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PROTECTED AREAS: A MAJOR ASSET IN THE FIGHT AGAINST CLIMATE CHANGE

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Although protected areas cover nearly 15.3% of the world's land area, including inland waters (Maxwell *et al.*, 2020), their role in fighting climate change remains insufficiently understood. They contribute substantially to optimizing carbon sequestration and storage by preventing deforestation and degradation of land and forest cover (Zapfack *et al.* 2013 and 2016; Noumi *et al.* 2018); the conservation of forests furthermore helps to maintain rainfall and regulate water flows and local and regional climates (Makarieva *et al.*, 2009; Nogherotto *et al.*, 2013; Bell *et al.*, 2015; De Wasseige *et al.*, 2015; Molina *et al.*, 2019). Protected areas also shelter many species of animals and plants and provide a range of ecosystem goods and services to human societies (Stolton *et al.*, 2015). Healthy, undisturbed ecosystems enhance resilience to the effects of climate change, and enable ecosystems and human populations to mitigate and adapt to these changes (De Wasseige *et al.*, 2015; Eba'a Atyi, *et al.*, 2015a).

Although they face multiple pressures, the overall health of natural ecosystems in Central Africa remains good. The Congo Basin forest is the second largest continuous tropical forest track after the Amazon. It contains one of the world's largest national forest parks, Salonga National Park, located in the Democratic Republic of the Congo (DRC). Protected areas in the subregion are home to unique biodiversity, one which remains rich, and highly diversified ecosystems (Doumenge *et al.*, 2015).

The dense humid forests of Central Africa contain the highest amount of biomass per unit area (418.3 ± 91.8T/ha) of all tropical forests, and thus store significant amounts of carbon (Saatchi *et al.*, 2011; Slik *et al.*, 2013). They contribute substantially to climate equilibrium at local, regional and continental levels. Diverse models of the impacts of deforestation in the Congo Basin on the climate indicate a likely increase in ground temperatures and reduction in rainfall in many areas of Central Africa, and severe deforestation could potentially impact the climate of neighboring regions (Nogherotto *et al.*, 2013; Akkermans *et al.*, 2014; Bell *et al.*, 2015).

Unfortunately, these high Central African deforestation scenarios may not be as far off as they seem. Deforestation rates in West and Central Africa continue to increase, edging up to 0.59% per year, and sometimes even higher. DRC, for example, has one of the highest deforestation rates in the world (0.83% per year), ranking just behind Brazil and ahead of Indonesia in terms of net forest loss for the period 2010-2020 (all forests included, dry and humid; FAO, 2020).

Protected areas in Central Africa also are contending with considerable anthropogenic pressures that are now being exacerbated by the effects of climate change. They face multiple threats, including deforestation, the clearing of land for agriculture, the development of mining projects, and poaching. These are weakening the protected area network, leaving it more sensitive to climate change impacts.

Climate change is causing noticeable impacts on biodiversity and protected areas, with changes in the distribution of species alongside reductions in population sizes and even local extinctions (Davis & Shaw, 2001; Balanyá *et al.*, 2006; Bush *et al.*, 2020). Increased air temperatures, changes in rainfall patterns, and increased frequency and intensity of extreme climate events (droughts, floods, etc.) are all manifestations of climate change, ones with far-reaching consequences on animal and plant species and on ecosystems as a whole (Hartley *et al.*, 2007; Belle *et al.*, 2016).

The threats to these ecosystems and the protected areas they contain diminish their effectiveness in providing ecosystem services and hamper their role in conservation, thereby undermining the contribution of these protected areas to climate change mitigation and adaptation processes (Ndiaye & Ndiaye, 2013). Among the key elements to be considered in strategies deployed by protected area networks to cope with climate change, several elements are particularly important. These include the management

effectiveness and connectivity of protected areas in relation to the dispersal capacities and vulnerability of species (Belle *et al.*, 2016).

Aware of the importance of protected areas in combating the damaging effects of climate change, Central African countries have ratified a range of conventions, treaties and agreements to strengthen and implement mechanisms for the sustainable management of their protected areas. Examples include the implementation of the 2011-2020 Strategic Plan for Biological Diversity adopted by the signatory parties to the Convention on Biological Diversity (CBD), Aichi Target 11 and the Paris Agreement (2015). With the signing of the Paris Agreement, governments decided to strengthen the global response to climate change, with the aim of limiting the increase in global average temperature to below 2°C above pre-industrial levels.

To achieve this objective, as advised by the Intergovernmental Panel on Climate Change (IPCC; GIEC, 2018), various scientists recommend reducing global greenhouse gas emissions by 45% by 2030 and achieving neutral emissions (offset by capture) by 2070. Considerable international efforts will be required to achieve this as figures unfortunately reveal a sustained rise in emissions, including in the areas of agriculture, forestry, and more broadly, land use (Shukla *et al.*, 2019).

Although fossil fuel use and industrial processes account for nearly 80% of greenhouse gas emissions (GIEC, 2018), increasing attention is being paid to agriculture and forestry due to their combined climate change mitigation and adaptation potential. IPCC recently addressed the issue of land use and the measures to be implemented in this area, which include reducing deforestation, the reforestation and restoration of land and ecosystems, changing land management methods such as agroforestry, better fire management, long-term integration of organic coals in soils, and improving livestock management (Shukal *et al.*, 2019). All of these measures, combined with energy efficiency and an increase in the share of green energy in the energy mix, represent today the first steps toward sustainable development.

In the light of the above, particularly the combined challenges of climate change mitigation and adaptation and the importance of land management in this synergy, several questions deserve to be considered:

- Are Central African protected areas contributing to the fight against climate change?

- Are Central African protected areas vulnerable to climate change?
- What measures should be taken to enable protected areas to fully engage in the fight against climate change threats?
- What are the "climate finance" opportunities for Central African protected areas?

We will try to answer these questions over the course of this chapter.

1. Contribution of protected areas to the fight against climate change

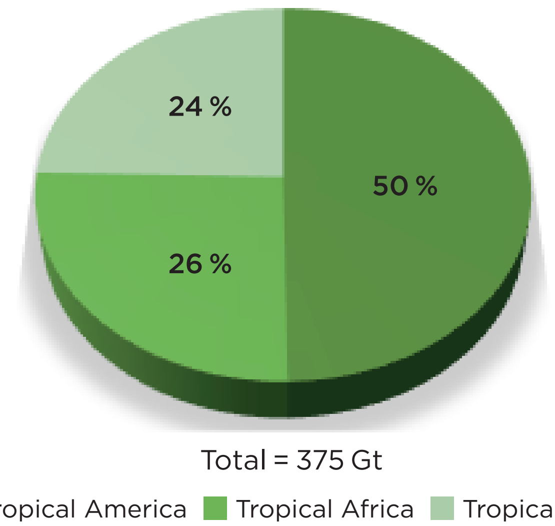
Global warming is presenting new challenges to the sustainable management of natural resource in protected areas. This is particularly due to the fact that protected areas are a "spatially static" management tool (the boundaries of protected areas are fixed) facing a "spatially dynamic" problem (climate variability, dispersion and adaptation of species). This problem can be addressed in part through more effective and adaptive management of protected areas. However, all this leads to an examination of the capacity of protected areas to serve as an important mechanism to combat climate change (Halpin, 1997; Heller & Zavaleta 2009). If managed effectively, protected areas can indeed play a major role in both adaptation and mitigation.

1.1 Mitigating climate change

The importance of Central African forests

African ecosystems play a significant role in climate change mitigation, storing just over one quarter of the 375 Gt of above-ground biomass in the intertropical zone (375 x 10^9 t, Avitabile *et al.*, 2016; Figure 1). The dense humid forests of Central Africa thus contain some of the highest above-ground biomass per unit area compared to Asian or American tropical forests: 418.3 ± 91.8 t/ha *vs.* 393.3 ± 109.3 and 287.8 ± 105.0 t/ha, respectively (Slik *et al.*, 2013; see also other references showing the variability of tree ecosystems: Baccini *et al.*, 2008; Saatchi *et al.*, 2011; Lewis *et al.*, 2013; Avitabile *et al.*, 2016).

Figure 1 – Above-ground biomass by continent in the intertropical zone

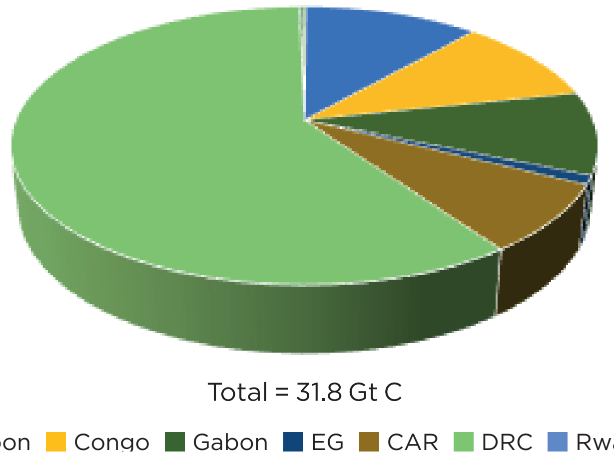


Source : Avitabile *et al.* (2016).

Central Africa alone holds more than 16% of intertropical above-ground carbon (Saatchi *et al.*, 2011). This percentage exceeds 20% of total carbon when soil organic carbon is considered, periodically flooded and swampy forests containing high amounts of both above-ground and below-ground carbon. These forests, in particular the vast expanses of peatlands in the Congo Basin, store 30.6 Gt of carbon in their soil, or the equivalent of the above-ground carbon stock of the entire Congo Basin (Dargie *et al.*, 2017; Ifo *et al.*, 2018). Unfortunately, they remain today very poorly protected (Dargie *et al.*, 2019).

In Central Africa, the above-ground carbon stock of ecosystems with tree cover greater than or equal to 10% is estimated to be about 31.8 Gt (Saatchi *et al.*, 2011). This carbon stock is very unevenly distributed between countries; due to its size and forest cover, DRC is in the lead, with nearly 60% of the subregion's above-ground carbon (Figure 2). The forested countries of Cameroon, Congo and Gabon also stock about 10%, and the Central African Republic (CAR) just slightly less. Rwanda and Burundi, on the other hand, are highly deforested but show good potential for land rehabilitation. This also is the case for Chad, a vast Sahelian country which does not stand out in the figure due to the difficulty of taking into account trees outside forests, but which has strong opportunities for afforestation.

Figure 2 – Above-ground carbon stocks by country in Central Africa



EG: Equatorial Guinea; CAR: Central African Republic; DRC: Democratic Republic of the Congo; STP: Sao Tome and Principe. Note 1: above-ground carbon stocks of ecosystems with tree cover ≥ 10%. Note 2: to convert carbon stocks into biomass stocks, doubling the former provides a fairly accurate estimate of the latter. Source: Saatchi et al. (2011).

By their very presence, these forests play a crucial role in regulating local and regional climates. They allow rainfall levels to be maintained up to several thousand kilometers inland; in contrast, rainfall decreases exponentially in deforested areas with distance from the sea (Makarieva *et al.*, 2009). Various simulations of deforestation in the Congo Basin have highlighted a likely overall rise in temperature (0.7 to 2 to 3 °C in the center of the basin) as well as a decrease in evapotranspiration and a drop in rainfall (Akkermans *et al.*, 2014; Bell *et al.*, 2015). These changes will not, however, be uniform. It is likely that the drop in rainfall will be greater in the western part of the basin (about −40%) than in the foothills of the Albertine Rift (about −10%), creating a climate anomaly dipole related, in particular, to the increase in horizontal winds from the Atlantic Ocean toward the rift (Bell *et al.*, 2015).

All of these changes will have repercussions beyond the Congo Basin itself through regional monsoon dynamics (Nogherotto *et al.*, 2013). From June to August, the monsoon could strengthen in West Africa, causing increased rainfall over the Sahel and decreased rainfall over the Guinean coast. From December to February, on the other hand, the African monsoon south of the Equator may strengthen, causing increased rainfall over this region. This further underscores the importance of considering all these phenomena at the regional and continental scale. Solidarity between countries, and the development of coordinated policies at the regional and continental level, including ones to develop a coherent forest and protected area network system, are vital.

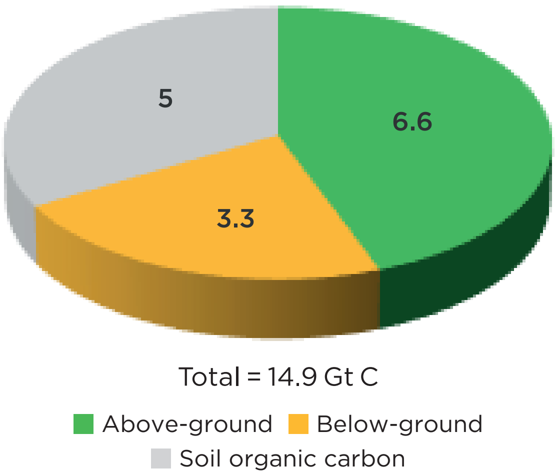
Protected areas and carbon stocks

By combating deforestation and land degradation, protected areas contribute to the maintenance of carbon stocks and carbon capture, as well as to climate equilibrium (Lewis *et al.*, 2009; Makarieva *et al.*, 2009; Marquant *et al.*, 2015; Harris *et al.*, 2021). These protected areas were designed mainly to safeguard biodiversity from direct human impacts, but they are equally capable of helping to fight climate change, beyond their primary role of protecting ecosystems.

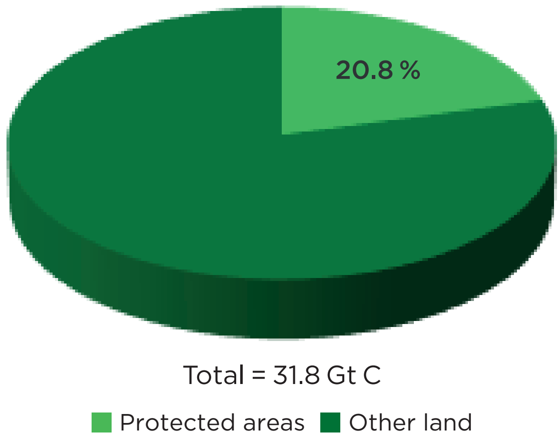
OFAC (*Observatoire des Forêts d'Afrique Centrale*) is currently assessing the carbon stocks conserved through the Central African protected area network. These protected areas extend over different biomes and contain a wide range of ecosystems. Some of these ecosystems, such as dense humid tropical and subtropical forests, store a significant amount of the world's carbon. An initial, very broad estimate indicates a total carbon stock of 14.9 Gt C for the ensemble of Central African protected areas, potentially representing three years of fossil fuel emissions of the United States. Above-ground carbon constitutes slightly less than 45% of this total (Figure 3a).

Protected areas cover approximately 17.6% of the land area of COMIFAC (*Commission des Forêts d'Afrique Centrale*) member countries (OFAC, 2020), yet they contain an estimated 20-25% of these countries' carbon stocks (Figure 3b). Salonga National Park, which is one of the world's largest tropical rainforest reserve, extending over 33,600 km^2, alone protects a stock exceeding 1.8 Gt C.

Figure 3 – Carbon stocks of the Central African protected area network



a) Distribution by reservoir (Gt C)



b) Importance in above-ground carbon storage in the subregion

Sources: OFAC (2020) and Saatchi *et al.* (2011).

Estimating the contribution of protected areas to the protection of carbon stocks in Central Africa

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Central African protected areas store large amounts of carbon but the size of these stocks has yet to be fully determined. This OFAC study is one of several currently underway to assess whether this ecosystem service could be used as a new instrument supporting the sustainable financing of protected areas.

To roughly estimate the total amounts of carbon stored in vegetation and soil in protected areas, OFAC compiled a set of available data on the main carbon reservoirs: above-ground carbon, below-ground carbon and soil organic carbon. The FAO GSOC map (2020) was used to obtain soil organic carbon data at a resolution of 1km. By applying a coefficient of 0.5 to the GLOBIOMASS map (ESA DUE, 2020), which lists all terrestrial above-ground biomass at a 100m spatial resolution, the mass of dry matter was converted into above-ground carbon. Finally, multiplying the figures provided by this map by a root-stem coefficient provided by IPCC, and applied to all ecological zones present in Central Africa (FAO, 2012), provided the results for the remaining reservoir: below-ground carbon.

The distribution between the three reservoirs (Figure 3a) seems to indicate a significant contribution from above-ground biomass, particularly due to the presence of dense forests, and from soil organic carbon. Recent discoveries of carbon stored in Central African peatlands suggest that these magnitudes could be revised upwards (Dargie *et al.*, 2017). At this point, the results obtained for Central African protected areas must be considered as rough estimates. They indicate the order of magnitude of protected areas' importance in regard to carbon storage, but they will need to be clarified in the future.

These results, coupled with a fair price per ton of carbon, point to the emergence of a new tool for sustainable financing of protected areas in Central Africa, particularly forest protected areas. To do so, the potential of each protected area will need to be analyzed.

In some countries, such as Rwanda and Burundi, agricultural and livestock activities have reduced perennial above-ground carbon stocks. The remaining forests survive thanks only to the network of protected areas (Doumenge *et al.*, 2015). They nonetheless help to regulate local climates and protect watersheds and water supplies essential for human societies.

While these old-growth forests do contribute somewhat to carbon capture, the major carbon sinks are primarily secondary forests and areas located in forest-savanna ecotones (Lewis *et al.*, 2009; Baccini *et al.*, 2017; Harris *et al.*, 2021). A natural reforestation dynamic has been reported for several decades around the entire dense humid forests (Youta Happi *et al.*, 2003; Maley & Doumenge, 2012; Aleman *et al.*, 2017). Protected areas allow this reforestation dynamic to flourish.

Encouraging forest regeneration and the restoration of land in protected areas that have been impacted in the past by human activities also enables significant amounts of carbon to be stored. This requires looking beyond the boundaries of protected areas to understand their interactions with their surroundings. As part of a landscape management approach, the management of carbon stocks and flows in these surrounding areas can and should complement the role of the protected areas themselves. Indeed, both secondary forests and agricultural land can store significant amounts of carbon if the planting of useful trees and agroforestry are encouraged (Fongnzossie *et al.*, 2014). In addition to protected areas, numerous forestry concessions can, under sustainable management, both maintain a large amount of standing timber and help reduce carbon emissions (Eba'a Atyi *et al.*, 2015b).

Initiatives are underway across the subregion to integrate climate considerations into protected area programs, mitigate the effects of climate change and implement adaptation activities.

1.2 Climate change adaptation

Various climate models applied to Central Africa converge to predict an increase in atmospheric temperatures. This warming will probably be higher north and south of the dense humid forest block and in the savannas, and lower in the center (except in the case of massive deforestation). With regard to rainfall, predictions are less consistent, suggesting a slight increase in annual rainfall in some areas such as the Sahel, but, more importantly, more irregular rainfall patterns and an increase in the duration and intensity of dry periods (Tsalefac *et al.*, 2015).

Protected areas help to improve the resilience of ecosystems and human societies facing climate

change. Healthy vegetation, in particular forest vegetation, help to protect watersheds, prevent soil erosion, and maintain the sources and quality of water required for human activities (livestock farming, agriculture). The presence of forests in landscapes make it possible to recycle 30 to 50% of rainfall through evapotranspiration (Salati *et al.*, 1983). Apart from this local effect of forest cover, air masses that have circulated over forested areas can generate at least twice as much rain as those that have circulated over deforested areas (Makarieva & Gorshkov, 2010; Spracklen *et al.*, 2012), favoring greater crop and livestock production.

Natural ecosystems also provide shelter to pollinating insects (including bees), which are essential for agriculture. Moreover, these natural ecosystems supply products essential to human societies (food and medicinal plants, game, etc.). These products can be exploited in some protected areas provided they are set up for this purpose (e.g., International Union for Conservation of Nature-IUCN categories V and VI). Above all, these ecosystem goods and services provide human societies with essential resources in the event of poor harvests, food shortages and epidemics (Hopkins *et al.*, 2015).

The old-growth forests in Central Africa, which thus far have been able to tolerate climate fluctuations, will likely be able to withstand future changes (Maley *et al.*, 2018). These old-growth forests also are commonly ecosystems with high biodiversity, and even harbour many endemic species (Gonmadje *et al.*, 2011). They may also contain large amounts of carbon, although the relationships between increasing carbon stocks, increasing biodiversity and endemism may not always move in the same direction; these relationships also may vary depending on whether plant or animal biodiversity is being considered (Beaudrot *et al.*, 2016; Gonmadje *et al.*, 2017; Ifo *et al.*, 2018; Van de Perre *et al.*, 2018).

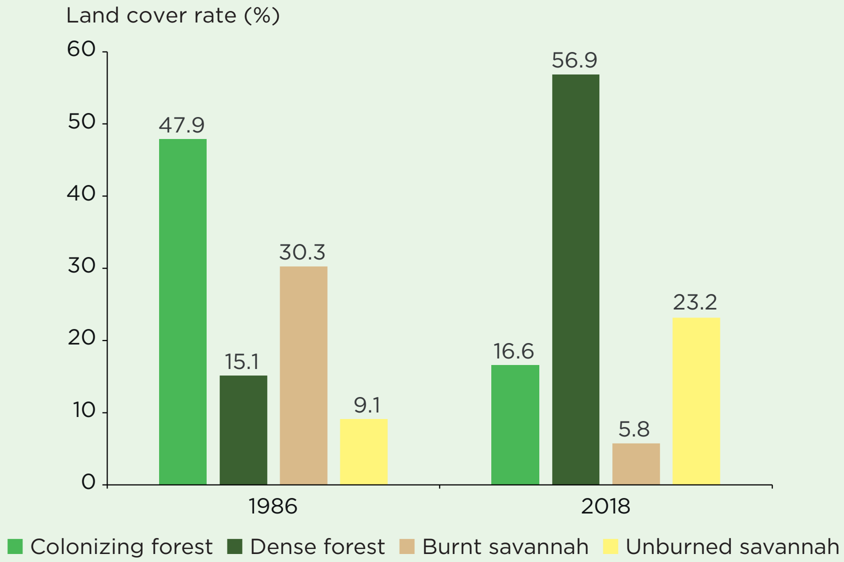
Overall, protected areas are essential tools for mitigating the impacts of climate change on ecosystems and human communities. They help maintain the integrity of ecosystems, buffer climatic fluctuations and reduce the impacts of extreme weather events that will increase in coming years (Hopkins *et al.*, 2015). Two elements may be highlighted here. First, the transboundary protected areas that have been established in Central Africa help to protect vast areas that are better able to maintain viable animal and plant populations, withstand climate change and mitigate its impacts. Second, the protected areas also can serve as barriers against uncontrolled fires, reducing their destructive effects, although very different strategies must be applied in forest and savanna areas (Nepstad *et al.*, 2006; Van Wilgen, 2009; Nelson & Chomitz, 2011).

Contribution of protected areas in the fight against climate change: the case of Mbam-and-Djerem National Park (Cameroon)

Mbam-and-Djerem National Park, situated in central Cameroon in a forest-savanna ecotone, is witnessing the forest reconquer the savanna (Youta Happi *et al.* 2003; Mitchard *et al.* 2009). The park extends over 4,165 km² (MINFOF, 2007) and is an essential component of Cameroon's protected area network. It was created in 2000 to compensate for the environmental impacts of the Chad-Cameroon oil pipeline.

Land cover dynamics within the park were assessed using Landsat satellite data (Figure 4). These data show a rate of advance of dense forest over savanna and young forests of about 40% between 1986 and 2018. In 1986, dense forests occupied just 15% of the territory, thirty years later, they covered 57% (Figure 2). This implies that a carbon stock is present and has grown considerably over this period (not estimated here).

Figure 4 – Evolution of different land cover classes between 1986 and 2018 in Mbam-and-Djerem National Park



Source: Kamgang *et al.* (2019).

Favorable environmental and climatic conditions, good soil conditions, low human population density and isolation are steering forest-savanna interface dynamics in the favor of the forest (Youta Happi *et al.*, 2003). This is true elsewhere in the central region of Cameroon, albeit to a varying extent. While dense forest is increasing inside the park, it has decreased over the past two decades in the areas around it (Fotso *et al.*, 2019).

Improved coordination between various actors, both within the park and in protected areas in general, would thus optimize climate change mitigation and adaptation. This involves taking into consideration carbon market scenarios when planning and implementing conservation activities. It also includes adapting protected area management to climate change in order to ensure the continued existence of biodiversity and ecosystem services. Deriving value from the carbon captured thanks to the advance of the forest would help to fund protected areas and improve the resilience of local communities to the effects of climate change.

2. Impacts of climate change on Central African protected areas

Increased air temperatures, changes in rainfall patterns, and increased frequency and intensity of extreme climate events (droughts, floods, etc.) are all signs of climate change. The threats to ecosystems and protected areas are reducing their ability to supply ecosystem services and are hampering their in situ conservation role.

2.1 Safeguarding ecological processes

The impacts of climate change on biodiversity in Central Africa are to a certain extent spread out. This leads to the need to develop appropriate methods to assess the vulnerability of species to the climate changes that are both underway and expected over the decades to come. To minimize global biodiversity losses, the species vulnerable to these changes must be identified (Pacifici *et al.*, 2015).

To assess threats to a species stemming from climate change, information on the species' vulnerability is required (i.e., the species' predisposition to be negatively affected by changes). This vulnerability depends on intrinsic and extrinsic factors, exposure to identified changes, sensitivity of the species to these changes and its adaptability (Williams *et al.*, 2008; Foden *et al.*, 2013; De Wasseige *et al.*, 2015: 57 and 58).

Although many studies have focused on the response of biodiversity to climate constraints, data on the mechanisms through which biodiversity adapts to climate change, and especially on the limits of this adaptability, remain patchy, and understanding of these mechanisms remains limited. Yet in order to consider how biodiversity may evolve in response to changes in the environment, a comprehensive overview is required (Lavorel *et al.*, 2017). A critical point concerns the speed of possible adaptive mechanisms and individual responses of species with respect to the time and space scales of disturbances.

Species' individual responses to climate change could cause cascading and feedback effects in biological systems, affecting ecosystem dynamics (Williams *et al.*, 2008; Ricard, 2014). The spatial reorganization of biodiversity, as well as changes in the phenology of species, are already causing the disruption of several biotic interactions (Parmesan, 2006) and could have important indirect effects on other species via food webs (Duffy, 2003; Schmitz *et al.*, 2003). The potential spread of invasive species, insect pests and pathogens may also affect ecosystems, and an increase in the frequency of pest infestations and diseases as a result of climate change already is apparent (Gitay *et al.*, 2002; Ricard, 2014; Biber-Freudenberger *et al.*, 2016).

2.2 Vulnerability of fauna

The vulnerability of wildlife to climate change, along with intensifying pressures from human activities, is causing the decline of biodiversity in protected areas. With changes already noticeable in the geographic distribution of diverse terrestrial and aquatic organisms in response to global warming, little information exists on the direct links between innate characteristics (including physiological traits, physiological tolerance limits and genetic diversity) and the vulnerability of species to climate change (Root *et al.*, 2003; Calosi *et al.*; 2008; Williams *et al.*, 2008; Pacoureau, 2018).

Over the past 100 years, the global average temperature has increased by approximately 0.714 ± 0.18 °C, and it is expected to continue to rise at a rapid rate (Pachauri & Reisinger, 2008; Welbergen *et al.*, 2008). During periods of rapid climate change, taxa which are unable to change their geographic range are at particular risk of extinction, especially if they cannot physiologically compensate for variations in the environment (Bradshaw & Holzapfel, 2001; Davis & Shaw, 2001; Balanyá *et al.*, 2006).

Although they may not disappear immediately, the populations of various species in Central Africa could decline sharply under the impact of extreme climate events. For example, sedentary antelopes and elephants could be sensitive to severe droughts (Maron *et al.*, 2015). Climate change will also alter the flowering and fruiting capacity of vegetation, with cascading effects on all of the species which depend on it (Butt *et al.*, 2015). This seems to be the case for forest elephants, whose health already has been impacted by a significant decrease in the plant species which they consume. Long-term studies

carried out in Lope National Park in Gabon have revealed a drastic drop of around 80% in the fruit production of plant species consumed by elephants between 1986 and 2018, and a decline of over 10% in the body condition of fruit-dependent elephants since 2008 (Bush *et al.*, 2020).

These in-depth studies concerning current and future changes in ecosystems and biodiversity are invaluable, but they remain rare and piecemeal. Certain models can partially compensate for these shortcomings, and seem to indicate that the Congo Basin could become unsuitable for mammals in the long term while the Atlantic side of Central Africa could prove to be an important refuge for mammalian biodiversity at the level of Africa (Thuiller *et al.*, 2006).

The effects of extreme temperatures on wildlife species highlight the complex ramifications of climate change on the behavior, demographics and survival of species. The physiological mechanisms underlying thermal tolerance limits and the capacity to adapt to these limits thus need to be better understood to predict the direct impact of global warming on wildlife diversity. This remains an area of research to be developed in the protected areas of Central Africa.

2.3 Vulnerability of flora

Climate change is now recognized as one of the major threats to the integrity of ecosystems around the world. In particular, climate change will affect biological diversity and the geographical distribution of habitats favorable to species, including useful and cultivated plant species (Parry *et al.*, 2007; Fandohan *et al.*, 2013; Eba Eba'a Atyi *et al.*, 2015a). Knowledge of the specific characteristics of the changes likely to impact species or their habitats is a key element in adaptation strategies (Heller & Zavaleta, 2009; Fandohan *et al.*, 2013). Climate change is an environmental issue that deserves special attention in terms of planning agricultural production, diversification of agricultural production, and conservation of plant species.

In Africa, 25 to 42% of plant species could be threatened with extinction due to a loss of 81 to 97% of suitable habitats by 2085 (Solomon *et al.*, 2007). It is projected that 20 to 30% of plant species will face a greater risk of extinction if global warming exceeds 1.5°C to 2.5°C (Parry *et al.*, 2007; Busby *et al.*, 2012). This makes it all the more important to identify the areas that could allow vulnerable species to survive. To do so, both ecological modeling (Hulme *et al.*, 2001; Bell *et al.*, 2015; Tsalefack *et al.*, 2015; Tamoffo *et al.*, 2019) and paleoecology (Willis *et al.*, 2013) approaches are required. Knowledge of past changes in the climate and their effects on ecosystems has helped identify former forest refuge areas that could prefigure, at least to some extent, future forest refuges (Maley *et al.*, 2018). An understanding of these refuge areas is essential for preparing adaptation strategies and establishing effective protected area networks.

In the very short term, some studies carried out in Lope National Park (Gabon) have found that the fruiting of certain plant species has already begun to plummet (Bush *et al.*, 2020). The reproduction of many tree species depends on a slight drop in temperature during the dry season, one which no longer occurs when temperatures rise (Tutin & Fernandez, 1993). As discussed above, this in turn affects animal populations. This increase in temperature is therefore likely to lead to the depletion or even the eventual disappearance of these plant species due to reproductive collapse.

Moreover, drought also leads to a general increase in tree mortality, especially of larger trees and those with low density wood; this is already the case in the Amazon and Southeast Asia (Phillips *et al.*, 2010). More droughts favors the selection of the most drought-resistant species and induces changes in vegetation. This was demonstrated in a study conducted in Ghana in dense tropical forests following two decades of a drier climate (Fauset *et al.*, 2012). The authors found an increase in canopy, deciduous, intermediate light demanding, dry forest species (often very widespread), and a decrease in sub-canopy, shade-tolerant, evergreen species (often rarer and more localized). A similar, albeit less pronounced, phenomenon has been observed in the Amazon in most of the sites studied there (Esquivel-Muelbert *et al.*, 2019).

Woody forage vegetation in landscapes used by livestock farmers would also be more vulnerable due to the strong pressures this vegetation is already experiencing (Nyasimi *et al.*, 2015; Zakari *et al.*, 2017). Across most of Africa, this vegetation is now generally decreasing due to the constant decline in rainfall since the 1960s, an expansion of land under cultivation, livestock farming systems which often lead to the overexploitation of this resource and a rapidly increasing urban demand for wood (Onana & Devineau, 2002). Protected areas could thus play a significant role as a refuge for natural vegetation and associated wildlife, and as a source of diaspores and genetic material for the restoration of degraded landscapes.

2.4 Vulnerability of human populations

In the light of current global climate change, protected areas offer an exceptional opportunity for the conservation of biological resources and human livelihoods (Mansourian *et al.*, 2009). Once biodiversity begins to crumble, the human species is itself in danger. Protecting and managing these resources in a sustainable manner appears essential, and fighting for the preservation of forest ecosystems and wildlife is necessary to stave off the most common types of threats and to reflect on mitigation solutions (Ongolo & Karsenty, 2011).

Climate variability is posing a significant threat for African populations and communities. Some studies already have revealed that global climate change is occurring in a wide range of areas, affecting almost all human societies (Sutherst, 2004; Ouedraogo, 2010; Goujon & Magnan, 2018).

Agriculture plays an important role in African economies, but it is highly sensitive to climate conditions. Most studies have demonstrated that climate change is having a negative impact on the productivity of food crops in Africa. Although farmers have demonstrated their capacity to adapt to past climatic and environmental variations in the past, their ability to overcome future challenges will depend on their knowledge and the support policies implemented by governments (Challinor *et al.*, 2007).

Recent data cover certain aspects of climate change and human health, including infectious diseases (Chan *et al.*, 1999; Martens, 1999; Patz *et al.*, 2000) and vector-borne diseases (Sutherst, 1993; Gubler *et al.*, 2001). However, there continues to be a lack of in-depth quantitative studies on the many processes underway (Martens *et al.*, 1997; Chan *et al.*, 1999). This is due in part to the complexity of various indirect and feedback mechanisms which involve every aspect of global climate change. This implies a need to adopt a holistic approach to risk assessment and the management of vector-borne diseases (Wilson, 1995; Gratz, 1999).

Unfortunately, due to the current state of expertise and analytical data and the limited resources available to the scientific community, only isolated subsets of these changes have been considered in quantitative risk assessments despite the numerous interactions between the different drivers of change (Sutherst, 2004). It is nonetheless vital to assess the risks of potential changes in the status of vector-borne diseases in an evolving world. Various approaches also must be considered to adapt effectively to these changes. Table 1 highlights some environmental effects of climate change factors relevant to vector-borne diseases and their potential biological effects.

The impacts of climate change also seriously threaten development efforts and opportunities in Central Africa due to the subregion's dependence on natural resources, limited capacity to adapt, and high levels of poverty (Ouedraogo, 2010). Eradicating poverty in the region will require increased access to clean energy and better redistribution of wealth, in particular through appropriate policies and institutions (Eba'a Atyi *et al.*, 2015a).

Table 1 - Climate change factors relevant to vector-borne diseases and their potential biological effects

Driver of global change	Potential effects on vectors, pathogens and hosts environments	Potential effects on vectors, pathogens and hosts
Higher CO_2 concentration	Increased ambient temperature and plant biomass; range expansion of woody vegetation; longer plant growth season with humid microclimates	Increased longevity of vectors for the same rainfall and temperature through wetter microclimates, with possible range expansion of humid-zone vectors
Temperature increase (regional/temporal variation)	Expansion of warm climatic zones, with longer growing seasons, less extreme low temperatures and more frequent extreme high temperatures	Faster development of vectors and pathogens, with more generations per year; shorter lifetime of vectors at high temperatures, reduced low-temperature mortality of vectors, and range expansion of warm-climate vectors and pathogens
Precipitation	Factor too uncertain and regionally variable to be estimated but increase in frequency of extreme rainfall events	Altered patterns of breeding of mosquitoes, with more flushing of mosquito breeding sites with increased flooding
Urbanization	Increased human host density with poorer sanitation and water supply in numerous countries	Higher rate of disease transmission at the same vector density; more vector breeding sites
	Increased urban development in or near forests	Increased contact between humans and vectors in peri-urban forested areas
Deforestation	Increased human entry into forests and increased surface water in soils exposed by logging or agriculture	More vector breeding sites and more contact between humans and vectors
Irrigation and water storage	Increase of surface water, prevention of seasonal flooding	More vector breeding sites; reduced flushing of snails and mosquitoes
Intensification of agriculture	Increased land and vegetation disturbance and increased surface water; reduced biodiversity	Greater diversity of vector breeding sites, with reduced vector predation
Chemical pollution	Fertilizers, pesticides, herbicides and industrial toxins and endocrine disrupting chemicals	Altered human immune systems
Increased trade	Increase in the volume of goods shipped	Increased vector transport, leading to «homogenization» of vectors in receptive areas
Increased travel	Increased movement of people between North and South and East and West	Increased transfer of pathogens between endemic and disease-free regions, and increased visitor exposure to endemic regions

Source: from Sutherst (2004).

2.5 Vulnerability and adaptation of protected area networks

As discussed above, climate change will cause shifts in the climate niches of species. In response, these species will have to either evolve or move in order to adjust their spatial distribution. Current models also predict major changes in the composition of biological communities.

The management of protected areas is directly impacted by these ecological challenges. The impacts of climate change on biodiversity, both actual and potential, must be integrated into the way protected areas are managed. Assessing the vulnerability of biodiversity is the first step in the process of adapting these management methods. The pressure that climate change is exerting on the distribution of species underscores the need to set up conservation strategies at local, national and international scales to achieve conservation goals (Ricard, 2014).

At present, protected area managers in Central Africa have not yet clearly identified reference species (fauna and flora) or biological indicators that could enable us to accurately measure the vulnerability of species and protected area networks to climate change. As baseline data needed for decision-making are scarce and scattered, particular emphasis should be placed on scientific research as a major component in the implementation of programs and projects under REDD+/++ (Reducing Emissions from Deforestation and Forest Degradation, including the role of conservation and enhancement of forest carbon stocks), carbon markets and green economy mechanisms, among others.

For example, it would be interesting to measure, in the Central African protected area network, how extreme temperatures influence certain plants (phenology), the distribution, physiological responses and other adaptation mechanisms and behavioral changes (feeding, reproduction, gene flow, etc.) of sensitive wildlife groups (mammals, birds, amphibians, etc.), and to identify tolerance thresholds. Current ecological monitoring programs, where they exist, are not always relevant or sufficient to assess the vulnerability of species and protected areas to climate change. They deserve to be updated or redefined in order to provide decision-makers and managers with adequate information for informed decision-making in this regard. Climate change research should not only be diverse but also multi-disciplinary, collaborative and oriented toward understanding "cause and effect" relationships at the level of different taxonomic groups.

Ultimately, assessments of potential climate change impacts should be continued using diversified analytical tools in order to increase our confidence in

the results obtained and to provide more answers to the concerns of protected area managers in Central Africa. To this end, the use of global circulation models (Zakari *et al.*, 2017) and the vulnerability index developed by NatureServe to assess the vulnerability of species of interest seems promising (Gendreau, 2016; Young *et al.*, 2016).

3. Financing Central African protected areas in the fight against climate change

Although they play an undeniable role in the fight against climate change, protected areas in Central Africa also are suffering the effects of climate change (see sections 1 and 2 of this chapter). In an international context where decision-makers, scientists and other stakeholders recognize the relevance of nature-based solutions to today's environmental challenges, the role of protected areas remains insufficiently acknowledged. However, this role should and must be strengthened.

In addition to the various sources of funding available to protected areas (Joyeux & Gale, 2010), carbon could add value to biodiversity conservation activities. The value of carbon storage should be considered as one of the criteria for determining support for existing protected areas and the boundaries of new protected areas (Kemeuze, 2015). It is important to note that the capacity for carbon sequestration and storage increases rapidly when degraded areas have been restored. These elements may enable protected areas to potentially access funds allocated for both climate change mitigation and adaptation. For this, it is necessary to include in strategies concerning protected areas their carbon storage function and their key role in reducing emissions from deforestation and ecosystem degradation. This implies regularly evaluating these elements and adjusting the management of protected area networks, not only according to biodiversity conservation objectives, but also those of combating climate change.

The financing mobilized at the international level to combat climate change, as well as payment mechanisms for environmental services, could make it possible to improve and maintain the contribution made by Central African protected areas to fighting climate change. These protected areas suffer, however, from a chronic lack of financial resources for effective and efficient management, which hinders them from fully contributing to this fight.

Contributions to the financing of Central African protected areas, within the "green finance" framework, could consist of public funds (national and international), funds from donations or foundations and other Non Governmental Organizations (NGOs), or resources from the private sector (carbon market, funds made available within the framework of Corporate Social Responsibility (CSR), etc.). Currently, traditional funds, mobilized by States or, for example, within the framework of Global Environment Facility (GEF) funding or by certain NGOs and international organizations, fall well below the funding needs of African protected areas, particularly in Central Africa. An analysis of financial flows to tropical forests over the past 10 years reveals that the Congo Basin has received only 11.5% of international funds, compared to 54.5% for Southeast Asia and 34% for the Amazon (Liboum *et al.*, 2019).

3.1 Green finance and financing opportunities for protected areas

Projects in the Central African forest-environment sector – including those related to climate change – currently mobilize nearly US$2.3 billion in international funding; these are projects that were operational in 2020, regardless of their duration. Slightly less than half of these funds cover projects whose primary objective is to fight climate change (Figure 5a).

DRC accounts for the lion's share of these climate change mitigation and adaptation projects, with over 60% of international financing for the subregion (Figure 5b). DRC has in effect been chosen as one of the pilot countries worldwide to implement REDD+ and climate change policies. The country contains nearly half of the forests and about 60% of above-ground carbon in Central Africa (see Figure 2). DRC is one of the flagship countries for investments by CAFI (Central African Forest Initiative) and other donors in the fight against deforestation and climate change.

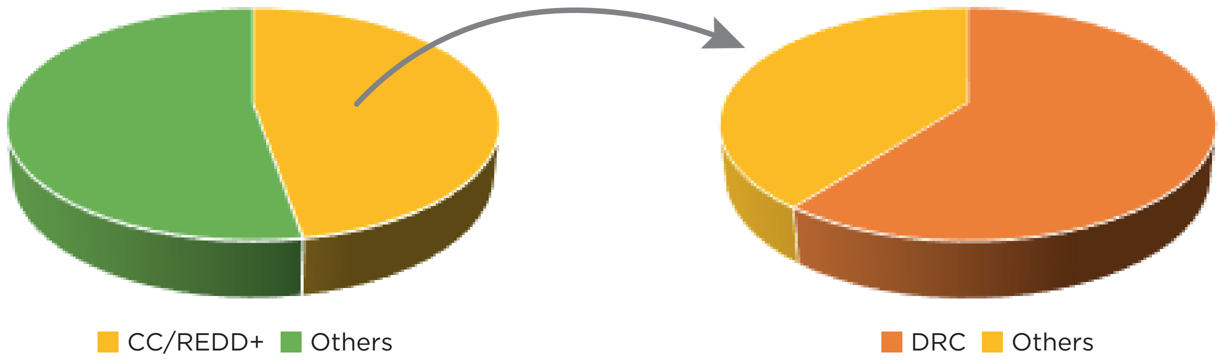
Analysis of "climate change/REDD+" financing: details on the method

The data presented here were compiled within the framework of OFAC. The following procedure was used:

1. an inventory was made of international financing focused primarily on climate change and REDD+. The following information was collected to describe each project or program: name of the project or program, country(ies) concerned, objectives, start and end dates, total financing, protected areas concerned or not;
2. only projects whose primary objective was clearly climate change and those active in 2020 were selected, regardless of their duration;
3. for multi-country projects, the total amount of funding was divided by the number of countries and the same proportion of funding was allocated to each country. In the absence of precise information on the distribution of funding by country, this provides an order of magnitude of funding for each country;
4. we compiled the relevant projects and programs identified from the OFAC analytical portal as of 17/12/2020 (https://www.observatoire-comifac.net/analytical_platform/projects/main), the bibliography, and websites such as that of the Green Climate Fund (GCF). For the latter, we have not taken into account preparatory activities (referred to as "Readiness");
5. the database was cleaned up by eliminating duplicates and arbitrating in favor of the official sites in case of contradictory data;
6. the exchange rate used was: € x 1.21741 = US$.

This method can and must be improved to obtain a more detailed picture of these funds and their allocations. Despite OFAC's establishment of an analytical platform, the collection and editing of data on international funding remains problematic (not to mention national funding, which remains very difficult to assess). Project managers struggle to respond to requests, and donors have not yet set up a procedure to automatically transfer information to OFAC, although this could be done easily. Some projects consequently have not yet been considered and, for those that have been, information on the allocation of funds (e.g., those allocated to protected areas) is not clearly detailed.

Figure 5 – International “climate change/REDD+” funding in Central Africa.



a) Importance of CC/REDD+ projects among international funding for the forest-environment sector

b) Importance of DRC-oriented funding among CC/REDD+ projects

CC: climate change; DRC: Democratic Republic of the Congo; REDD+: Reducing Emissions from Deforestation and Forest Degradation. Source: OFAC.

Although it is difficult to gain a comprehensive overview of these international projects, the funding data compiled by OFAC makes it possible to formulate an initial diagnosis of funding focused on climate change, REDD+ and protected areas. Other information also may be found in various publications produced by the observatory (Eba'a Atyi *et al.*, 2015a; Sonwa *et al.*, 2018; Liboum *et al.*, 2019).

In a desire to tackle environmental issues on a global scale while promoting sustainable development at the national level, the international community launched GEF in 1991. This fund subsequently became the most important financial mechanism of the conventions resulting from the 1992 Rio conference, namely the CBD, the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention to Combat Desertification (UNCCD). To date, the GEF has mobilized nearly US$25 billion in 4-year cycles. The most recent replenishment cycle (GEF-7), which closed in April 2018, mobilized US$4.1 billion, slightly less than the previous mobilization (GEF-6) of approximately US$4.5 billion.

The regional project, “Partnership for Biodiversity Conservation: Sustainable Financing of Protected Area Systems in the Congo Basin”, was for example funded under GEF-4. This project aims to establish an environment conducive to the increased mobilization of funding for the protected areas system. Sustainable financing of protected areas in Central Africa would enable managers to have sufficient resources and integrate all of the management parameters of a protected area into their work, taking into account climate change monitoring in daily protected area management, including financing related studies. Through the project, financing strategies have been developed for protected areas in the six beneficiary countries, but their implementation has been severely hindered by the Covid-19 pandemic.

Again under the GEF, a new project could be started to better understand the impacts of climate change on Central African protected areas and to formulate mitigation measures. This project would make it possible to better address the needs identified in the second part of this chapter.

In response to growing concerns about climate change and sustainable development in the least developed countries, the 16th UNFCCC Conference of the Parties (COP 16), held in Cancun, Mexico, in 2011, launched the creation of a Green Climate Fund. This fund became operational four years later, with an initial capitalization of US$10.3 billion. It is now UNFCCC's primary financing mechanism. Its second replenishment phase, which closed in November 2019, mobilized over US$10 billion in additional funds (financing mobilized in September 2020; GCF, 2020b).

The GCF aims primarily to help developing countries tackle the challenges of adapting to the negative impacts of climate change and of reducing greenhouse gas emissions. It mainly finances direct actions on the ground as part of the fight against climate change, in connection with the sectors of energy, agriculture, forest plantations and agroforestry, land use planning, green finance, etc. All developing countries, including those in Central Africa, may submit project proposals to the GCF at any time.

The current GCF project portfolio is valued at US$7.2 billion. Over 37% involve Africa through national or multinational projects, with US$2.7 billion earmarked for the continent. Africa is the priority region for the GCF; the other two priorities are small island states and least developed countries (GCF, 2020c). In the case of Africa, the bulk of this financing takes the form of public sector grants, although loans and some private investment also are involved.

Regional project for the sustainable financing of protected area systems in the Congo basin

A. Malibangar, UNDP

Six Central African countries (Cameroon, CAR, Congo, DRC, Equatorial Guinea, and Gabon), have secured US$8,181,818 in GEF funding for the implementation of a regional project "CBSP - Partnership for Biodiversity Conservation - Sustainable Financing of Protected Area Systems in the Congo Basin - PIMS3447". This five-year project was launched in 2017 and is managed by the United Nations Development Programme (UNDP).

Project objectives and components

The project's primary objective is to help address the challenge of funding protected areas at local, national and regional levels. It focuses on supporting the development of human resources, institutional frameworks and pilot mechanisms for the long-term financial sustainability of protected area systems and associated ecosystems in the six countries to bolster their conservation efforts.

The project is organized around inter-connected components contributing to the: (1) establishment and/or strengthening of legal, policy and institutional frameworks to support sustainable financing of protected areas at national and regional levels; (2) improvement of existing or innovative mechanisms for generating and sharing (disbursing) revenues in protected areas; and (3) strengthening and/or implementation of business plans and tools for the cost-effective management of protected areas and their associated ecosystems (at least two pilot sites per country), at the national level.

Current status

In 2021, the project is entering its final year. Considerable progress has been made in all six countries, including the development of the following in each country:

– a National Strategy for Sustainable Financing of Protected Areas for the Conservation of Biodiversity (NSSFPA/CBD) with an associated action plan (the periodicity of which varies from one country to another);

– a communications and resource mobilization strategy and plan for the implementation of the NSSFPA/CBD;

– two pilot sites designated by policy makers to serve as demonstration sites for the establishment of a sustainable funding mechanism in the future.

Regional project for the sustainable financing of protected area systems in the Congo basin

What challenges remain?

The unforeseen arrival of the global health and environmental crisis stemming from the Covid-19 pandemic impeded countries from beginning demonstration activities prior to the establishment of a potential sustainable financing mechanism in at least one pilot site. Virtually all component 3 activities have been restructured to contribute to the global response to Covid-19. This component will now focus on strengthening the resilience and sustainable livelihoods of local communities and indigenous peoples on the pilot sites to enhance joint biodiversity conservation and local development efforts. The project must still launch Calls for Expression of Interest (CEI) and calls for proposals for activities on sites in the six countries. However, their deployment is hampered by difficulties in moving around due to the current health crisis, security challenges in some countries, and the limited amount of time remaining before the end of the project, which is scheduled for November 2021. Activities will need to be prioritized, taking into account both the remaining available resources and the possible timelines of the disbursement of GEF funds in early 2021.

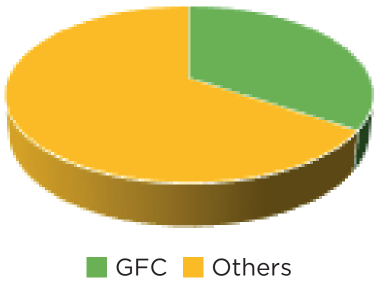
Website: www.financeapbassincongo.org
Twitter: @APbassinCongo
Facebook: https://www.facebook.com/financeAPbassincongo

The GCF accounts for about one third (Figure 6) of the international funding targeting climate change/REDD+ in Central Africa (see Figure 5a). Rwanda and, to a lesser extent, Cameroon, DRC and Burundi are the main beneficiaries of GCF-funded projects, particularly in the field of green energy such as solar energy (Figure 7; GCF, 2020a); no project specifically addresses protected areas. Only two projects cover the adaptation of rural populations to climate change and the management and restoration of ecosystems and forest resources, one in Rwanda (a project in the north of the country) and one in Cameroon and Chad (a cross-border project on the Niger River Basin).

As a GCF Delivery Partner, COMIFAC is among the beneficiaries of a Readiness regional programme aiming to establish a pipeline of projects that is required to set up a future REDD+ Catalytic Fund. A strategy also should be put in place to help Central African protected areas access this major global source of funding for climate action.

In view of accessing new financing, Central African countries have been active in REDD+ negotiations under the UNFCCC. The convention recognizes the role of conserving tropical forest ecosystems in fighting against greenhouse gas emissions produced by the forest sector. Furthermore, Article 5 of the Paris Agreement highlights all of the components of REDD+ (UNFCCC, 2015). It invites Parties to take measures to conserve and, where appropriate, strengthen sinks and reservoirs of greenhouse gases, including forests. It also invites them to take measures for the conservation and sustainable management of forests and to increase forest carbon stocks in developing nations. The provisions of Article 9 of this agreement further call on the international community to finance climate actions, notably by supporting country-led strategies and taking into account developing countries' needs and priorities.

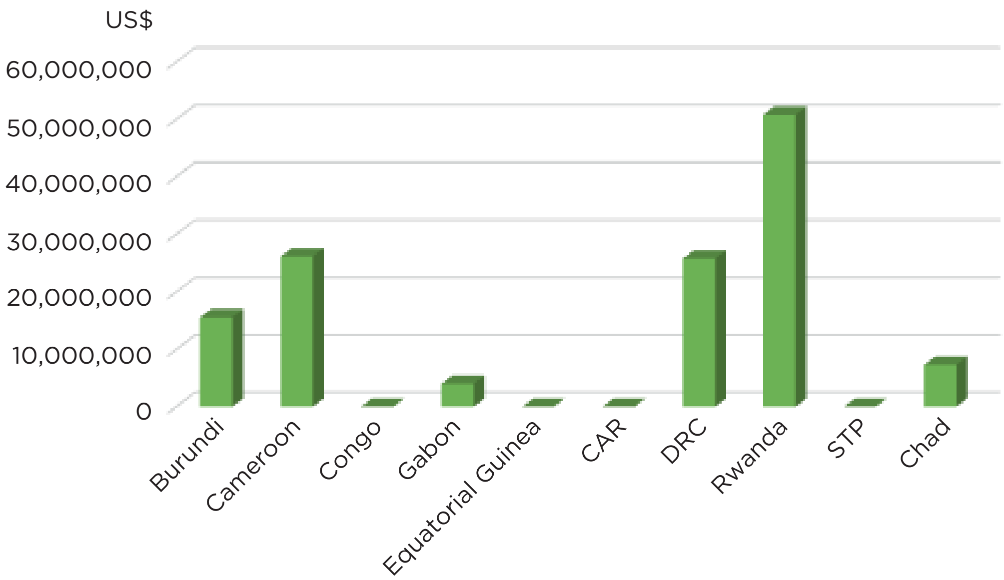
Figure 6 – GCF financing among "climate change/REDD+" projects in Central Africa



GCF: Green Climate Fund. Source: OFAC.

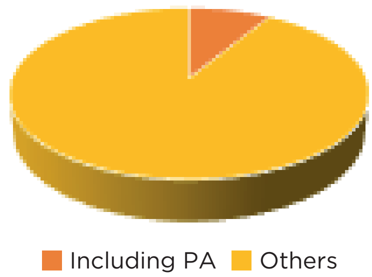
Currently, of the climate change/REDD+ projects being implemented in Central Africa, less than 9% (in terms of funding) concern protected areas (Figure 8), even though these areas play a major role in carbon sequestration and storage and in climate regulation through the protection of forests (see sections 1 and 2). Extending protected area networks and managing them efficiently are among the priorities of the convergence plan for the management of Central Africa forest ecosystems (COMIFAC, 2015), but climate financing continues to largely overlook this fact. The international communities' financial and technical support helps not only to maintain, but also to increase, the role of protected areas in combating climate change (see the insert on the Mbam-and-Djerem National Park in Cameroon in section 1.1).

Figure 7 – GCF financing per country in Central Africa in 2020



Source: GCF (2020a).

Figure 8 – The paltry share of financing covering actions for protected areas among the "climate change/REDD+" projects in Central Africa



Source: OFAC (2020).

3.2 The start of the mobilization of green finance by Central African countries

In addition to initiatives strictly related to the UNFCCC, some Central African countries (Cameroon, Congo, DRC) have engaged in the preparation of jurisdictional Emission Reduction Programs (ERPs) under the World Bank's Forest Carbon Partnership Facility (FCPF). Two programs have already been validated under the FCPF: the Mai-Ndombe ERP in DRC, and the Sangha and Likouala ERP in the Congo.

All of these programs identify biodiversity conservation as one of the "non-carbon benefits" among the expected outputs. Although conservation activities may receive REDD+ benefits, protected areas currently are not or are only marginally benefiting from REDD+. How these resources are delivered to conservation sites, and how they will contribute to improving their management, must be examined.

Mai-Ndombe Emission Reduction Program (RDC)

This program covers 123,000 km² and includes numerous activities, including the implementation of sustainable development plans and protection of High Conservation Value Forests (HCVF) in return for Payments for Environmental Services (PES). More specifically, it also includes support for: (i) the creation and operation of conservation concessions,

(ii) the conservation of local community forests, and (iii) the management of protected areas (FCPF, 2016).

It receives various types of funding:

- FCPF: emission reductions purchase and sale agreement; World Bank financing of US$55 million, future payments conditional on the reduction of greenhouse gas emissions;
- Integrated REDD+ Plateaux program (PIREDD Plateaux); World Bank financing for the Forest Investment Program (FIP), covering the former Plateaux district, of US$14.2 million (2016-2019);
- Integrated REDD+ Mai-Ndombe program; CAFI financing and World Bank implementation, mainly covering the former Mai-Ndombe district, of US$20 million (2018-2021);
- Mai-Ndombe Integrated REDD+ program, phase 2 (forthcoming), covering the entire province, of US$16 million (planned for 2022-2023);
- Additional GEF financing of US$6.21 million (2021-2022).

PIREDD Mai-Ndombe, the challenge of supporting development while preserving the forests of an entire province

C. Mbayi Mwadianvita, PIREDD Plateaux WWF, N. Bayol, & P. Breumier, FRMi, C. Vangu Lutete, CU FIP-DRC

Mai-Ndombe province was identified as a key province in the DRC in terms of REDD+ challenges for the following reasons: it is a forest province (forests cover 75% of the total area of the province) located close to Kinshasa (challenges related to the growing demand for fuelwood, timber, and food), and hosts endemic and endangered animal species such as the bonobo (*Pan paniscus*).

This province has thus benefited from REDD+ initiatives for several years with, in particular, a program to reduce greenhouse gas emissions included in the FCPF project portfolio and materialized by the signing of a purchase-sale contract for emission reductions between the Government of DRC and the World Bank Carbon Fund, for a value of US$55 million over five years. Payments will be linked to project performance, meaning to the difference between measured carbon emissions and emissions estimated in a baseline scenario without a project. A benefit sharing plan is currently being finalized. It defines the financing arrangements for the management of the program and for sharing revenues from the sale of emission reductions between the Mai-Ndombe provincial government, indigenous populations and local communities, as well as private operators who have developed their own “nested” projects.

To create an emission reduction dynamic, two Integrated REDD+ Programs successively have been financed since 2016, first in the former Plateaux District, by FIP (implemented by WWF, the World Wide Fund for Nature), then in the former Mai-Ndombe District, financed by CAFI/FONAREDD – National REDD+ Fund (implemented by FRMi - *Forêts Ressources Management International* and WWC - Wittenberg Weiner Consulting). Funding must be approved for this program to be continued until 2023. These Integrated REDD+ programs aim to meet two challenges: 1) ensure economic development to fight poverty, and 2) reduce carbon dioxide emissions compared to an established baseline scenario.

Activities aim to tackle the direct and indirect causes of deforestation and ecosystem degradation. They are based on land-use planning at different administrative and customary scales and on the creation of local governance structures for natural resources, the *Comités Locaux de Développement* (CLD: local development committees). Following a participatory approach, these CLDs develop Natural Resource Management Plans (NRMPs), planning land use, and then coordinate their implementation (Figure 9). The CLDs represent the local community in discussions with development partners, such as PIREDD Mai-Ndombe.

PIREDD Mai-Ndombe, the challenge of supporting development while preserving the forests...

Emission reduction efforts are based in particular on the development of agroforestry plantations of acacia or fruit trees associated with food crops in savanna areas (5,720 ha planned by the end of 2021), the development of palm oil plantations in savanna areas (2,060 ha), the protection of anthropic savannas against fires to allow their natural regeneration (9,670 ha to date), the improvement of agricultural practices in forested areas, and the use of forest areas for conservation within village territories (100,000 ha to date).

Although investments have been made by local communities, motivated by both the presence of project agents and PES payments, their adoption and long-term sustainability are not yet secured. The investments in question are in effect long-term investments (perennial crops) that have not yet become productive. The communities therefore are not yet convinced that they will yield economic benefits. Support for the communities involved should be continued until these investments have reached the end of their first production cycle.

Additional GEF funding (2021-2022) also will go to community forest management and the management of the Tumba-Lediima Reserve in order to focus on biodiversity aspects.

Figure 9 – Managed village lands within the framework of PIREDD Plateaux and Mai-Ndombe

Source: CU FIP-DRC.

Sangha-Likouala Emission Reduction Program (Congo)

The Sangha-Likouala ERP is located in the northern part of the Republic of the Congo (Figure 10). It extends over nearly 124,000 km^2, covered mainly by relatively intact dense humid forest. The contract is scheduled to be signed in January 2021.

The objectives of the program are to:

- reduce emissions by 9,013,440 te CO_2 from 2019 to 2023;
- enhance sustainable landscape management;
- improve and diversify local livelihoods;
- conserve biodiversity.

As part of the preparation of this program, Congo has finalized a range of specific tools: a sub-national Forest Reference Emission Level (FREL), REDD+ Principles, Criteria and Indicators (PCI) adapted to the ERP, a Reduced-Impact Logging (RIL) guide, a document specifying benefit-sharing options in the context of the implementation of the RIL, and additional studies on land use (CNREDD, 2019).

With initial funding of US$92.64 million, the financing plan for the program is as follows:

- guaranteed or committed investments that will target various program activities, including support from the GEF, International Development Association (IDA), IFP, the French Development Agency (AFD), the African Development Bank (AfDB), and the UK Department for International Development (DFID);
- the mobilization of additional investments, including through the CAFI initiative and the *Projet d'appui au Développement de l'Agriculture Commerciale* (PDAC), financed by the World Bank;
- private investments from interested companies;
- advance payment from the FCPF Carbon Fund for activities not covered by investment sources (FCPF, 2018).

Reducing emissions in North Congo: a multi-sectoral challenge

C. Milandou and C.-B. Ouissika, CNIAF

The Sangha-Likouala program plans to reduce carbon emissions while supporting sustainable landscape management and biodiversity conservation. The program area includes territories under various management and operating statuses (Figure 10):

– 17 forestry concessions covering 72,007 km^2 (including one which one is not in operation), assigned to ten companies;
– 13 mining exploration and research concessions assigned to 13 companies;
– 3 national parks and a nature reserve covering 26,701 km^2;
– several villages and towns (FCPF, 2018).

The planned intervention strategy combines sectoral and enabling activities (CNREDD, 2020). Sectoral activities fall under four main areas of intervention, within which efforts will be made to engage stakeholders to develop low-carbon practices that promote the protection of carbon stocks:

– **forest concessionaires** will be encouraged to apply RIL principles more systematically and to establish conservation series (non-logged areas);
– **agro-industrial** producers of sustainable palm oil will have to reduce emissions from deforestation in agricultural concessions, avoiding the conversion of HCVF. They will also be encouraged to move toward RSPO certification (the international standard of the Roundtable for Sustainable Palm Oil);
– **local communities and indigenous peoples** will be supported in (i) sustainable cocoa production through agroforestry systems in degraded forests, (ii) introduction of sustainable subsistence farming to increase agricultural productivity and crop diversification through agro-

Reducing emissions in North Congo: a multi-sectoral challenge

forestry systems, (iii) the promotion of small producers sub-contracting from agro-industries on deforested areas within oil palm concessions, (iv) the sustainable use of Non-Timber Forest Products (NTFP) and (v) the provision of PES for individuals and communities protecting forests;

– **protected area managers** will be supported in improving site management and developing income-generating activities to benefit local communities and indigenous peoples;

– **mining companies** will be encouraged to contribute to the economic development of the region while minimizing their impact on the forest.

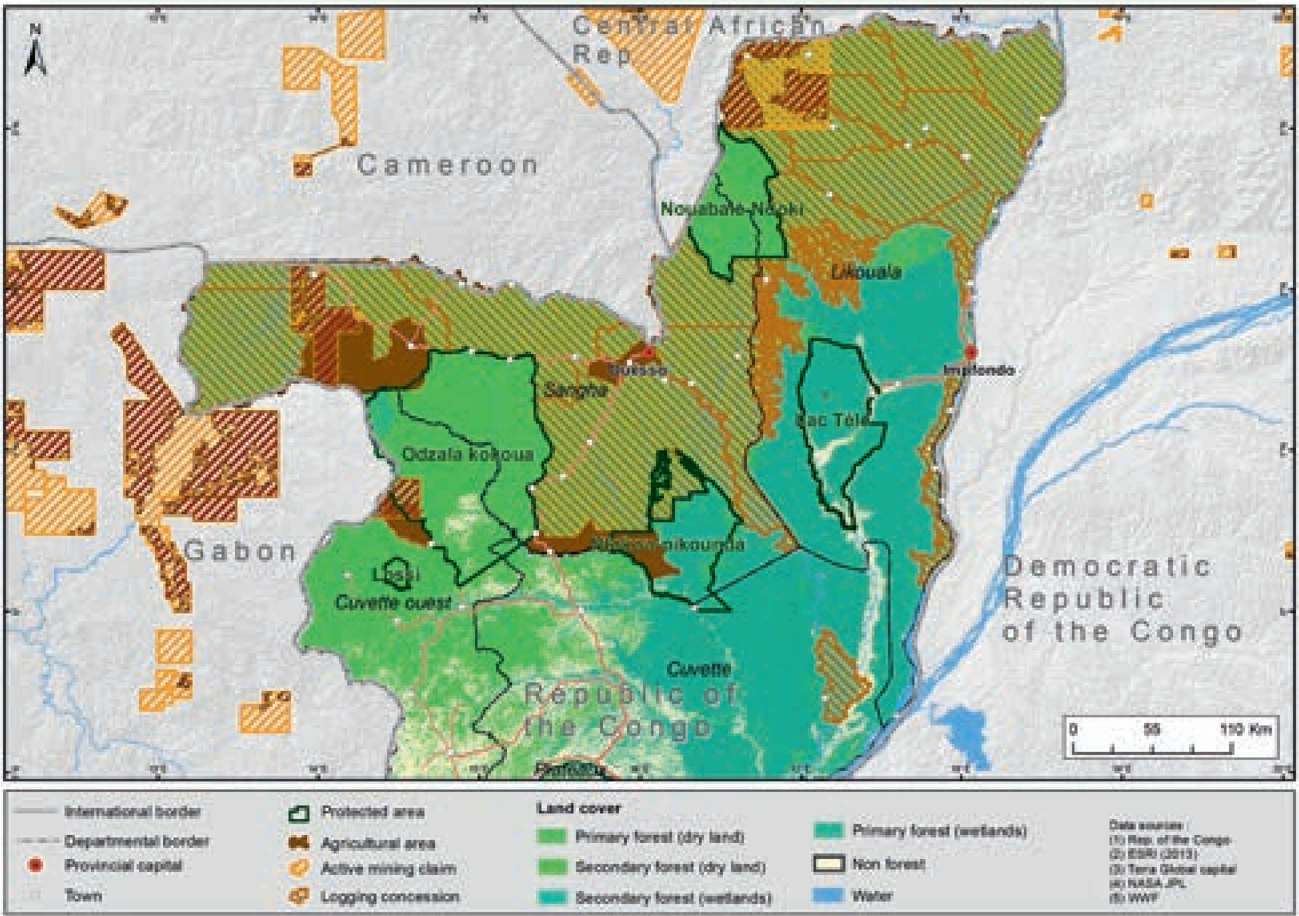
The enabling activities will include:

– improving governance, e.g., through capacity building of program partners and synergies with the Forest Law Enforcement, Governance and Trade (FLEGT) process;

– strengthening land use planning at local and national levels;

– improving livelihoods by developing agricultural value chains, e.g., for cocoa and palm oil.

Figure 10 – Spatial extent and land use of the Sangha-Likouala program



Source: FCPF (2018).

3.3 Payments for environmental services

Protected areas play an essential role in the provision of ecosystem services. However, despite their economic importance, few assessments of these services have been conducted in Central Africa. Under the Regional Project for Sustainable Financing of Protected Area Systems in the Congo Basin (see inset in section 3.1), financing strategies for the protected area systems in some countries of the subregion are being prepared under the aegis of COMIFAC. Payments for environmental services are identified in these strategies as one source of financing for protected areas.

Following the conclusion of a historic agreement between Gabon and Norway, this approach should be reinforced. Norway has committed to pay US$10, compared to US$5 on the current market, for each ton of certified carbon not emitted, based on the country's recent average emissions (2005-2014), with a maximum amount of US$150 million over ten years (CAFI, 2020). Gabon is thus the first country in Africa to receive payments for safeguarding its forest.

Gabon is receiving payments for protecting tropical forests

G.-L. Itsoua-Madzous, COMIFAC

Adapted from the addendum to the letter of intent Gabon-CAFI, September 2018

Gabon has the highest percentage (approximately 90%) of forest cover in Central Africa and a very low deforestation rate (FAO, 2020). While the country faces less pressure on its forests than its neighbors due to a lower demand for agricultural land, its voluntary commitment to fighting deforestation has made Gabon stand out. As early as the 1990s, Gabon introduced the sustainable management of forestry concessions, which cover most of the country's forests (Marquant *et al.*, 2015). Gabon also completely overhauled its protected areas network in 2002 by creating 13 national parks, one of which is listed under the World Heritage Convention (Doumenge *et al.*, 2015). The country furthermore has made significant progress in the sustainable management of its wood resources, banning all log exports as early as 2010 and deciding that all forestry concessions must be FSC-certified by 2022 (Forest Stewardship Council).

These measures offer the dual benefit of meeting socio-economic and environmental demands (Karsenty, 2020). They make it possible to protect forests and carbon stocks and reduce emissions generated by deforestation and logging. They also serve to reassure potential investors and donors about the country's credibility in meeting its commitments. These and other efforts led to the signing of a historic agreement with Norway in September 2018, through the CAFI initiative. This agreement involves a US$150 million payment intended to recognize the reduction of greenhouse gas emissions from deforestation and degradation and the absorption of carbon dioxide by Gabon's natural forests over a 10-year period (2016-2025). The agreement will reward both past performance – verified results since 2016 compared to the previous decade from 2005 to 2014 – and future outcomes, to be paid annually until 2025.

Third party certification

The parties are committed to a learning-by-doing approach and will jointly seek to adapt the partnership to global best practices. Gabon will seek to obtain ART (Architecture for REDD+ Transactions) certification for emission reductions and removals under this partnership.

Gabon is receiving payments for protecting tropical forests

ART's REDD+ environmental excellence standard, TREES (The REDD+ Environmental Excellence Standard; ART, 2020), does not yet include a robust method for crediting countries with high forest cover and historically low rates of deforestation such as Gabon. The Gabon-CAFI partnership intends to spearhead a new incentive approach for these countries and identify lessons to improve the TREES standard.

CAFI is ready to contribute up to US$150 million over 10 years

This contribution will depend on the results achieved by Gabon under the partnership. The CAFI initiative will guarantee a floor price of US$5/ton of carbon, with a maximum of US$75 million, for results achieved between 2016 and 2020, and up to an additional US$75 million for results achieved in 2021-2025. CAFI will also guarantee a floor price of US$10/ton for results certified by ART, subject to the maintenance of CAFI's overall financial commitment of US$150 million for the 2016-2025 period.

Gabon can accept this offer or sell its carbon credits to another buyer offering a higher price. The parties will seek to use the floor price to attract additional funding sources, in particular private buyers.

Gabon's climate commitments

Prior to the first payments, Gabon is, inter alia, expected to submit the following elements to the UNFCCC:

– a nationally determined contribution (NDC), confirming the provisions of the letter of intent signed with CAFI. In its new NDC, Gabon must seek to reduce its emissions by over 50% compared to 2005 by cutting forest sector emissions in half;

– a FREL or a forest reference level as provided for in the relevant decisions of the Conference of the Parties to the UNFCCC;

– a summary of information on how REDD+ safeguards are addressed and complied with, in accordance with relevant UNFCCC decisions.

By supporting national low-carbon investment frameworks and the land-use sector, the CAFI initiative has, among other things, committed to financing the expansion of Gabon's protected areas network by creating 4,000 km^2 of new forest protected areas in border regions currently open to logging. This is part of a wider package that includes a support programme for land use planning and forest monitoring.

3.4 Government funding and public-private partnerships

First, it should be noted that although the budgets allocated by the States often fall short of the funding needed by protected areas (Joyeux & Gale, 2010), this support nonetheless helps to maintain a minimum level of activity in a large number of Central African protected areas. This activity slows down deforestation and makes it possible to preserve the boundaries of protected areas, contributing to the conservation of existing carbon stocks (see section 1.1) and the maintenance of low emission rates by countries in the subregion.

It is clearly not enough, and in several protected areas, Public-Private Partnerships (PPP) have been established between governments and various partners. In most of these partnerships, the government expects the private partner to make a significant financial contribution (see Chapter 4). This funding can come from public, bilateral or multilateral donors, as well as from private foundations or specifically created trust funds. All of these financial tools can be used to combat climate change and to help protected areas adapt to changes.

Furthermore, all countries in the subregion have regulations relating to the environment, Environmental Impact Assessments (EIA) and CSR. Funding from corporate social and environmental obligations can deliver co-benefits in the area of climate change mitigation and adaptation. For example, environmental compensation for the construction of the Chad-Cameroon pipeline supported the creation and management of the Mbam and Djerem National Park in Cameroon (see Chapter 8). Located in a region where forests are naturally expanding at the expense of savannas, the creation of this park makes it possible to increase the carbon stock present in Cameroon's protected areas (see inset in section 1.1 of this chapter).

For some large industrial and energy projects, compensating for the loss of carbon due to deforestation also is involved. This is the case for the Nachtigal dam construction project in Cameroon, located 64 km northeast of the capital, Yaounde. This project is being implemented by a consortium involving the Government of Cameroon, *Electricité de France* (EDF) and the International Finance Corporation (IFC, a subsidiary of the World Bank). The installed capacity is expected to be 420 MW, making it a major undertaking for the electrification of the country. However, this hydroelectric facility threatens a very rare endemic aquatic plant (*Ledermanniella sanagaensis*), which grows almost exclusively at the Nachtigal waterfalls (Takouleu, 2019). The project's environmental and social management plan must take into account the impacts on biodiversity. It provides for a compensation mechanism for the loss of forests caused by the construction of the dam, including a PES component. This PES component aims to compensate neighboring communities for their efforts to sustainable manage and restore their forests (Liboum *et al.*, 2019).

4. Opportunities and challenges

In Central Africa, the relationship between protected areas and climate change presents many challenges for support efforts. Commitments and initiatives are underway in the subregion, with the support of technical partners, to integrate climate considerations into programs involving protected areas and to mitigate the effects of climate change through adaptation activities.

4.1 Challenges of mobilizing funds for protected areas

Strengthening the importance of protected areas in political agendas

The main actions supported by the Global Climate Fund in Central Africa concern clean energy production projects (solar) and some land-use planning and reforestation projects (GCF, 2020a). These two sectors illustrate the key elements of strategies to fight climate change, with on the one hand the promotion of low-carbon development (low-carbon economies, deployment of "green" energies) and, on the other, carbon storage (maintaining and increasing stocks).

Protected areas are important land management tools that can be used to halt deforestation and the reduction of carbon stocks. They promote long-term carbon storage and increased stocks in areas where forests are regenerating. Moreover, protected areas make it possible to develop actions for the adaptation of human communities to climate change, as discussed earlier (section 1). Policy makers remain largely unaware of these different roles, which are not sufficiently considered in sustainable development and land-use planning policies. It is COMIFAC's task to act as an ambassador, with support from OFAC and all conservation partners.

To be socially acceptable, efforts to combat climate change must first be understood as necessary and useful for the development of countries and their inhabitants. This involves communicating to the general public, but also, in a more targeted manner, to policy makers and private operators. These efforts also must support the sustainable development of countries and contribute to poverty reduction (Eba'a Atyi *et al.*, 2015a and b; Reyniers *et al.*, 2016), including in landscapes where protected areas are located.

If fighting against climate change is to be effective, this concern also must be integrated into sectoral policies and requires improvements in intersectoral institutional coordination (energy, mining, forestry, agriculture, environment, etc.; Heller & Zavaleta, 2009). This will require major changes in decision-making and management mechanisms, often involving a complete break with current practices. Here again, COMIFAC, as a regional coordinating body in the fields of forestry and biodiversity conservation, must develop a proactive attitude to support governments in their intersectoral coordination efforts.

Developing confidence

How governments and institutions function are among the many factors contributing the success of projects and financial mechanisms (Joyeux & Gale, 2010; Karsenty & Ongolo, 2012). Some of these factors, which relate to governance and to institutions and practices, also ultimately refer to the relationships of trust that are necessary between the parties, first of all between donors and recipients, but more broadly, between all stakeholders. Three factors playing a role in the development of "climate" financing and financing for protected areas may be highlighted here:

- **1.** the government must respect the views and actively support the participation of stakeholders in the project, giving them a full role in discussions, decision-making and project implementation (stakeholders may be local communities, private actors, NGOs or associations; Reyniers *et al.*, 2016). It is not a question of necessarily agreeing about everything, but of leaving the door open for discussion and making decisions together;
- **2.** all stakeholders must feel that they really benefit from the projects and have an interest in the changes in practices that these projects are likely to bring about. For example, paying farmers to cut down less trees under a PES framework will not suffice if these same farmers do not find it worthwhile to intensify their farming practices or to plant trees that they will be able to exploit in a not-too-distant future (Bouyer *et al.*, 2013; Eba'a Atyi *et al.*, 2015b; Reyniers *et al.*, 2016). Not everyone will receive the same benefits from a project, but everyone should be able to derive benefits that are important to them. If one of the stakeholders feels cheated, mistrust will set in and the project will fail;
- **3.** governments must put in place institutions and legal and financial practices that donors and all stakeholders can trust. Concerns over the effective management and secure use of funds, along with the reliability and efficiency of monitoring and sanction mechanisms, are some of the sticking points in the development of international financing.

4.2 Putting in place and operationalizing a strategy to mobilize green finance for protected areas

Relying on domestic financing to attract other investment

Protected area networks are important both in supporting sustainable national development and in contributing to strategies for populations to cope with climate change. As such, governments have a duty to finance them, and there is hope that their investments will increase in the coming years, as can already be seen in countries such as Gabon (the beneficiary of a ground-breaking agreement with Norway) and Rwanda (a major GCF beneficiary, see Figure 7). This is expected to encourage international donors to provide more substantial support.

Considering the question from another angle, these protected areas play a role that goes beyond national borders, and they help to combat climate change, with their efforts benefiting countries that are sometimes located far from Central Africa. It is therefore appropriate that the international community contribute to their operations and effectiveness.

Under the aegis of COMIFAC, several countries in the subregion have begun a process of preparing national strategies for the sustainable financing of protected areas (see section 3.1). These documents will enable them to make better use of current sources of financing and to access financing that continues to be insufficiently tapped in Central Africa. This should, for example, make it possible to increase the contribution of the Green Climate Fund and mobilize a range of financial mechanisms other than the market mechanisms advocated by REDD+ (Eba'a Atyi *et al.*, 2015b).

Several obstacles to mobilizing additional funding for protected areas have been highlighted in the past, including the lower debt-carrying capacity of Central African countries compared to countries in the Americas or Asia. This translates into a lower financial volume as well as a higher proportion of grants relative to loans (Liboum *et al.*, 2019). However, several countries in the subregion have significant mining and energy resources and could easily reverse this trend.

It should be noted that the European Union provides greater support to Central African protected areas than protected areas in the other two tropical forest basins. Other countries traditionally had fewer political ties with the subregion and tend to make far greater financial contributions to the protection of the Amazon, for example. This is the case of Norway, although the situation is substantially changing with the support provided for several years to the DRC and the country's involvement in the CAFI program. As mentioned previously, Gabon has benefited from a unique agreement with Norway, which could inspire others (see section 3.3).

Another obstacle hindering increased international investment in Central Africa involves the risk that such investments may fail, one which is seen as being higher in the subregion than in other continents. To overcome this obstacle, the countries must present stronger projects. To be more convincing, they also must refine their NDCs and rely on more detailed analyses of the impacts of past actions and of future needs (Sonwa *et al.*, 2018; Liboum *et al.*, 2019). As of December 2020, Rwanda was the only country in the subregion to have submitted an updated NDC (Rwanda, 2020).

Documenting changes, planned actions and their impacts

As noted above, protected area planners and managers should have the latest scientific data on climate change and biodiversity in a form that is easy to access. It is equally important that countries set up permanent and transparent monitoring and evaluation mechanisms (Eba'a Atyi *et al.*, 2015a and b). These mechanisms must be able to provide information concerning management effectiveness on the ground, as well as a comprehensive overview of the evolution of protected area systems and the fight against climate change at the national scale.

There are two issues at stake here. One is to boost the confidence of potential donors (by monitoring and evaluating activities). Above all, however, it is a question of enabling protected area management institutions and their partners to manage the sites under their jurisdiction more effectively (with adequate information). Chapter 5 in this book delves deeply into the importance of information to support the management of protected areas. At the subregional level, OFAC should be at the forefront

of collecting and sharing information enabling effective monitoring and evaluation of protected areas and climate change. OFAC can make it possible to overcome certain obstacles to knowledge transfer between actors (Sufo Kankeu *et al.*, 2020), and promote both the transfer of knowledge and skills between countries and actors.

Potential for the establishment of secondary forests in CAR's protected areas

Adapted from RCA (2017)

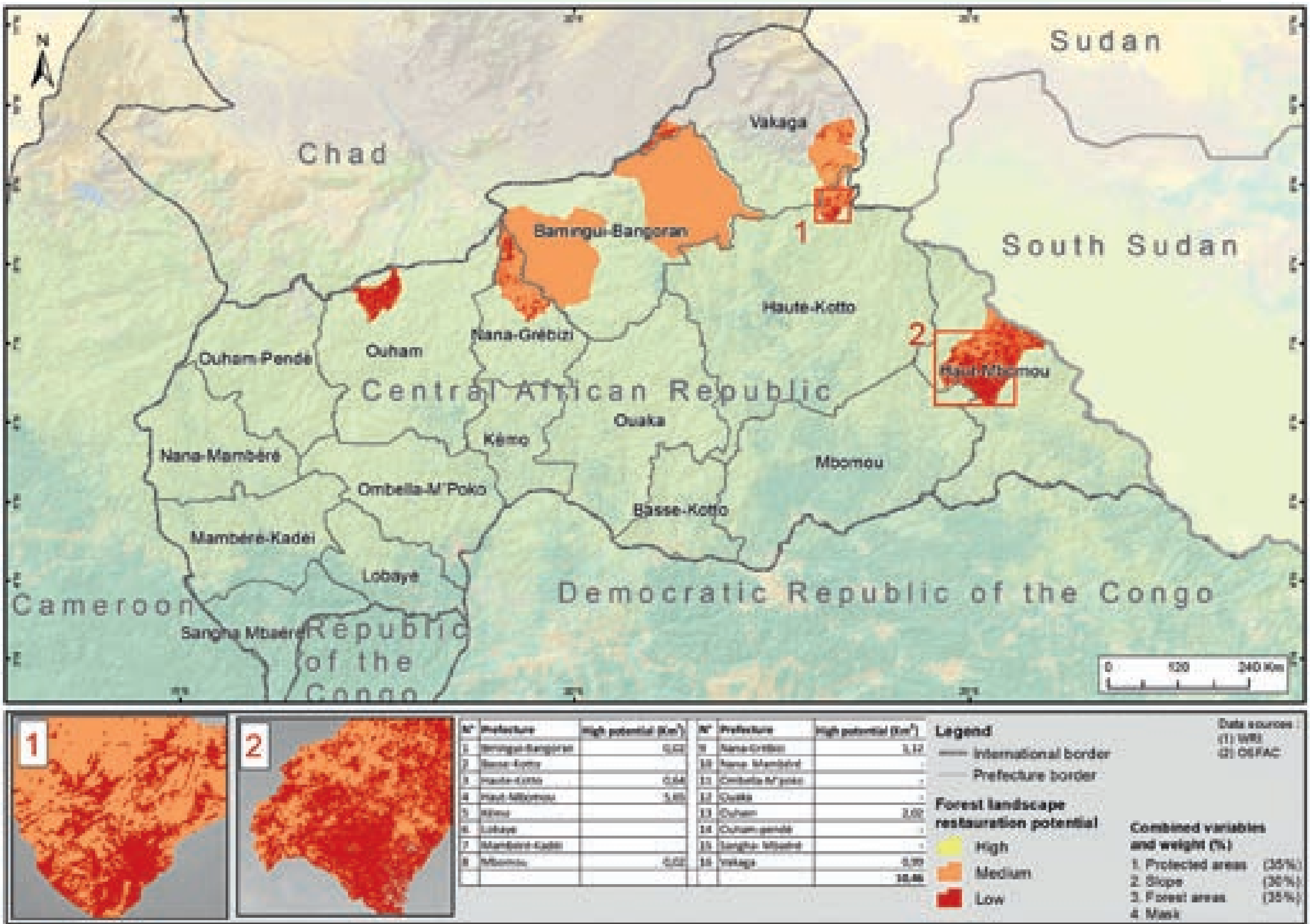
CAR has 16 parks and reserves covering approximately 70,000 km², representing 11% of the country's territory. This protected area network is complemented by 46 hunting grounds, including 11 village hunting zones, bringing the total to 180,000 km², or 29% of the territory. To combat the effects of climate change in the country's northeast, the Government, supported by the World Resources Institute (WRI), has begun work to identify the potential for the growth of secondary forests in and around protected areas. These data will make it possible to better specify the baseline scenarios in the framework of NDC and REDD+ policies, carry out more precise monitoring, and enhance the potential of protected areas in the fight against climate change.
The results of this analysis estimated the potential for the restoration of forest landscapes and the establishment of secondary forests in protected areas at about 10,465 km² (medium potential) and 46,029 km² (high potential; Figure 11). In some protected areas, such as the national parks and strict nature reserves, only conservation activities are authorized, promoting an important natural regeneration dynamic (see inset in paragraph 1.1).

Potential for the establishment of secondary forests in CAR's protected areas

Elsewhere, in protected areas intended for both conservation and economic development (wildlife reserves, hunting estates or zones, biosphere reserves…), protection may be combined with active afforestation activities. This could include the development of practices such as assisted natural regeneration, as well as reforestation and agroforestry. This will particularly be the case in areas that have been degraded in the past, as well as on the outskirts and in the buffer zones of protected areas.

The information presented in Figure 11 takes into account both the ecological potential (more or less degraded forest areas, slopes) and the management category of protected areas. It must be combined with demographic, economic and social data to enable the managers of protected areas to better plan their conservation and reforestation activities, and to evaluate their effectiveness in the future.

Figure 11 – Potential for the establishment of secondary forests in CAR's protected areas



High potential: priority areas for restoration activities; medium potential: secondary areas for potential interventions; low potential: areas not conducive to restoration options and therefore not recommended for intervention. Source: RCA (2017).

Conclusions and prospects

African forests, mainly in Central Africa, store more than one quarter of the carbon in the intertropical zone. Protected areas play a significant role in protecting these carbon stocks, regulating local and regional climates, and providing ecosystem goods and services to human populations. Transboundary protected area complexes that have been set up in the subregion make it possible to protect vast areas in an ecological continuum capable of maintaining viable forest ecosystems and plant and animal populations.

Climate change predictions indicate a trend toward increasing global temperatures and a disruption of other parameters (rainfall, winds, etc.) with an increased frequency and intensity of extreme climate events (droughts, flooding, etc.). These changes will have negative impacts on protected areas in the region, jeopardizing the many services which they provide people, including in the fight against climate change.

Scientific studies undertaken to date in the subregion on ecological processes and the impacts of climate change remain scattered and limited, although they already have confirmed the vulnerability of protected areas to these changes. Protected areas are particularly well suited for long-term monitoring and analysis of ecological processes that are underlying and affected by climate change. This research should be not only diversified but multidisciplinary, collaborative and oriented toward understanding cause and effect relationships between different taxonomic groups.

Given the role played by protected areas in preserving the world's climate for the benefit of humanity, their protection and rational management should be a global priority in the context of "nature-based solutions" now advocated by the international community. Although a great deal of funding is currently being mobilized globally to fight climate change, Central African protected areas have been largely overlooked by projects and programs supported by climate finance.

The traditional funds mobilized, for example, within the GEF financing framework or by certain NGOs and international organizations, fall far short of protected areas' funding needs. REDD+ projects developed in the subregion, particularly in the DRC, have not yet met expectations despite the significant investments made. The projects need to be better anchored by promoting more participatory governance and by clarifying land tenure and local use rights (Reynier *et al.*, 2016). Other avenues also should be explored, such as the Gabon-CAFI agreement and greater use of the GCF.

To conclude, our analysis indicates that it is absolutely crucial to:

1. intensify the consideration of climate change in the day-to-day management of Central African protected areas. On one hand, the impacts of climate change in Central African protected areas need to be better understood, and measures for their mitigation identified; on the other, protected area managers need to be trained in these domains;

2. seize the opportunity offered by green finance to increase financial and technical resources to improve the management of protected areas in Central Africa through the development and implementation of a strategy to mobilize green finance in their favor.

COMIFAC should play a major role in the implementation of these actions with the help of its technical and financial partners.

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