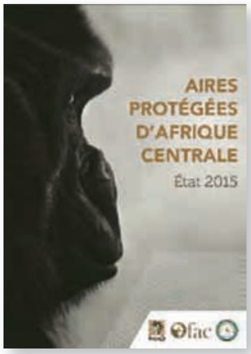








The State of the protected areas 2015 is available in french on the OFAC web site at:
http://www.observatoire-comifac.net/edAP2015.php



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