CHAPTER 1

The importance of Central Africa's forests

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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.

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.

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

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

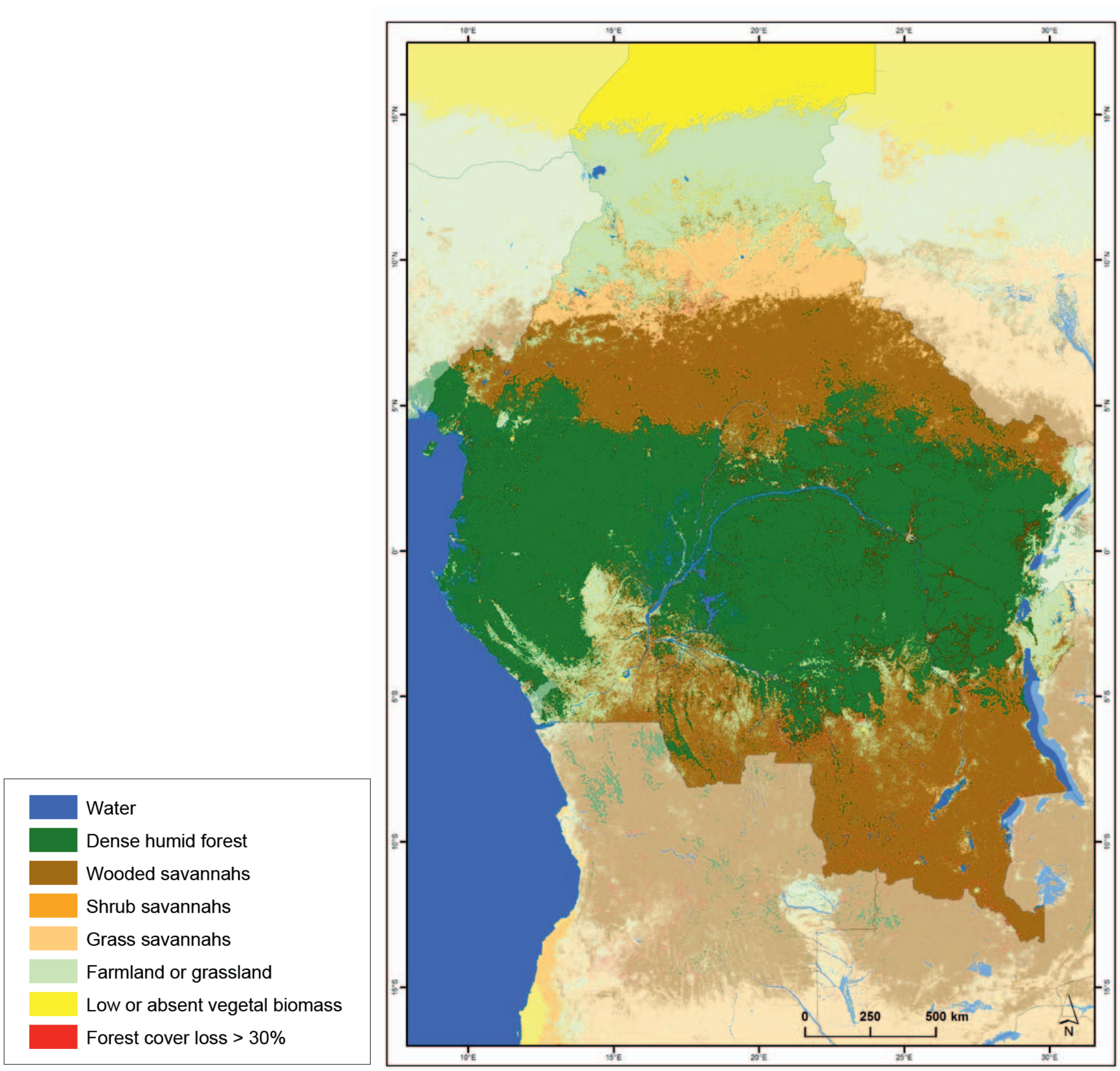

Figure 1.1: Forest cover in Congo Basin and forest covers loss between 2000 and 2012 according to data from MODIS Land Cover Type product – MCD12Q1

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)	

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).

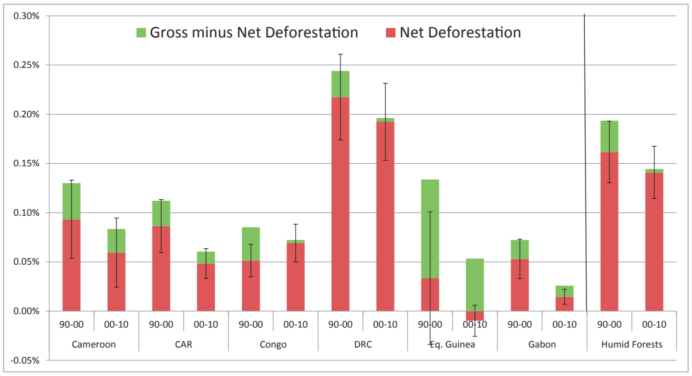

Figure 1.2 : Annual deforestation rates (gross and net) of Central Africa rainforests between 1990 and 2000, and between 2000 and 2010.

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

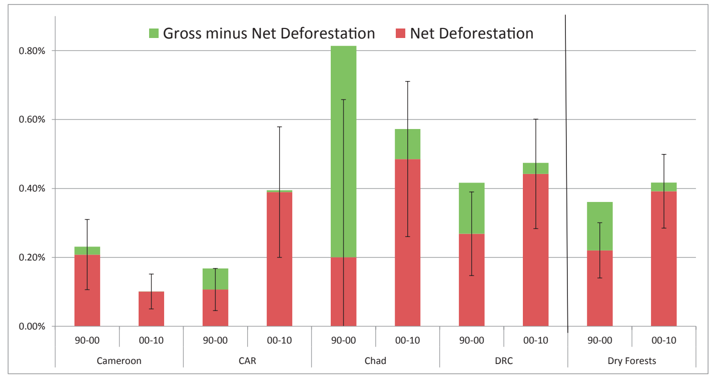

Figure 1.3 : Annual deforestation rates (gross and net) of dry forests in Central Africa between 1990 and 2000, and between 2000 and 2010.

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.

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.

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 1.2 : Itinerant household agriculture

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

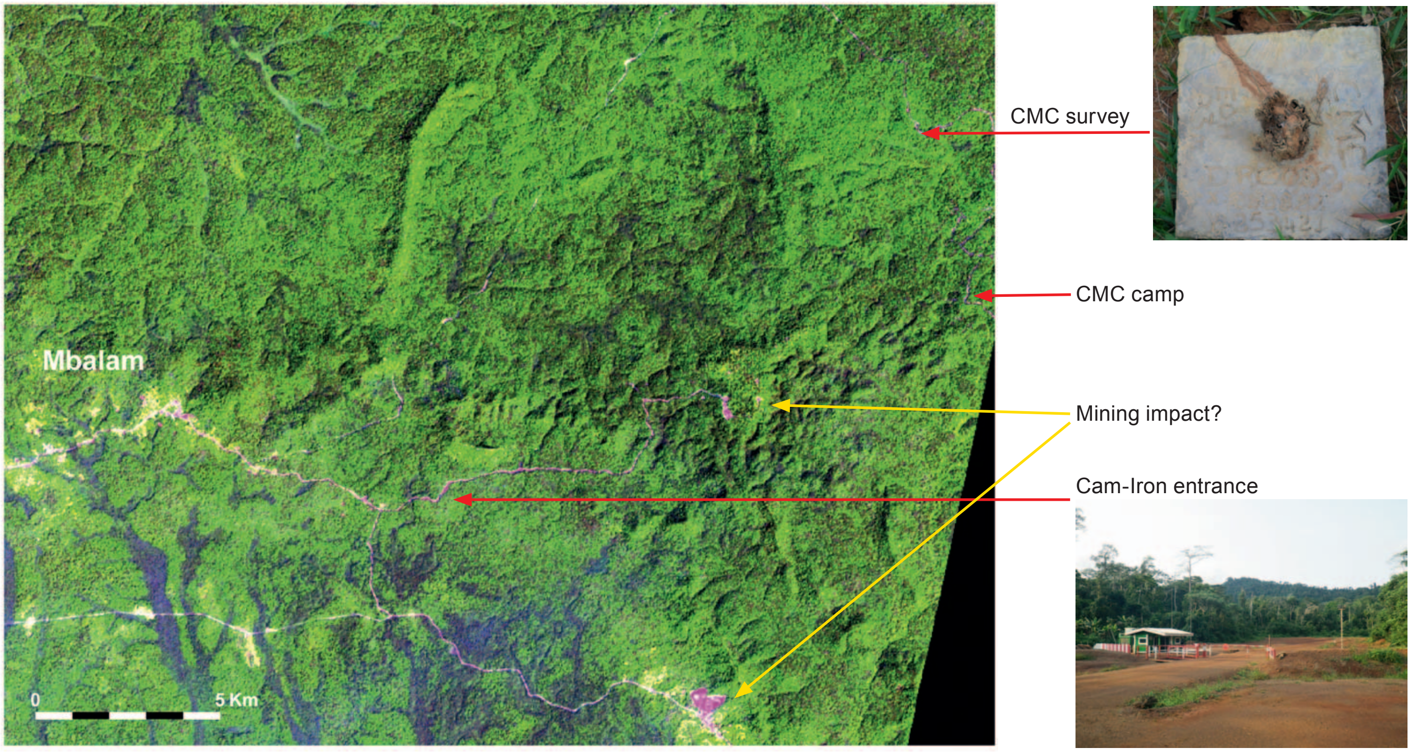

Figure 1.4 : Cartography of impacts in a mine in the south-east of Cameroon

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

can develop agricultural activity on new pieces of land and excert some more pressure on fuel-wood 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 ecosystem 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.

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?

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.

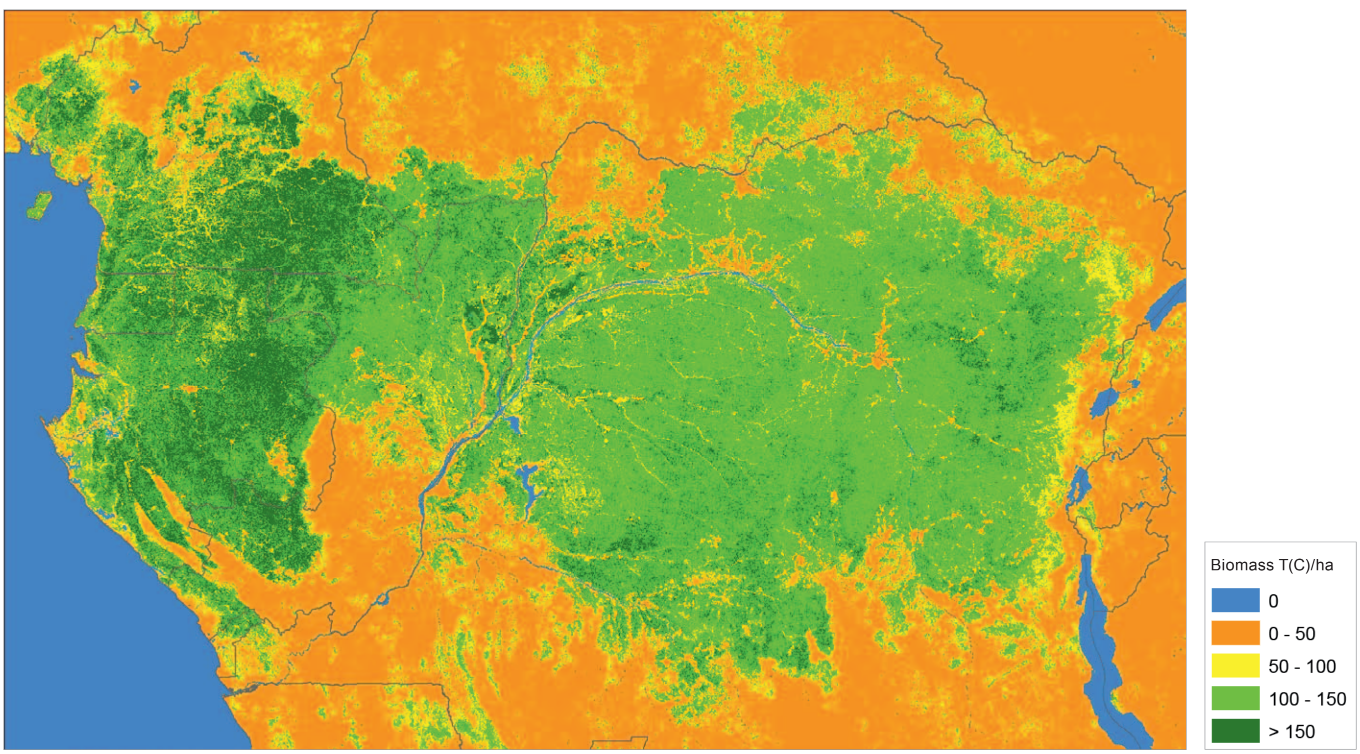

Figure 1.5: Distribution of biomass stocks of the main forest types in the Congo Basin.

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.*).

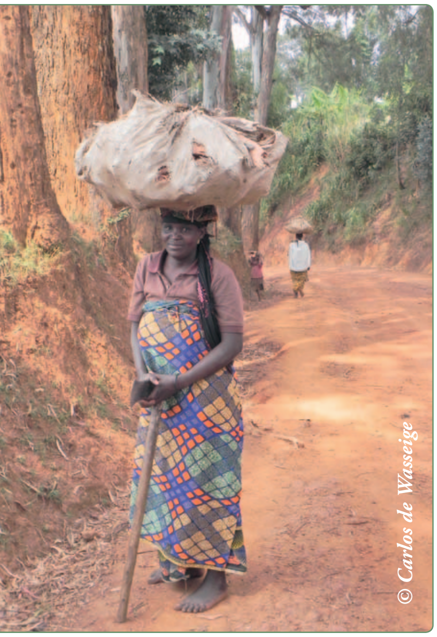

Photo 1.9: Fuelwood collection in the countryside in Burundi

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]".

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).

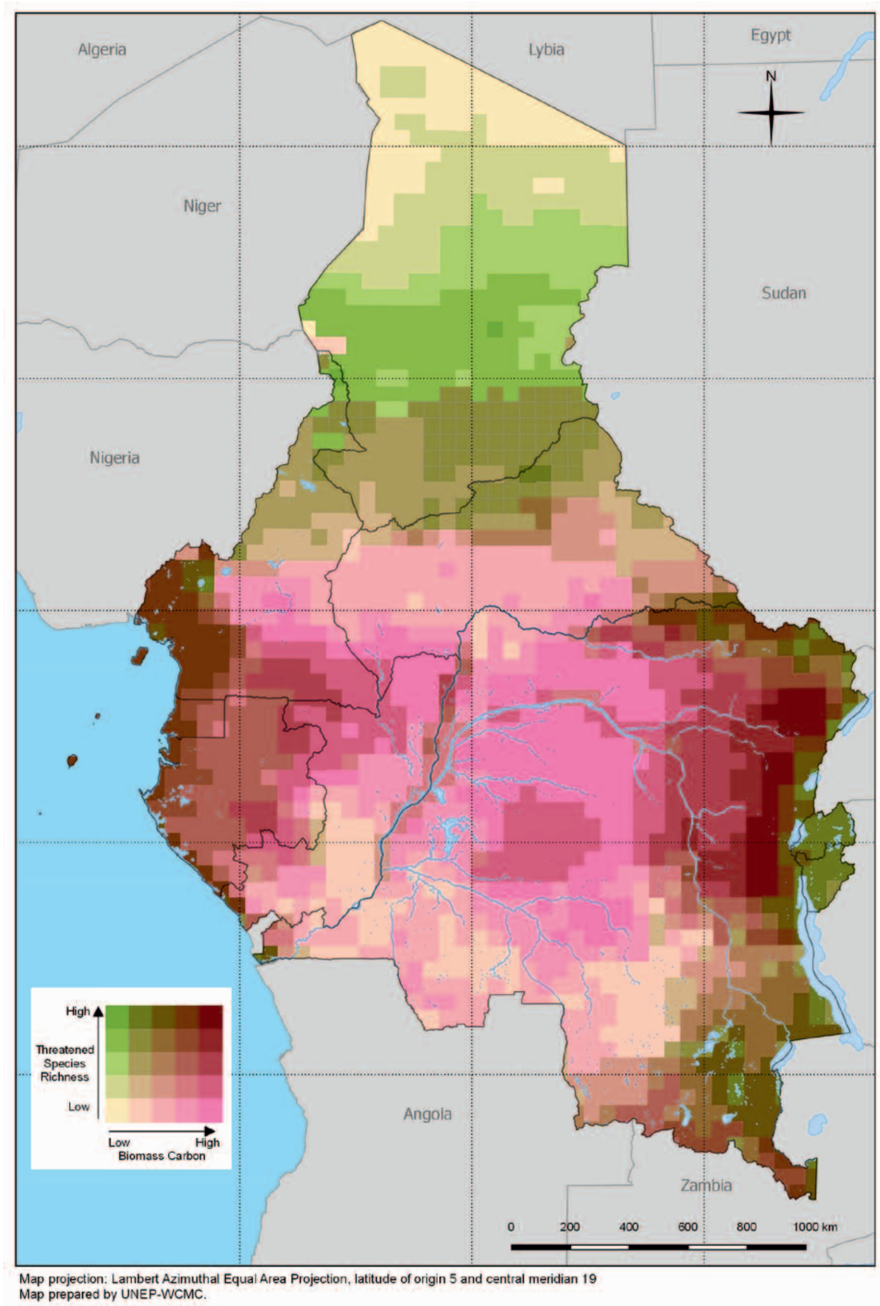

Figure 1.6 : Spatial variation of carbon density and potential specific richness of endangered species

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.

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).

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.

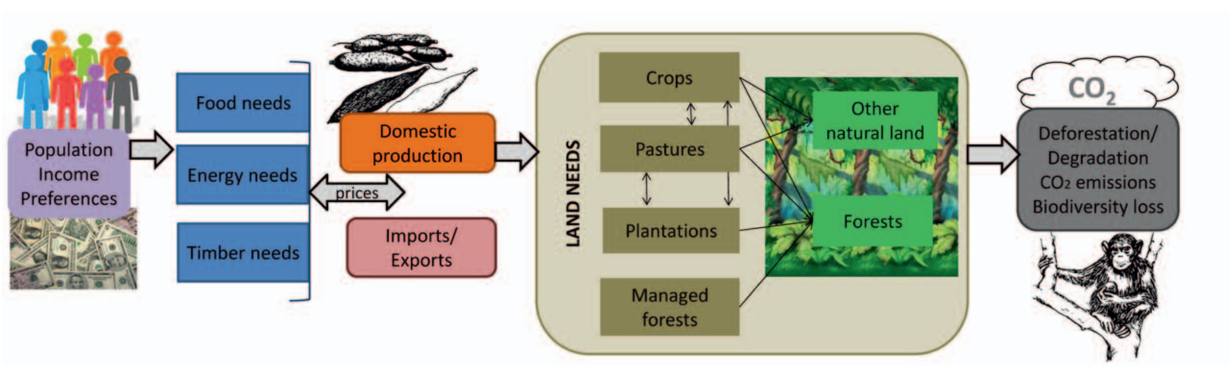

Figure 1.7: Future deforestation depends on future needs in food, in fuelwood and in energy in the CongoBIOM model

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.

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].

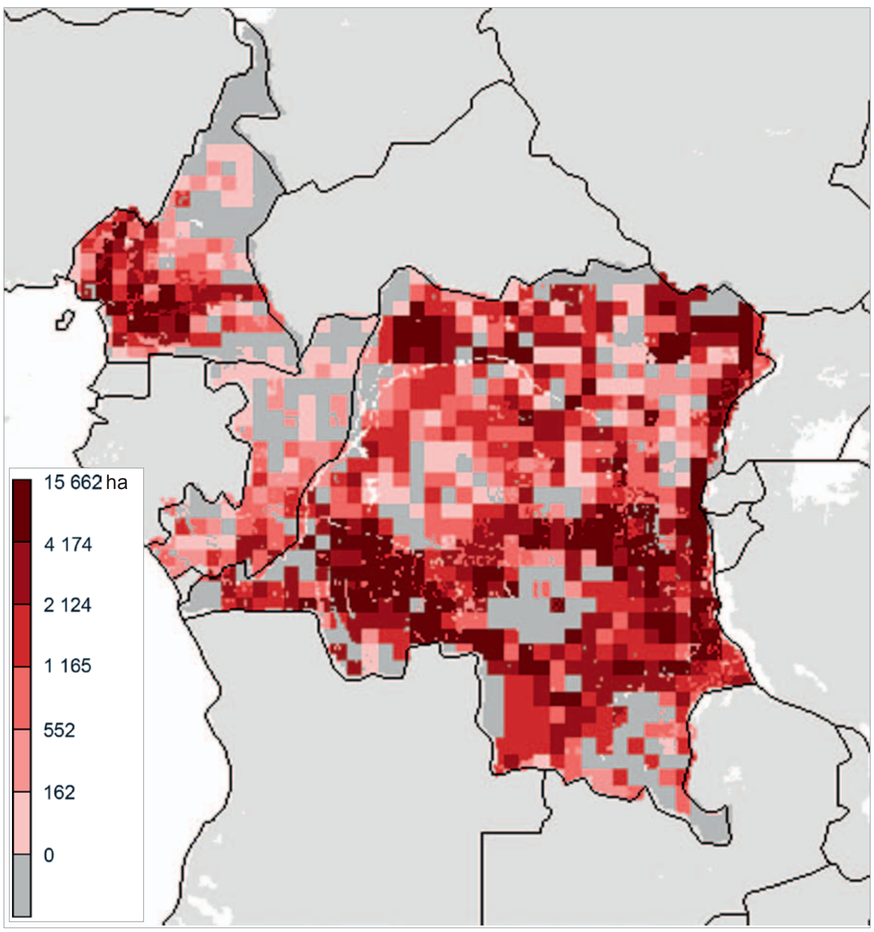

Figure 1.8 : Cumulative deforestation for the period 2010-2030 in Cameroon, Congo and DRC (findings resulting fom the CongoBIOM model)
Unit : ha per cells of 0.5 x 0.5 degrees

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.

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

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

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.

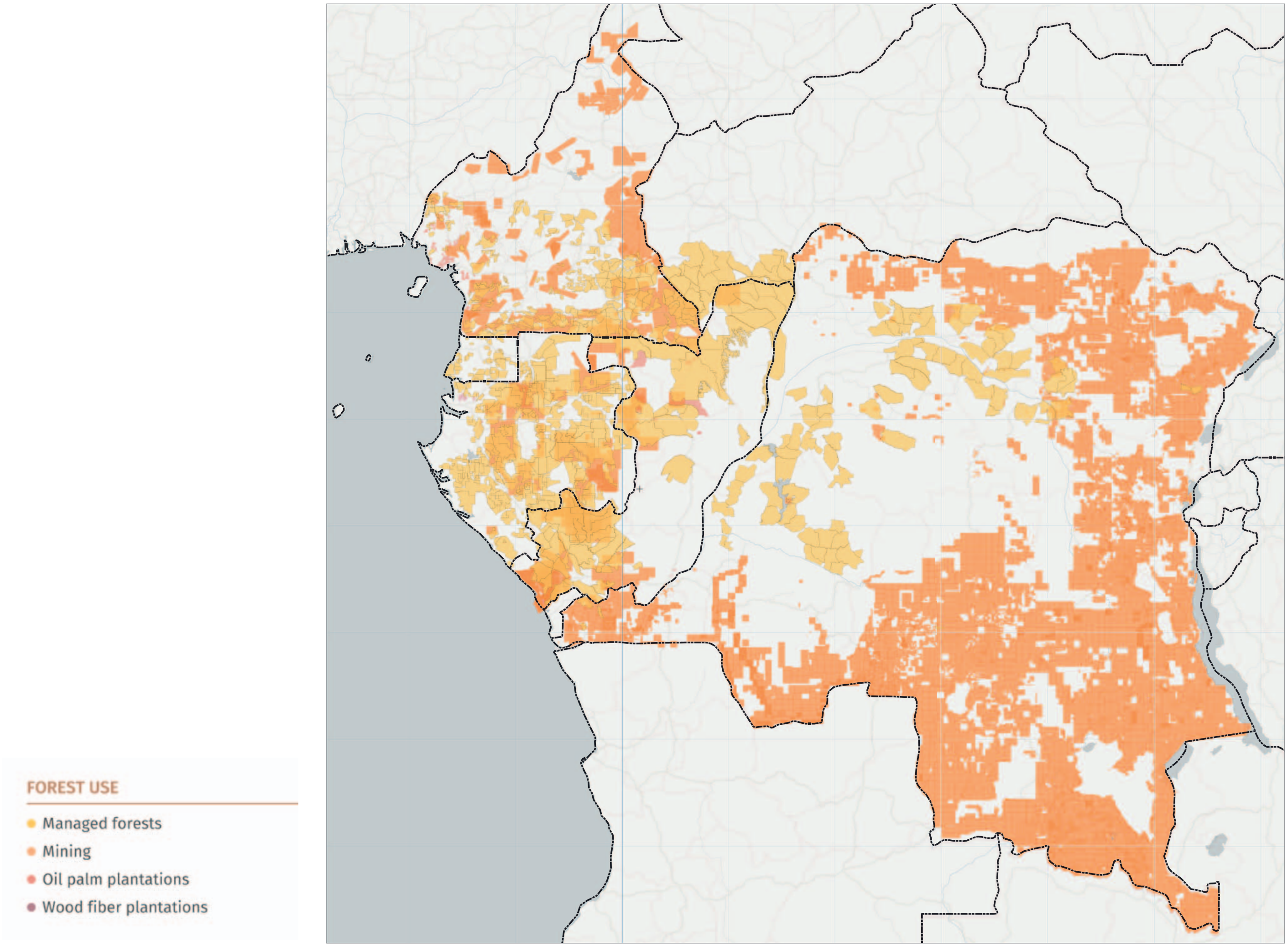

Figure 1.9: Overlaying of various land uses in some COMIFAC countries

Source: www.globalforestwatch.org/map/