CHAPTER 10
THE CONTRIBUTION OF BIODIVERSITY TO THE MAINTENANCE OF FOREST GOODS AND SERVICES

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Introduction

For this chapter the term biodiversity is defined as the variability among living organisms in the terrestrial and aquatic ecosystems of the Central African humid forests. This includes diversity within and between species and among ecosystems types (Hooper *et al.*, 2005).

Biodiversity provides ecosystem goods and services in two ways. Firstly, it is used as a source of food, fiber, fuel, and other extractable resources. Secondly, it plays a key role in regulating ecosystem processes such as pollination, nutrient cycling, erosion control, water cycling, climate regulation etc...

Goods and services provided by the forest are generally categorized as follows (Kettunen and ten Brink, 2006; Millenium Ecosystem Assessment, 2005):

- ***provisioning services***: food, fiber, fuel, bio chemicals, fresh water, ornamental resources;
- ***regulating services:*** benefits obtained from the regulation of ecosystem processes, such as the regulation of climate, floods, erosion, disease, water quality, carbon sequestration, pollination, biological control of pests, fire tolerance;
- ***cultural services***: recreation, aesthetic and spiritual values, tourism;
- ***supporting services***: services that are necessary for the production of all other ecosystem services, such as photosynthesis, primary production, soil formation, nutrient cycling.

Although the links between biodiversity and ecosystem processes are extremely complex there is a broad consensus within the scientific community on many aspects of the relationship (Hooper *et al.*, 2005). In particular there is general agreement that ecosystem processes are influenced by functional diversity. Functional diversity is a measure of how individual species contribute to the working of an ecosystem by, for example, reducing erosion, improving soil fertility through nitrogen fixation, and ensuring plant regeneration through pollination or seed dispersal. In other words species composition and characteristics, including the effects of keystone species (species that have a disproportionate effect on their environment relative to their abundance) are central to the maintenance of ecosystem processes and services (Hooper *et al.*, 2005; Kettunen and ten Brink, 2006). Species richness (a measure of the number of species in an ecosystem) is also important for the maintenance of ecosystem processes. Having a range of species that respond differently to different environmental perturbations can stabilize the effects of these disturbances (e.g., resilience to exotic species invasion).

Hooper *et al.*, (2005) summarize current knowledge of the effects of biodiversity on ecosystem functioning as follows:

- Species' functional characteristics strongly influence ecosystem properties. Relative abundance alone is not always a good predictor of the ecosystem-level importance of a species, as even relatively rare species (e.g., a keystone predator) can strongly influence pathways of energy and material flows.

Photo 10.1: The canopy houses a unique and poorly known biodiversity.

- Alteration of biota in ecosystems via species invasions and extinctions caused by human activities has altered ecosystem goods and services in many well-documented cases. Many of these changes are difficult, expensive, or impossible to reverse or fix with technological solutions.
- The effects of species loss or changes in composition, and the mechanisms by which the effects manifest themselves, can differ among ecosystem properties, ecosystem types, and pathways of potential community change.
- Some ecosystem properties are initially insensitive to species loss because a) ecosystems may have multiple species that carry out similar functional roles, b) some species may contribute relatively little to ecosystem properties, or c) properties may be primarily controlled by abiotic environmental conditions.
- More species are needed to insure a stable supply of ecosystem goods and services as spatial and temporal variability increases, which typically occurs as longer time periods and larger areas are considered.

In view of the extreme complexity of ecosystem processes, and the far reaching effects that degradation of these processes can have on the food and health security of human populations and on climate change in general, placing economic values on the services that they provide remains a highly inexact science. The ecosystem service of food production, for example, contributes by far the most to economic activity and employment globally. In 2000, the market value of food production was $ 981 billion, or roughly 3 % of gross world product, but represented 24 % of total GDP in countries with per capita incomes less than $ 765 (the low-income developing countries, as defined by the World Bank) (MEA, 2005). The demand for ecosystem services is so great that trades-offs among services are constantly made. A country can increase food supply by converting a forest to agriculture, for example, but in so doing it decreases the supply of services that may be of equal or greater importance, such as regular rainfall, clean water, timber and non timber forest products, flood regulation ... Very little reliable information exists on the economic value of ecosystem goods and services provided by the Central African humid forests. However since the overall net annual deforestation rate in the Congo Basin, estimated at 0.16 % for the period 1990 and 2000 (Duveiller *et al.*, 2008), is half that of South America and four times lower than Southeast Asia, the economic value of forest services in the Congo Basin are likely to be comparatively important. A more detailed analysis deforestation rate estimates is given in chapter 12.

Overview of Products and Services Provided by Central African Forests Biodiversity

This section describes the goods and services provided by the forests according to the four categories mentioned in section 1: provisioning services, regulating services, cultural services, supporting services. Climate change, carbon sequestration, watershed protection and fuel wood are not covered in detail as they are treated more fully elsewhere in this report.

Provisioning Services

More than 90 % of the people of the Congo Basin depend to varying degrees on natural resources, including agriculture and non-timber forest products, for food, medicine, income, and timber (Clark and Sunderland, 2004). The Central African forests provide a very wide range of non timber forest products, NTFP, (FAO, 2001) and these make a significant contribution to the livelihoods of the rural poor (Ndoye, 2005). Several categories of plant and animal NTFP are recognized. Animal NTFP include: bushmeat (mammals, birds, reptiles, fish, insects); skins and trophies (ceremonial, decoration, fetish); live animals (pet trade); wild honey and wax; raw materials for traditional medicines; raw materials for colors. Categories of plant NTFP include foods (fruits, vegetables, nuts, spices); browse for livestock; traditional medicines and aromatic preparations; raw materials for colors and dyes; tools, arts and crafts and construction materials; ornamental plants; exudates (saps, oils).

Bushmeat (which is generally used to denote mammal meat but in fact also includes other vertebrates such as reptiles and birds) and fish are the most commonly exploited animal NTFP, followed by edible insects and honey. The forests of Central Africa contain about 270 species of mammals (Vande weghe, 2004). Virtually all of the large- and medium-bodied species (about 120 species, Kingdon, 1997) are consumed and at least 80 small-bodied mammal species (rodents, insectivores, bats) are also taken. Where faunal assemblages are relatively intact, ungulates, particularly forest duiker (*Cephalophus spp*) and small primates are the most commonly consumed animals. Certain rodents, such as the brush-tailed porcupine (*Atherurus africanus*) and the cane rat (*Thryonomys swinderianus*), are also favored species, particularly in situations where faunal assemblages are depleted. It has been estimated that bushmeat contributes between 30 and 80 % of the protein intake of forest-based communities in the region (Wilkie, 2001).

Photo 10.2: The pangolin, a common animal in the African forest.

Fish diversity and endemism is very high in the Congo Basin (over 700 species with 80 % endemism) and new species are being discovered with every expedition (Mamonekene, 1998; Stiassny *et al.*, 2007). Fresh water fish form an extremely important part of rural populations' diets. For example in the north of the Congo Republic freshwater fish make up an average of 41 % of rural populations' household protein depending on the season (Poulsen *et al.*, 2007) and can rise as high as 60 % depending on the season (Banque Mondiale, 2006).

Insects are also an important component of rural populations' diets. A review of the literature in Hoare (2007a) identifies at least 110 species traded in Central African markets including 82 species of caterpillars and larvae, 20 species of cricket and grasshopper and 8 species of termite. Caterpillars belonging to the moth genus *Imbrasia*, many of whose host plants are commercially important timber species of the Meliaceae family such as *Entandrophragma cylindricum* (sapelli), are particularly sought after during the hatching season. Beetle larvae, such as *Rhynchophorus phoeonicius* collected from raphia and oil palms, are also commonly eaten and traded.

A few animal species from Central Africa are collected for the pet trade. African grey parrots (*Psittacus erithacus*) are exported from Cameroon. BirdLife International (2006) reports that between 1994 and 2003 over 359,000 wild-caught birds were reported in trade by CITES Parties, of which 86 % came from Cameroon, Congo and DRC. Freshwater fish for the aquarium trade, and butterfly specimens for collectors (particularly from CAR) are also traded internationally but no reliable data on the level of the trade are available. Brummet (2005) suggests that a large number of fish species (from 13 genera) in the Central African rainforest rivers and lakes, where levels of endemism are particularly high, have potential as ornamentals and wholesale at an average of $ 2.43 per fish. The difficulty of capturing, holding and transporting these fish explain the high prices. Natural fecundity forest river species is very low, and breeding has also proved extremely difficult because they rarely reach sexual maturity outside of the special and complex rainforest ecosystem. The excessive or uncontrolled extraction of ornamental fish is considered to be a problem in all countries bordering Lake Tanganyika (EC, 2008).

Plants

Some 65 million people are estimated to live in, or in proximity to, the forests of Central Africa and use plant NTFP to varying degrees (Mala, 2008; Hoare, 2007a) for food, medicines and materials. The bulk of vegetable calories come from cultivated agricultural products. Most wild NTFP species are probably only used occasionally, the vast majority of use coming from a relatively small number of species which are used for essentially subsistence purposes. Many of the wild plants and mushrooms collected are rich in micronutrients, proteins and, in the case of seeds, fats. They therefore serve as important dietary supplements to the traditionally cultivated agricultural crops. Many species are used for multiple purposes including commercial timber. For example 61 % of the main commercial timber species exported from Cameroon have non-timber values and are used by local communities and poor urban households (Ndoye and Tieguhong, 2004).

It is estimated that 80 % of Africans use plant NTFP for medicinal purposes (Mala, 2008). They are readily available and are much cheaper than pharmaceutical equivalents, an important consideration at a time when medical services in Central Africa have collapsed. Many thousands of species are probably involved. For example, for the treatment of malaria alone, the Metafro–Infosys database[14] in the Royal Museum for Central Africa in Tervuren, Belgium lists over 500 plant species in sub-Saharan Africa. The Central African forests contain about 10,000 species of vascular plants (Mittermeier *et al.*, 2002) and an extensive scientific literature on Central African plant NTFP reveals that many hundreds of these species are used for medicinal purposes. For example in Cameroon alone, over 500 species are reported to be used for medicinal purposes (Mala, 2008). However it is important to underline that the widespread use of NTFP for medicinal purposes in Central Africa probably has much more to do with their cheapness than their real effectiveness in treating illnesses. For example malaria continues to kill untold thousands of people in Central Africa, despite so many different plants being used to treat it. The biochemical properties of only a handful of Central African plant species have been exploited for use in the international pharmaceutical industry, in particular *Prunus africana* and *Pausinystalia johimbe* for the treatment of prostate hypertrophy and sexual impotence respectively.

Photo 10.3: The forest offers a wide variety of consumable goods.

While most NTFP use can be considered to be for essentially subsistence purposes a small number of plant species are collected and traded on a large scale both regionally and internationally. Well known examples of these include:

- leaves: Marantaceae (packaging) and *Gnetum sp* (vegetable) ;
- barks: *Prunus africana* (treatment of prostate conditions), *Annickia chlorantha* (treatment of hepatitis), *Pausinystalia johimbe* (treatment for sexual impotence), *Garcinia cola* (stimulant, and bitter additive for palm wine) ;
- fruits and seeds: *Cola acuminata*, *Dacryodes edulis*, *Ricinodendron heudelotii, Irvingia gabonensis, Baillonella toxisperma, Piper guineensis, Xylopia aethiopica,* (fruits, seasoning, oils);
- saps: *Raffia* palms for palm wine ;
- canes: *Laccosperma spp* (rattan furniture).

[14] http://www.metafro.be/prelude/plant_collection

Box 10.1: NTFP in the Congo Basin

Across Central Africa, over 74 plant species and 67 species of animals (primarily mammals, birds, snails and lizards) have been recorded as sources of nutrition (FAO, 2007). The majority of these species are unevenly distributed across the Congo Basin and their use for sustenance varies widely based on accessibility, as well as culture, socioeconomic status, price and to an extent, especially for bushmeat species, legal regulation. The greater part of data on the use of NTFP in the Congo Basin concerns the use of NTFP as food, with studies showing the percentage of NTFP harvested for food in the range of 65% of NTFP for the whole of the Central African Republic to 88% for Baka communities in Cameroon. The second most common use for NTFP is medicinal: up to 80% of the African population is estimated to use NTFP for medicinal purposes. This number is as high as 91% of the population in the Democratic Republic of Congo. Over 500 different species of medicinal NTFP have been recorded in Cameroon. With several medicinal species traded internationally, notably *Prunus africana* and *Pausinystalia yohimbe*. A wide variety of other uses for NTFP has been also been documented, including construction materials (e.g. *Raphia spp.*, *Elaeis guineensis*), cosmetics and as wrapping for food products (*Afromomum spp.*).

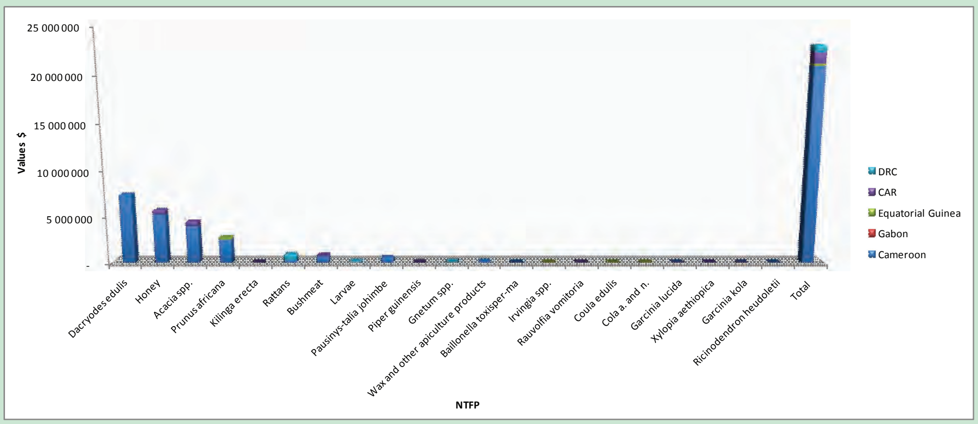

Figure 10.1: Market values for Congo Basin NTFP

More in-depth analytical data exist for certain NTFP, with over 30 studies in the last decade reporting on both individual NTFP and/or the variety of NTFP used in specific regions. The majority of information has been gathered in Cameroon. Although consistent and comparable data from across the Basin are inexistent, a literature review by CIFOR (CIFOR, 2008) reports that the annual market value of 21 specific NTFP amounts to approximately $ 23 million annually. This figure is likely the tip of the iceberg, as most of the studies included in the review focus on one of two types of species: (1) high value international products (39 % of all studies), such as acacia species for gum arabic or the highly regulated species *Rauvolfia vomitoria*, *Prunus africana* and *Pausinystalia yohimbe*; or (2) products with significant and well known national markets (36 % of the studies), such as Rattan, honey, *Irvingia spp.*, *Gnetum spp.* and *Cola spp.* Nearly all NTFP traded on national markets are unregulated. If harvesting quotas exist, they are not founded in scientific understanding. Seventy –eight percent of studies on NTFP are concerned with plant species, whose regulation is under the authority of Ministries concerned with forests and environment. However, for some animal products, such as honey in Cameroon, the authority is the Ministry of Livestock. International NGOs and other organizations such as, SNV, IUCN, and CIFOR, often coupled with international and national research institutions, have been the primary organizations documenting the NTFP trade in Central Africa to date. NTFP markets across the region are often characterized by high numbers of small scale actors, who often have a low level of organization. In addition there are often a wide range of intermediaries between the forest-based collectors and eventual processing, transformation or the end consumers in national urban and international markets.

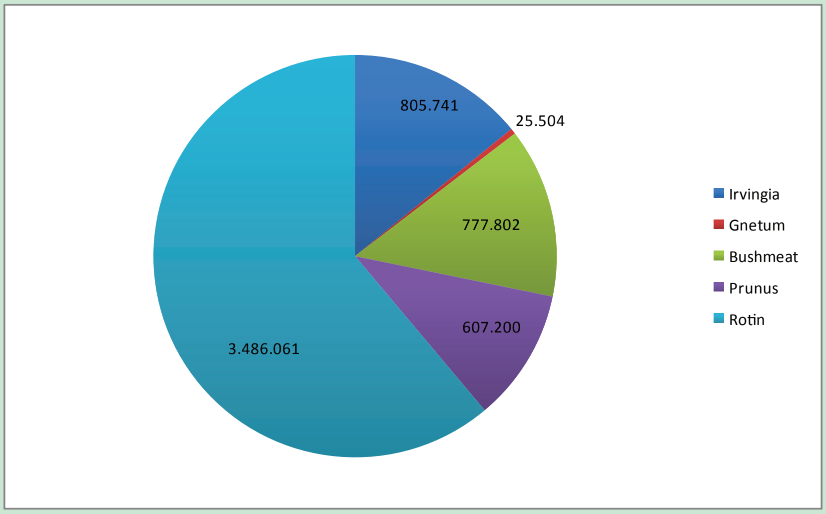

Figure 10.2: High value NTFP in the Congo Basin (in $)

In Cameroon, the markets for bush mango, Ndjansang, Eru, honey, Cola, Safou, bushmeat, Pygeum, Moabi oil, gum arabic, and rattan have a total annual value of sales of approximately $ 21,872,000. In Equatorial Guinea, *Prunus africana*, bushmeat, rattan, *Piper guinensis*, Irvingia, *Cola spp.* and *Coula edulis* amount to $ 187,000. In CAR, bushmeat and estimates for *Piper guinense*, *Xylopia aethiopica*, *Kilinga erecta*, *Rauvolfia vomitoria*, honey, rattans, and gum Arabic, amount to $ 1,210,000 per year. In DRC, Gnetum, larvae, caterpillars and rattan amount to some $ 842,000. The highest value products are listed in figure 10.2.

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Regulating Services

Tropical forests affect cloud formation, rainfall and temperature by absorbing high levels of solar energy and producing high rates of evapotranspiration. They also affect global climate processes. However while there is growing evidence to show that deforestation (the consequence of which is biodiversity loss) affects global climate processes (Stern, 2006; Shem and Dickinson, 2006; Maniatis, 2007; Hoare, 2007b), there is little if any empirical evidence to demonstrate to what extent the biodiversity in itself has a direct influence on climate patterns and other ecosystem services (Myers, 1996). Nevertheless since the vegetation structure and biomass of tropical forests is largely determined by its biodiversity (functional diversity, species richness) there may indeed be a relation between biodiversity and the regulating services that the tropical forests supply. However biodiversity is only one of several parameters, including species composition, nutrient supply and disturbance that influence ecosystem structures and processes (Tilman, 1999).

In the Congo Basin most of the rainfall comes from recycling of moisture by the forest (Brinkman, 1989), in contrast to other monsoon regions where much of the rainfall comes from the water vapor accumulated over the oceans. Loss of forest cover is therefore likely to cause a reduction in local rainfall and this has been confirmed by some modeling studies (Shem and Dickinson, 2006). There is also evidence that deforestation in the Congo Basin will affect weather patterns in distant parts of the world through its affect on large-scale atmospheric circulations (Avissar and Werth, 2005). However it should be remembered that much of the research is based on modeling which is limited by the quality of data available from the Congo Basin and the use of oversimplified scenarios for deforestation (Nasi, 2005). The current knowledge of the role of tropical forests on rainfall patterns and hydrological services is discussed in greater depth in chapter 9.

Biomass in tropical humid forests is much greater than in other types of forest so they are important reservoirs of carbon. Of the total carbon pool found in the terrestrial biosphere about 17 % is contained in tropical forests (Locatelli and Karsenty, 2004). An estimated 46 billion metric tons of carbon are stored in the Congo Basin of which 60 % are stored in evergreen lowland forests which cover only 35 % of the area (see chapter 12). The dense humid forest of the Congo Basin is therefore an extremely important reservoir of carbon. However global rates of deforestation are such that tropical forests during the 1990s accounted for 25 % of total anthropogenic emissions of greenhouse gases (Houghton, 2005), although reliable estimations of carbon fluxes for the Congo Basin, where deforestation rates are much lower than in the Amazon or Southeast Asia, are hampered by lack data. A more detailed analysis of carbon stocks and their variations in the Congo Basin is given in chapter 12.

Provisioning and supporting hydrological services provided by the Congo Basin forests include navigation, fisheries and hydroelectric power generation. These aspects are dealt with in detail in chapter 9. Here again however there appears to be little if any empirical evidence to show the extent to which biodiversity in itself contributes to these services. A monodominant *Gilbertiodendron* forest is likely to be just as effective for water flow regulation, for example, as a more diverse mixed forest.

Essential ecosystem functions of the Central African forests such as pollination and seed dispersal are highly dependant on animal biodiversity. It is estimated that two thirds of the world's flowering plants require animals, largely insects, for pollination (FAO, 2007). Pollination is known to be a central component in the evolutionary process of plant and animal communities but remarkably little is actually known about pollinators of wild plant species in Central Africa. Their role in agriculture is also of enormous importance. This is well illustrated by the weevil *Elaeidobius kamerunicus* which is the natural pollinator of the African oil palm *Elaeis guineensis*. When large-scale oil palm plantations were first established in Southeast Asia production was very poor. It was only after researchers in Cameroon discovered the pollinating role of *E. kamerunicus* that production could be increased by importing the weevil into Malaysian plantations (FAO, 2007). Central African forests are probably also important reservoirs of many predators and parasites of agricultural plant pests although here again very little is known.

Up to 80 % of tropical forest plants rely on animals to disperse their seeds (Vande weghe, 2004). In the Congo Basin large- and medium-sized fruit and seed-eating mammals, particularly apes, monkeys, ungulates (duiker, wild pigs), and elephants are known to play a key role in the regeneration of the forest. Seeds eaten are widely disseminated in the dung and passage through the digestive system is often a precondition for successful germination. Large keystone species such as the elephant can have a particularly important impact on these processes because of the large variety and quantity of fruits consumed (a dung pile can contain several hundred seeds from more than a dozen plant species), the distances they move (forest elephants can have home ranges up to 2,300 km²) and the physical impact that these large-bodied animals have on the structure of the forest as they move through it feeding (Blake, 2006).

There are also links between biodiversity and human health. Intact ecosystems maintain a diversity of species in equilibrium and can provide a disease-regulating effect if any of these species are directly or indirectly involved in the life cycle of an infectious disease. Disease agents with much of their life cycle occurring external to the human host, such as water- and vector-borne diseases, are subjected to environmental conditions, and it is these diseases for which most linkages to ecosystem conditions have been found (Patz and Confalonieri, 2005). Changed environmental conditions resulting from deforestation have been implicated in the upsurge of several diseases in Central and West Africa including malaria, onchocerciasis (river blindness) and yellow fever. The increased contact between wildlife and humans as a result of human-induced forest loss and the large-scale trade in bushmeat and live animals also brings the risk of emerging diseases from cross-species transmission since 61 % of a list of 1,415 known human pathogens are zoonotic – i.e. capable of infecting humans (Taylor *et al.*, 2001). HIV, monkey pox, Ebola and Severe Acute Respiratory Syndrome (SARS) are recent examples (Karesh *et al.*, 2005). Cross-species transmission can also work in the opposite direction – from humans to wildlife. For example the rare mountain gorilla, *Gorilla gorilla berengei*, in the Bwindi forest and the Virunga volcanoes could be at risk from close contact with humans through ecotourism (Robbins and Williamson, 2008).

Photo 10.4: Bushmeat hunting (duikers shown here) feeds urban markets

Cultural Services

Cultural services provided by forests in Central Africa include sacred forests and consumptive and non consumptive tourism.

A sacred forest is a place that is venerated and reserved for the cultural and/or religious expression of a community. Access and management are often governed by traditional power structures. Sacred forests are found throughout Central Africa. They serve a variety of functions including religious activities, protection of ancestors' spirits, secluded sites for cult or initiation ceremonies, forest cemeteries for particular members of the community who may have died in unusual circumstances. In areas where human activities have led to extensive forest degradation, the sacred sites are often harbors of biodiversity although they are generally rather small in size (0.5 to 5 ha) and are therefore unlikely to be important for biodiversity maintenance over the long term. Where they contain water sources sacred sites can play a role in protecting village water supplies in the dry season.

Box 10.2: Evaluating Protected Area Management and the RAPAC Pilot Action Program (PAP)

In 2007, RAPAC carried out an assessment of 40 protected areas distributed across 7 ecological complexes in the sub-region to assess management effectiveness. Using PAMETT (Protected Areas Management Effectiveness Tracking Tool), developed by the World Bank/WWF to monitor progress in forest conservation, the evaluation was based on thirty questions covering broad elements of protected area management. From now on, RAPAC will carry out this appraisal every two years. The next appraisal in 2009 will be extended and standardized across all protected areas in Central Africa. Moreover, information collected will be systematically inserted into the RAPAC database through collaboration with partner databases.

Results

Threats and enforcement

Among the ten threats indexed in PAMETT, poaching represents the main threat to protected areas in Central Africa and monitoring is the primary activity (in nearly 72.5 % of protected areas).

It appears that all protected areas have a decree announcing their creation, but there are still problems regarding the exact limits of some protected areas.

In nearly half of the protected areas, there are mechanisms to monitor unsuitable land use and illegal activities. However, effective implementation of these mechanisms raises major problems. Logistical and financial problems hinder the surveillance process and human resources are generally lacking compared to the IUCN norm of 1 person/5,000 ha.

In 70 % of the cases, the staff is sufficiently skilled to enforce laws and regulations, but some issues remain, especially in terms of staff numbers and staff retraining. Increased collaboration with legal agencies and the acquisition of more suitable equipment are required to improve the enforcement of regulations.

Environmental knowledge

Overall there is well-documented information on sensitive habitats, species, cultural values, and the potentialities of protected areas. Inventories are often implemented when partners are funding them and are inexistent otherwise. Generally, the available data and information is sequential and scattered, which hampers its capitalization.

In thirteen protected areas, there are integrated programs for inventory and research. For eight protected areas, the results of the research programs still need to be validated. In the remaining protected areas, these activities are sporadic and carried out by lone researchers or students.

Protected areas do not have any monitoring-evaluation strategy or regular collection of information.

Management efficiency

Effective implementation of desired objectives and activities is limited by insufficient financial and human resources. Poor local participation is another obstacle. Moreover, the absence of management plans for most Central African protected areas represents a weak point. Four protected areas were found to have management plans under implementation (Korup, Lobéké, Bénoué and Campo Ma'an in Cameroon).

Operations

No protected area was found to have an adequate budget, and funding from governments is insufficient to meet management needs. Protected areas that have acceptable levels of funding are those with partner support. The parks of Los Altos de Nsork, Corisco and Elobeyes, and Caldera de Luba have no budget. Nearly a quarter of protected areas have no basic equipment and infrastructure. Often there is no maintenance plan and equipment maintenance is sporadic.

Sensitization and local involvement

Education and sensitization programs were found to be targeted and limited in scope, and rarely part of a broader plan. Exchanges with public and private actors operating in the areas around protected areas are few and far between, although there is informal contact between protected area managers and tour operators. When local communities or indigenous peoples take part in management discussions, they do not participate in decision making.

With few exceptions (Pongara - Gabon, Dzanga-Ndoki - CAR, and Korup - Cameroon), visitor infrastructure is non-existent and, while provisioned for, access fees and taxes are generally not paid. On the other hand, the protected areas of Dzanga-Ndoki, Binder Léré, Monte Alén and Obô provide good examples of how income generated from protected areas can be redistributed.

Realization of opportunities

To date and across the board, the essential biodiversity values of protected areas have not been severely damaged and the partially degraded zones are found on the outskirts of the protected areas. At the same time, protected areas have neither compromised nor promoted local economies and employment opportunities have only benefited a few individuals.

Pilot Action Program (PAP)

In light of that assessment, RAPAC launched a request for applications for a Pilot Action Program in April 2008. The main goal of this Program is to improve the effectiveness of protected area management in Central Africa. Since the pilot actions that were financed would act as a "showcase" for RAPAC at the field level, priority was given to projects that best met the following criteria:

- innovative in character and replicable;
- located in or on the periphery of a site, in a transborder zone or in a marine protected area;
- implementing a participatory management model;
- working to improve livelihoods;
- potential to serve as a source of experiences and of tools that could be shared with other protected areas in Central Africa.

A total of CFA 188 million was provided to support fifteen projects through national organizations, and one of these projects (PROTOMAC, a project on turtles) has a regional scope. Each RAPAC member country (Cameroon, Congo, Gabon, Equatorial Guinea, CAR, DRC, Sao Tomé and Principe, and Chad) benefited from at least one project.

Because of its unique assemblages of tropical forest species the Congo Basin has considerable potential for two types of tourism - consumptive (sport hunting) and non consumptive (wildlife viewing). In both cases however the potential is based not so much on biodiversity, but rather on the presence of a few charismatic mammal species. Furthermore with the exception of tourism in the Great Lakes region, both forms of tourism remain relatively under-developed for various reasons. These include the high transport and living costs in Central Africa, the political and economic instability of the region, the logistical difficulties of access to many of the best sites, and the absence of reliable local operators capable of meeting the standards required by international tour operators. Non consumptive tourism has been most successful in sites where viewing of spectacular charismatic species such as gorillas, forest elephant and bongo, can be guaranteed (Wilkie and Carpenter, 2002). Mountain gorilla viewing in the Great Lakes region (Virunga volcanoes and Kahuzi-Biega) brings in millions of dollars annually for the three countries that share their range (Languy and Demerode, 2006). Demand is so high that parks authorities are able to charge up to $ 500 per person per day for gorilla viewing permits. The economic value of this species is undoubtedly one of the main reasons that this species remains relatively well protected despite the ongoing conflict. Indeed even after the gorilla sector of DRC's Virunga National Park was taken over by rebel forces in 2008 it is reported that they continued to organize gorilla viewing visits for tourists[15]. However elsewhere in the Congo Basin wildlife tourism is much more difficult to organize because of the difficulties of access to the few sites where wildlife viewing can be guaranteed. Gorilla viewing has been developed in Congo, Gabon and CAR where forest clearings (*bais*) provide ideal conditions for observing gorillas, as well as several other charismatic large mammal species such as elephants, buffalo, bongo, sitatunga and giant forest hog. In the early 90's (before the Rwandan and Congolese wars), the Rwandan and Congolese sectors of the Virunga volcanoes ecosystem were each receiving between 6,000 and 8,000 visitors per year (ORTPN, 2004; Aveling, unpublished

[15] http://gorilla.cd/2008/03/09/our-position-on-engaging-with-the-rebels/

Photo 10.5: There is high insect diversity in DRC: a Longhorn beetle from the Cerambycidae family.

data) for gorilla viewing, compared with a range of between 290 and 1,120 visitors per year between 1992 and 2006 in Dzanga Sangha in CAR (Blom, 2000; Blom, unpublished data).

Safari hunting in the Congo Basin also has considerable potential to generate revenues because of the presence of a few charismatic tropical forest species. The forested areas of Cameroon and RCA are the main areas where safari hunting is currently organized. Trophy hunters are particularly interested in forest elephant and bongo but the smaller, typically Central African, forest species such as duiker and sitatunga are also marketable. As with gorilla viewing this type of tourism targets the high end of the market. In Cameroon a 16-day safari currently sells for up to € 25,000[16]. High-paying, low-volume tourism is probably the most suitable form of tourism for the forest milieu because of the difficulty of approaching and observing forest species and the logistical difficulties of access. It has the potential to make a significant contribution to livelihoods of local communities and sustainable management of wildlife resources if partnerships and revenue-sharing agreements are established within the framework of community-based wildlife management structures, such as the ZICGC (*Zones d'Intérêt cynégétique à Gestion communautaire*) in Cameroon.

With the exception of the special case of gorilla viewing, non consumptive and consumptive tourism in the Central African forest is unlikely ever to be able to compete with logging in terms of financial spinoffs for local populations. However it can play an important role in achieving buy-in for conservation measures from local populations (Blom, 2000).

Supporting Services

Gross primary production of tropical forests is very high because of the high light intensities, high temperatures and abundant rainfall. However tropical forest soils, including those of the Congo Basin, are often poor because of leaching due to the high rainfall. Tropical forests have therefore developed efficient nutrient cycling systems which ensure that nutrients from the plants, in the form of fallen vegetation and other organic matter of plant and animal origin, are rapidly reabsorbed by the roots and recycled into the plants. A huge diversity of soil fauna (essentially invertebrates), fungi and microbes ensures that organic matter is rapidly broken down in the hot humid conditions of the forest floor. The nutrient cycle is therefore an essentially closed one with the majority of nutrients being stored in the plants themselves rather than in the soil. The efficiency of this system is due in large part to the high biodiversity of the tropical forests and the functional diversity of the different ecosystems. For example the vast areas of swamp and riverine forests, by filtering the water draining from *terra firma* forests, play a vital role in conserving "escaped" nutrients from these forests (Vande weghe, 2004). Loss of this diversity, through forest clearance, is therefore likely to impact negatively on the efficiency of the nutrient cycling processes in the Congo Basin. Nutrients will be lost and annual production will decrease.

The Impacts of Biodiversity Loss on Forest Products and Environmental Services

General Remarks

Poor people in tropical ecosystems rely on ecosystem services more than do wealthy people (Reid and Huq, 2005). To meet their daily needs they tend to have multiple livelihood activities based on access to common property forest products such as bushmeat, fish and plants. Some food species are used on a daily basis while others are exploited as an alternative when staples are in short supply. Rural peoples' access to these products is therefore severely affected when the forest is degraded through deforestation and biodiversity loss. At a more general level, as we have seen in a previous section, ecosystem services such as pollination, seed dispersal, climate regulation, nutrient and water cycling, primary production, soil formation and retention, and human health regulation are also affected by biodiversity. The well-being of rural populations in the Congo Basin is thus directly linked to the state of conservation of the ecosystem (Biringer *et al.*, 2005).

This section looks briefly at some of the implications of harvesting of forest products and biodiversity loss in relation to the environmental services provided by the Congo Basin forests.

[16] http://www.huntineurope.com/usa/hunting_AFRICA.asp

Harvesting of NTFP

In species-rich forests most species are rare or patchily distributed and occur at relatively low densities. This means that commercial exploitation of most species of value to humans can easily lead to overharvesting. The "bushmeat crisis" has received much attention in the international press over the past decade. No reliable data exist for overall quantities of bushmeat consumed in the Congo Basin because the trade is conducted almost entirely within the informal sector and is therefore very difficult to monitor. Bushmeat is traded and consumed in both rural and urban settings and figures of up to 1.1 million tons consumed annually are quoted by the Bushmeat Crisis Task Force (BCTF, 2006). Opening up of the forest through road building and industrial extraction activities (particularly timber) are known to facilitate the bushmeat trade and the received wisdom is that the markets in the large cities are the principal drivers of this trade. However recent evidence suggests medium-sized towns and rural villages may play a much more important role in the trade than was previously thought. For example in Gabon 50 % of bushmeat is consumed in rural areas and it has been shown that the value of bushmeat as income in villages is more important than its value for consumption, and its income value is greater in remote villages than in more wealthy ones which have easier market access for alternative products (Starkey, 2004; Wilkie *et al.*, 2005). What is clear however is that sustained hunting pressure significantly alters the structure and composition of wildlife populations and there is now a growing body of evidence to show that the bushmeat trade is leading to unsustainable levels of harvesting, particularly with respect to large-bodied, slow-reproducing mammals. This effect is particularly marked closer to urban centers where depletions, and even extinctions, have been reported (Starkey, 2004; Colishaw *et al.*, 2004). Where local extinctions of keystone species, such as the forest elephant or seed-dispersing ungulates, occurs this can have a disproportionate effect on ecosystem processes (Nasi *et al.*, 2008). Sheil and Salim (2004) observed a marked difference in forest composition and structure in two forests in Uganda, one with elephants and one where elephants had disappeared.

However some small-bodied fast-reproducing species, such as the blue duiker, brush-tailed porcupine and cane rat appear to be able to resist high levels of off-take. Colishaw *et al.*, (2004) have coined the phrase "post-depletion sustainability" for areas where intense hunting over many years has eliminated large-bodied slow-reproducing mammals and the bushmeat trade is confined to robust small-bodied species that can sustain heavy exploitation. However in terms of animal diversity these forests are impoverished, even if the off-take of the small-bodied species appears "sustainable." This impoverishment is likely to be particularly acute because the loss of all large-bodied mammals, several of which may be keystone species, impacts the functional diversity of the forest. In many areas however, particularly around large towns and cities, bushmeat species have been essentially eliminated and people have switched to domestically-reared livestock.

Although most plants NTFP are collected mainly for subsistence purposes several species are harvested intensively (Mbolo, 2006) and in some cases this may be at unsustainable levels (Ndoye and Awono, 2005; Hoare, 2007a). Most are collected from the forest, in general from secondary or early successional forests. A few, for example the African plum tree *Dacryodes edulis* and the wild mango *Irvingia gabonensis,* have been integrated into the agricultural systems and would perhaps be better described as crops rather than NTFP. As with animals, the scale of harvesting is difficult to monitor precisely because it is mainly confined to the informal sector. Also the impact of harvesting on the survival of the plant is very difficult to asses as it varies according to the part of the plant that is collected. Harvesting of reproductive parts (fruits, seeds) or vegetative parts whose removal kills the plant (bark, roots) has a greater impact on the survival of the plant populations than harvesting of leaves, saps and resins.

Photo 10.6: Bosman's Potto (Perodicticus potto) in the Ituri forest in DRC.

Photo 10.7: Display of honey and other products extracted from the forest.

Leaves of Gnetum (*Gnetum africanum* and *G. buchholzianum*), rattan canes (*Laccosperma spp*), kola nuts (*Garcinia spp*), wild mangos (*Irvingia* sp), and African plum (*D. edulis*) are some of the most widely traded both within the region and internationally. Trade in rattan canes, which is harvested exclusively from the wild in Central Africa, is considerable and rivaled only by bushmeat (Sunderland *et al.*, 2002). There is also a large trade in *D. edulis*. A study in Cameroon estimated its annual worth at $ 7 million in-country and $ 2.2 million for the African diaspora in Europe and North-America (Awono *et al.*, 2002).

There is abundant evidence for overharvesting of some species. For example *Gnetum* is becoming rare in some areas (Ndoye and Awono, 2005; Bikoue and Essomba, 2007) because of the large quantities harvested and the destructive methods used which involve cutting the vine at the base to pull it down and remove the leaves. Plants such as *Garcinia*, which are used for both food and medicinal purposes, are particularly at risk of overexploitation (Guedje and Fankap, 2001). In this case destructive collection methods include ring barking and felling for collection of the roots. Barking and felling of *Prunus africana* trees for the multi-million dollar international pharmaceutical trade has also led to the virtual disappearance of this species in many areas particularly in the montane forests of Cameroon (Stewart, 2003) and eastern DRC.

As with bushmeat the open access nature of most plant NTFP is an important factor contributing to overharvesting. However, unlike wild animals, possibilities exist for integrating certain species into existing agroforestry systems (van Dijk and Wiersum, 1999). For example a study in Cameroon (Tchatat, 2002 cited in Bikoue and Essomba, 2006) showed that up to 40 % of the plant species used for NTFP occurred at higher densities in habitats modified by human activities (secondary forest produced by slash-and-burn agriculture, cocoa plantations) and that farmers apparently make a deliberate effort to preserve species of particular value when they clear the forest.

Biodiversity Loss, Rainfall and Climate Patterns

As noted earlier most of the rainfall that falls on the Congo Basin is thought to be generated from the Congo Basin itself so it is likely that rainfall patterns will be affected by changes in forest cover. The Congo Basin rainforests are considerably "drier" than the Amazon and Southeast Asian rainforest blocks. Average rainfall over most of the Congo Basin fall within the range of 1,200 to 2,000 mm while in the central Amazon and Southeast Asia averages generally fall within the 2,000 to 3,000 mm range (Cutrim *et al.*, 1999; UNEP, 2006; Globalis web site[17]). The rainfall threshold for the maintenance of dense humid forest in Central Africa is low at around 1,350 mm, and only if the dry season does not exceed 3.5 months (Jacobs, 1981 referring to the work of André Aubréville). If average annual rainfall over the Congo Basin were to drop slightly for whatever reason (forest fragmentation, global warming), or the dry seasons were to extend beyond 3.5 months this might bring large areas of the Congo Basin below the threshold level for maintenance of humid forests, thus accelerating the process of forest loss, and hence biodiversity loss. Evidence for a significant decrease in rainfall in the Lac Tumba area of DRC, resulting in a drop in the water level of the lake, has been reported by Inogwabini *et al.*, (2006). They argue that these changes, which they suggest may be attributable to the global climate change phenomenon, will have important ecological consequences on the adjacent forest ecosystems. They also point out that lack of long term meteorological data in Central Africa is a major constraint to understanding the effects of climate fluctuations on the Congo Basin forests.

Biodiversity Loss and Nutrient Cycling

As mentioned above the efficiency of tropical forest nutrient cycling is closely linked with its biodiversity. It follows that loss of biodiversity through forest clearance will lead not only to a massive loss of the nutrients stored in the plants themselves but also to the loss of the litter and upper soil layers, where all the nutrient cycling takes place, through erosion. Traditional farmers in the Congo Basin have long understood this process and have developed an itinerant form of slash-and-burn agriculture with, until relatively recently, sufficiently long fallow periods (>20 years) to allow soils to recover. Unfortunately increasing human populations is leading to a significant shortening of the fallow periods in the Congo Basin (Ngobo *et al*, 2004) and this is having adverse effects on soil fertility, forest regeneration and, ultimately, biodiversity.

[17] http://globalis.gvu.unu.edu

Photo 10.8: Basket making is an activity that relies on forest products.

Biodiversity as a Gene Pool for Crops and Pharmaceuticals

Although about 7,000 plant species have been cultivated for food since agriculture began about 12,000 years ago only about 200 have been domesticated and today about 15 plant species and eight animal species supply 90 % of our food. Many traits incorporated into these modern crop varieties came from wild relatives to improve their productivity and tolerance to pests, diseases and growing conditions. Wild relatives are therefore an insurance for the future (UNEP, 2007) but human food production currently rests on the tips of pyramids of biodiversity, leaving the majority of species little-used and undomesticated (DFID, 2002). It should be remembered however that, with the notable exception of the oil palm and two species of *Dioscorea* yams, almost all other crops grown in the Congo Basin originate from Central-South America and South Asia or from African regions outside of the Congo Basin (e.g., coffee from Ethiopia).

Similarly 25 % of modern prescription drugs contain at least one compound derived from, or patterned after compounds derived from, higher plants (Duke, 1993) but the majority of plant species remain untested. The genetic diversity of the Congo Basin therefore constitutes a reservoir of potentially useful compounds waiting to be discovered although care should be taken not to raise expectations about the likelihood of major new discoveries being made and the scale of economic spinoffs that these might bring. Simpson *et al.*, (1996) consider that the conservation incentives provided by biodiversity prospecting are, at the most, modest. So far only a handful of species have been commercially exploited by pharmaceutical companies for their medicinal properties, the most well known examples being *Prunus africana* and *Pausinystalia johimbe*. However this has involved the export of large quantities of plant parts and has lead to unsustainable harvesting levels. In recent years there has been a move towards a more systematic process of bioprospecting of Central African plants to identify active compounds. Where this is conducted by reputable international scientific research institutions, working with private research labs within the framework of transparent agreements with host countries, intellectual property rights and national interests can be safeguarded. The Missouri Botanical Gardens[18] and the United States National Cancer Institute have been running such a program in tropical Africa and Madagascar since 1986 and a number of promising compounds have been discovered from this program, including the anti-malarial korupensamines from the recently discovered liana *Ancistrocladus korupensis*.[19] The Biodivalor program, implemented by the NGO Pro Natura International in collaboration with IPHAMETRA (*Institut de Pharmacopée et de Médecine traditionnelle*) also undertook bioprospection work in Gabon between 1997 and 2001 and established contracts with several pharmaceutical and cosmetic companies (Dior, Aventis, Fabre, Novartis-Syngenta) for the commercialization of locally-transformed products. The results in terms of economic spinoffs nationally and locally appear to have been disappointing (Lescuyer, 2006), although this may be more to do with institutional failings rather than a lack of genetic potential of the Gabonese forests.

Conclusion

The relationships between biodiversity, ecosystem function, climate patterns and human well-being are highly complex and tightly intertwined and clearly cannot be treated exhaustively in a chapter of this length. This chapter has attempted to provide a broad overview of the ways that biodiversity contributes to the maintenance of some of the key forest goods and services in the Congo Basin and highlights, within the limits of current knowledge, the most likely impacts of biodiversity loss on these goods and services. Although empirical data on these impacts are sketchy to say the least, there is general consensus among scientists that the genetic and functional diversity of the Congo Basin is of exceptional global importance. It provides essential food, fiber, medicines and water for the majority of the inhabitants of the Congo Basin and has global impacts through its effects on global climate patterns. Biodiversity loss in tropical forest ecosystems is an insidious process which is likely to go unremarked until it is too late to reverse the slide. There is therefore an urgent need for wise management of the Congo Basin forests so that sufficient forest cover is preserved to maintain these essential goods and services. Given the relatively slow rate of forest loss in the sub-region, the countries of the Congo Basin still have a rich and abundant heritage of forest resources and are in the enviable position of being able to react before it is too late.

[18] http://www.wlbcenter.org/bioprospecting.htm

[19] http://www.wlbcenter.org/discoveries.htm