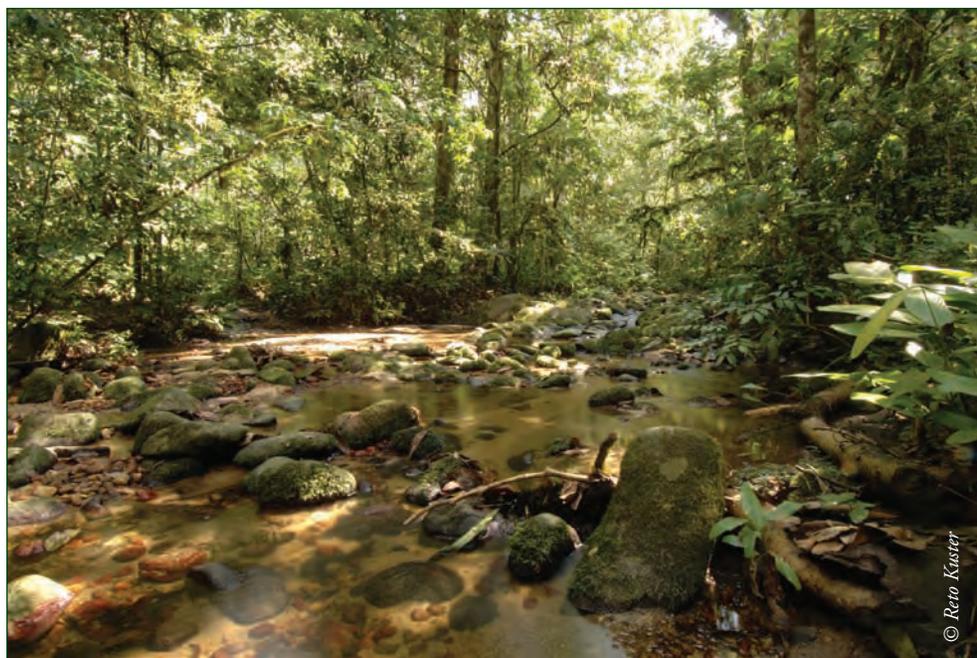


CHAPTER 9

WATER RESOURCES, FORESTS AND ECOSYSTEM GOODS AND SERVICES

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Among the ecosystem goods and services supplied by rainforests are numerous vital, but often underappreciated, goods and services linked to water resources. The Congo Basin forested region forms part of the Congo Basin watershed that provides its inhabitants with multiple water-related benefits, including water supply, flow regulation and water quality. The watershed is characterized by a dense river system that serves as an important navigation system for Central Africa, plays a large role in food supply and local livelihoods, acts as habitat for a range of plants and animals and has significant hydropower potential. In this chapter we examine some of the goods and services provided by the hydrological system in the Congo Basin and explore the relationship between forest ecosystems and the water resources that provide these benefits. A flexible spatial definition will be applied; the primary focus is on the Congo Basin forested region, but some consideration is given to the entire Congo River Basin and to major coastal cities on rivers outside the hydrological basin that benefit from hydrological goods and services. The chapter begins with an overview of the water system in the Congo Basin, presents a synopsis of select hydrological goods and services,



describes the relationship between forests and water resources in large river systems and concludes with a section on the state of knowledge and water resource management in Central Africa.

Photo 9.1: The forest plays an important role in maintaining the quality and quantity of water in the Congo Basin.

The Congo Basin Hydrological System

The forests of Central Africa overlap with several major basins (figure 9.1): the Congo, the Ogooué, the Sanaga, the Cross, and the lower Niger. There are also many smaller basins that drain into the Gulf of Guinea.

The Congo River basin, with annual renewable water resources of about 1.3 billion cubic meters, is the largest of these basins and accounts for about 30 % of the water resources in Africa and was estimated to contain a population of approximately 77 million inhabitants in 2005 (African Development Bank, 2006). It is the largest basin in Africa with an area of approximately 4 million km²; the Congo River has an annual average discharge at Brazzaville of about 41,000

m³/s (Nkounkou and Probst, 1987). The Basin includes portions of ten different countries, but 85.3 % of the Congo River basin falls within the largely forested regions of four countries: Cameroon, Central African Republic, the Democratic Republic of Congo and the Republic of Congo. Within the Basin the hydrological network is very dense and includes a complex river network, vast inundated forests and lakes.



Sources: WWF, USGS, SDSU, UMD, Tom Patterson, US National Park Service.
 Figure 9.1: Congo Basin Hydrological Watersheds



Source: NASA.
 Figure 9.2: Image of the Congo River at Stanley Pool. Taken from the International Space Station on June 6, 2003

The Basin extends from latitude 09°15' N in the Central African Republic to 13°28' S in Angola and Zambia, and from longitude 31°10' E at the Great African Lakes in the East African Rift to 11°18' E on the Atlantic Ocean. The waters of the Congo River originate in the highlands (1,400 m) and mountains of the East Africa Rift, as well as Lake Tanganyika and Lake Mweru (Shahin, 2002) and flows north towards Boyoma Falls. The Upper Congo (Lualaba River) ends at Boyoma Falls where the Middle Congo begins. After the town of Kisangani, the Congo River turns west and southwest following a great curve. The Middle Congo ends at Stanley Pool, where the capital cities of Kinshasa and Brazzaville are located (figure 9.2). There, the river expands some 24 km across and the waters slow down considerably. Between Kinshasa and Matadi, a distance of about 350 km, the river descends some 280 m in elevation and is interrupted by numerous stretches of rapids, the largest and most well known of which are the Inga rapids. The River reaches the Atlantic Ocean between Banana Point in the Democratic Republic of the Congo, and Sharks Point in Angola, from where it continues its course underwater. The length of the Congo is approximately 4,700 kilometers. The major tributaries are: the Luapula and the Lualaba (the two headstreams), the Lomami, Ruki-Tshuapa and Oubangui (the main navigable tributaries of the Congo), the Sangha, and the Kasai.

In the central Basin there are vast areas of flooded forests, characterized by brown humic (acidic) waters that fluctuate with rainfall and seasonal changes in the Congo River level. Figure 9.3 shows the extent of flooded forest in the central Congo Basin.⁴

The Congo River system covers three different climate zones, including an equatorial zone with tropical zones to the north and south and a more temperate zone in the elevated region to the east. The heart of the Basin is within the equatorial climate zone where there is no real dry season. The rainfall in the equatorial region varies between 1,500 and 2,000 mm a year, with an average temperature of approximately 26° C. Average humidity is around 77.8 % and evapotranspiration is around 1,700 mm.

⁴ Data used in mapping the extent of flooded forests include: Landsat TM and ETM+ imagery, JERS-1 SAR and SRTM.

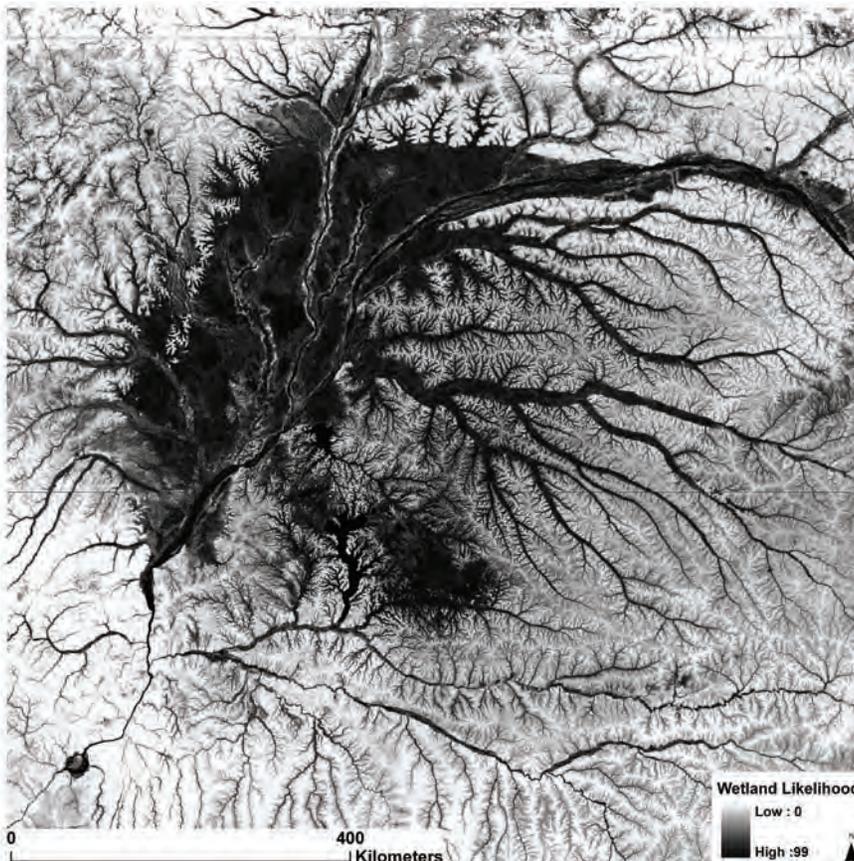
The flow of the Congo is influenced by a complex series of factors across the Basin, but overall the Congo is more constant than many other African rivers because large sections of the watershed lie above and below the equator, in the path of the Intertropical Convergence Zone. However there is some inter-annual variability with December being the month of maximum flow and July and August the months of lowest flow. The tributaries from the South, such as the Kasai, have two

periods of low water and two of high water each year, but the tributaries from the north, such as the Oubangui, have a single peak causing the regime of the main river to vary from place to place (Shahin, 2002).

Since 1960 there has been a general decrease in flow which coincides with a reported decrease in precipitation from major meteorological stations.

Box 9.1: Wetlands Likelihood in the Cuvette Centrale

A new approach to mapping the wetlands of the Congo Basin has been applied to a 1,175,918 km² region centered on the *Cuvette centrale* of the Congo Basin watershed. Mapping challenges include data limitations, vegetative structural heterogeneity, wetland seasonal variability, and limited opportunities for data collection for ground-based training and validation. To overcome these limitations, a multi-source statistical supervised classification approach was undertaken. Passive optical remotely sensed imagery provided by the Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensors, JERS-1 active radar L-band horizontal co-polarization imagery, and 3 arc-second elevation data derived from the Shuttle Radar Topography Mission (SRTM) were used as inputs. These data were related to wetland/non-wetland training data through a classification tree algorithm to yield a wetland probability map for the central Congo Basin. Wetland probability was expressed at a spatial resolution of 57 meters. The proportion of wetland cover for the study area equaled 32 %, equivalent to 359,556 km². Figure 9.3 shows the results of the study and the fine-scale variation of central Congo Basin wetlands. The unique ecological characteristics of humid tropical forest wetlands merit their mapping and monitoring. Improved wetland mapping can be used by a variety of applications, including hydrological modeling, forest use planning and biodiversity assessments. Future efforts will extend the method to cover the entire Congo Basin and to develop approaches for quantifying changes in wetlands extent over time.



Source: SDSU and CARPE.

Figure 9.3: Wetland likelihood map for the central Congo Basin area.



Photo 9.2: Rainfall is abundant and supplies rivers with large quantities of water.

Hydrological Goods and Services in the Congo Basin

Among the ecosystem services provided by forests in the Congo Basin are hydrological services related to water resources, including the vast Congo River system. Following the classification used by the Millennium Ecosystem Assessment, these services can be categorized into: (1) provisioning services - for example services related to water supply, that can be used through extraction, for purposes such as agriculture and municipal water supplies, and *in situ*, for maintaining freshwater fish production, navigation or hydropower generation; (2) regulating services, including services that help to maintain biophysical processes; (3) cultural services; and (4) supporting services, such

as maintaining biodiversity habitat. Hydrological services also include water mitigation services that diminish flood damage, stop in navigation due to low waters, sedimentation of water bodies, salt-water intrusion and dryland salination.

In this section we review several of the provisioning and supporting hydrological services in the Congo Basin, including: navigation, fisheries, hydroelectric power generation, and biodiversity habitat. This section does not review all the ecosystem services provided by water resources in the Congo Basin, but instead serves as an introduction to some of the services of most immediate concern for human populations.

Navigation

Within the Congo Basin, waterways provide a dense navigation system that extends for over 12,000 km and supply a vital means of transportation within and between different countries in the region. This network is the primary means of exchanging goods and services for the bordering communities and is the basis for a regional multimodal transportation network extending outward from the main ports of Pointe-Noire, Matadi, Brazzaville, Kinshasa, Bangui, and Kisangani (figure 9.1).

In the colonial era, rivers were used to transport goods and passengers between the Atlantic and the interior. To bypass the un-navigable falls and rapids three portage railways were built: Matadi to Kinshasa, Pointe-Noire to Brazzaville and Ubundu to Kisangani. All were abandoned at some point due to sabotage and civil war. Since

1997, periodic suspension of the Congo-Ocean Railway, linking Brazzaville to Pointe-Noire led traders to use an overland route through Cameroon. Limited freight and passenger services were resumed in 2000 and 2001 and restoration of the line is being discussed. The line between Matadi to Kinshasa does not work and the line from Ubundu to Kisangani has long since been reclaimed by the forest (Butcher, 2008).

With outdated railways and relatively few roads, the complex system of waterways is vital for local economies throughout the Congo Basin and the revival of the regional economy. Inland, the Congo and the Oubangi rivers form the two main axes suitable for commercial traffic and yet despite the importance of these waterways river traffic has severely decreased. This is partly due to political instability and a decrease in water



Photo 9.3: Navigation is important in Central Africa, but is sometimes interrupted by waterfalls.

level on the Oubangui over the last 30-years. The *Service commun d'Entretien des Voies navigables* (SCEVN) noted an 18 % decrease in discharge since 1985 (figure 9.4). Shallow water levels on the Oubangui River during the dry season prohibit the use of barges for navigation for five months of the year. When water levels are sufficiently high it takes approximately 21 days for a convoy of barges carrying about 1,500 metric tons to complete the 2,360 km round trip from Bangui loading either in Kinshasa or Brazzaville and back to Bangui.

In general the navigation system in the Congo Basin suffers from significant problems: poor maintenance, insufficient beaconing of waterways, modest traffic, lack of regulation, out datedness and insufficiency of transport facilities, as well as additional non physical barriers. Managing navigation on shared waterways is a key objective for CICOS, the International Commission for the Congo-Oubangui-Sangha (box 9.2).

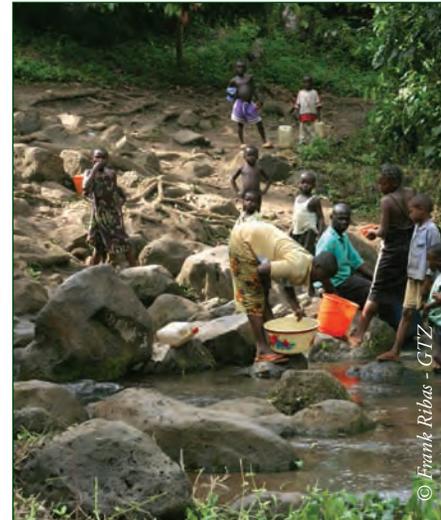
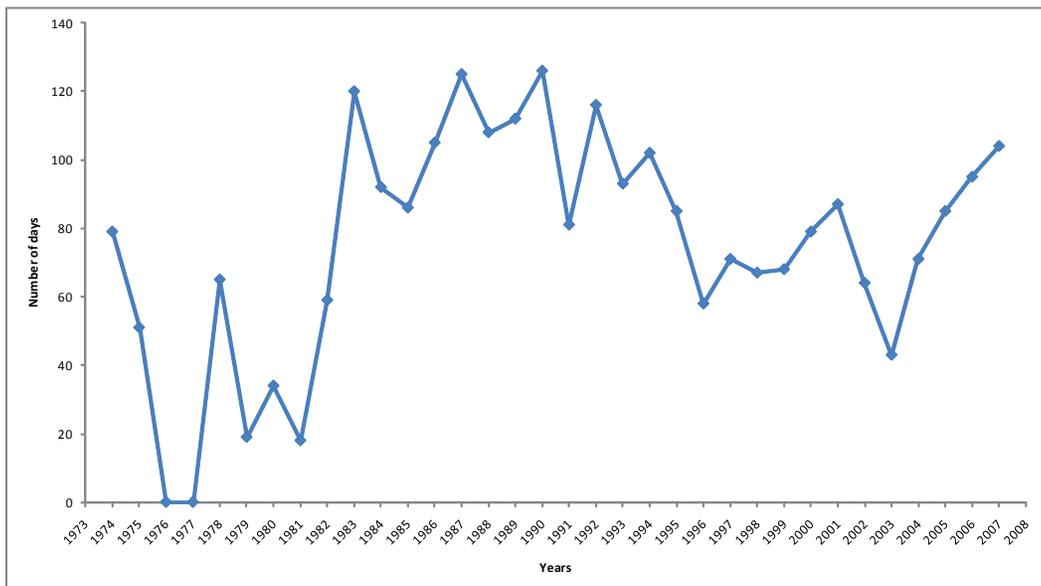


Photo 9.4: Water is a basic necessity; its quality is preserved by the forest.

Box 9.2: CICOS - International Commission for the Congo-Oubangui-Sangha

On November 17, 1999, CICOS, the International Commission for the Congo-Oubangui-Sangha Basin, was created to strengthen trans-border management of water resources between the four riparian countries which together compose 85.3 % of the Congo's hydrological basin: DRC, Cameroon, Republic of Congo and CAR. The original Accord, ratified by the four Heads of State, identified internal navigation as the key objective. On February 22, 2007 an amendment to the Accord supporting the Integrated Management of Water Resources (IWRM) was ratified. The overall aim of CICOS is to manage water resources based on shared strategies that promote trade and economic development, while also controlling pollution and adhering to IWRM principles.

The institutional framework of CICOS is composed of two bodies: (1) the Ministerial Committee, which serves as the decision making body of CICOS and (2) the Management Committee, which acts as the advisory body or steering committee.



Source: Ladel et al., 2008.

Figure 9.4: Number of days with a water height of less than 90 cm required for an economic navigation on the Oubangui River.



Photo 9.5: A "residential" boat on the Salonga River in DRC.

Estimates of annual fish catch from the Congo Basin vary widely and range as high as 120,000 metric tons. In addition to generating the majority of animal protein consumed by rural communities, the value of the catch represents an important proportion of gross national income in the rainforest zones. An estimated 20 % of the adult population living in rainforests are engaged in river fisheries (Brummett and Teugels, 2004). Actual fish yields and their value are unknown but the potential for the fishery in the mid 1980's was estimated at 520,000 tons worth \$ 208 million (Neiland and Béné, 2008). Chapman and Chapman (2003) estimate that this value represents only 41 % of the potential total catch in DRC.

There is very little actual or published data on the Congo Basin fisheries. The following descriptions are summarized from an ongoing research by the World Fish Center (funded under CARPE) in lakes Tumba and Mai-Ndombé, the Salonga River and the Lomako River.

The Fishery

The most widely used gear is the traditional basket trap. These come in a wide range of lengths from 30 cm up to 3 m or more. These are placed in streams and shallow sections of main rivers at fish migration routes. They are held in place with stakes, rarely baited and checked daily for fish. Such traps are cheap, being mostly manufactured by the fishers themselves.

A widespread women's traditional fishery or "écoupage" is also based on home-made baskets used as the waters recede from the forest during the dry season to capture small and juvenile fishes, crabs and freshwater prawns. The "epoko" is a small, nearly watertight basket that is used to bucket water out of depressions in the swamp forest or from small dams constructed on low-order streams. Usually, 6-10 women, lead by an older and more experienced matron, will work together to share the work.

The most widely used "modern" gear in the commercial (all male) fishery is the "Lubumbashi" style gill net, named after the defunct fishing net factory that produced netting up until 1983. Gill nets are generally placed in parallel with the river current across entry/exit points where fish move between the main river and the flooded forest. Hooks are comparatively rare among the typical fisher, but "professional" fishers (see below) report using baited hook-lines for the preferred

Parachanna obscura ("mongusu") an ambush predator difficult to catch with set nets.

The use of dynamite, chemical poisoning of ponds and burning vegetation have been reported as illegal fishing methods in Salonga National Park (Inogwabini, 2005).

Out of some 1,000 estimated species in the Congo river system (Thieme *et al.*, 2005), only 50 are regularly captured. Due to the inability of most fishers to access deep water or main river channels, many of these are taken only as juveniles while they are feeding and growing in the flooded swamp forest or during (horizontal) spawning migrations between the main river and the flooded forest.

The Fishers

Most fishing occurs during the dry season when the water is relatively low, the swamp forest is relatively dry and fish are concentrated in the rivers. However, some fishing, especially for household nutrition, occurs throughout the year. During the peak fishing seasons, groups of fishers operate from small villages or temporary camps. Fishing is seen as a complimentary activity to agriculture. Most fishers remain dependant upon a larger village where they cultivate land for agriculture.

Despite well-known village boundaries, the fishery is open-access with people fishing pretty much wherever they please. Most fishers are, nevertheless, from the village on whose land they are situated, which permits them to retain traditional property rights to any agricultural plots they manage. All of the interviewed fishers insisted that newcomers are welcomed and that there are no constraints put on fishing access and no requirements to seek permission from traditional authorities.

Fishing is seen as a complimentary activity to agriculture and many fishers are only fishers because of a lack of capital and markets needed to undertake traditional agriculture on a larger scale. When asked specifically what they would do if they had "enough money," fishers indicated that they would go back to the village, build a house and obtain a plot of land to farm. These fishers operate an average of about 13 nets (approximately 50 m wide) and a few dozen hooks and manage to capture 20-30 *valises* (3-5 kg) of dried fish per year.

There are a minority of fishers who are considered professionals. These people usually bring manufactured goods (e.g., clothing, sandals, mosquito nets, torches, batteries, fishing gear) from outside to barter for fish as well as doing their own fishing. The typical professional fisher operates about 100 nets plus 1,000-1,500 hooks and catches 60-100 *valises* per year. Once they have enough fish to fill their pirogue, they go to town, sell their catch, replenish their supply of consumer goods and return. These trader-fishers tend to move around and compete with each other for a presence in the best fishing camps.

The Fishery Value Chain

It is estimated that fishers keep about 1 kg per family (avg ~6 persons) per day for household consumption. The rest is destined for market. These are usually smoked in a single layer over an open hot fire using dry wood for a period of about 6 days. This results in a product that is charred on the outside but poorly preserved on the inside. The typical practice is to store these fish throughout the dry (fishing) season until prices rise in the following rainy season, meaning that most fish are held for at least 2-3 months, and sometimes up to 6 months prior to marketing. Smoking is often repeated monthly during storage to combat insect infestation and mould. The process leads to dry matter losses estimated by the fishers at between 30 and 50 %.

Salting and sun drying produces a higher quality product, but relies on expensive salt that has to be brought in from either Kisangani or Basankusu. The high cost of salt, approximately 10,000 Congolese Francs per 20 kg (roughly \$ 20 in 2008), encourages fishers to try to brine their fish in lower-than-optimal concentrations, reducing quality. Although the data collected on fish are sparse, observations indicate that the relative return on salted fish has the potential to be double that of smoked fish, and may possibly surpass that of fresh fish due to its longevity.

The catch from the women's *écoupage* fishing is primarily consumed by the household, but in times of abundance may be marketed locally. Women are heavily involved in the smoking of the men's commercial catch, cleaning the fish, gathering firewood and tending the fires. In the "professional fisher/trader" camps, all processing and trading is done exclusively by the women, leaving the men to spend more time fishing.

Fish are marketed in a variety of baskets and basins. The smallest unit is the "valise" which holds about 30 smoked fish (estimated 5 kg dry weight, 10-20 kg wet weight). A "basket" contains 5-6 *valises* while a "suzuki" in turn holds some 3-4 baskets. None of the above units are standardized, so one often hears of a "small valise" or a "large suzuki." Salted fish are transported on open "paniers" that hold roughly 10 fish. *Écoupage* catches are transported either in the small *epoko* used in the *écoupage*, but more frequently in large baskets called "corbeilles" that equal roughly four *epoko* in volume. In more accessible camps fish can be kept alive for several days in 15 L plastic basins for sale as fresh fish, and contain between 120-140 fish. Price is a function of the size of the unit, species and condition of the fish.

From a study in Basankusu a *valise* of the most valuable species, *P. obscura* ("mungusu") in good condition sells for about 3,000 Congolese Francs (roughly \$ 6). At the other extreme, the least preferred *Malapterurus sp* ("neena") in bad condition sells for about 1,000 Congolese Francs per valise (\$ 2). Overall, prices vary by 30-50 % according to the state of the fish and supply in the market.



Photo 9.6: The waters of Central Africa are rich in fish species.

Table 9.1: Indicative enterprise budget (in Congolese Francs*) for a fishing family working the two main fishing seasons on the Lomako River

| | Quantity | Units | Low market | | High market | |
|------------------------|----------|-------------------|------------|----------------|-------------|----------------|
| | | | Unit price | Total | Unit price | Total |
| Nets | 13 | 50-m | 3,000 | 39,000 | 3,000 | 39,000 |
| Transport | 2 | 2 oarsmen | 7,000 | 14,000 | 7,000 | 14,000 |
| Food and accommodation | 14 | days | 500 | 4,200 | 500 | 4,200 |
| “Taxes” | 25 | valises x 2 ports | 2,000 | 50,000 | 2,000 | 50,000 |
| Total cost | | | | 107,200 | | 107,200 |
| Fish sales | 25 | valises | 2,500 | 62,500 | 5,000 | 125,000 |
| Profit/loss | | | | -44,700 | | 17,800 |

Exchange rate \$ 1 = 500 Congolese Francs

As markets can be distant and expensive to reach, marketing tends to be opportunistic. It has been reported that many fishers sit in their pirogues along the main channel waiting to sell small quantities of fresh fish, or occasionally *valises* of smoked fish to passing boats. A minority of fish is sold this way, most likely to the professional fisher-traders.

Most fishers choose to go to market when they need money or when the fishing is poor, rather than waiting until there are enough fish to make

a full load. This means that most of the fishers travel to markets around the same time, after the end of the dry season, when the fishing starts to get worse, and when people need money to invest in clearing land for farming.

Overall, lack of market access, poor quality and illegal taxes levied arbitrarily by government officials render fishing a subsistence activity. Under the right conditions, aquaculture could make a significant contribution to food security and economic growth (Brummett *et al.*, 2008).

Hydropower Potential

The varied hydrological arrangement associated with the topology of the river courses in the Congo Basin offers numerous opportunities for hydropower development. At the end of 2005, most of the installed capacity for generating electricity in the Congo Basin was from hydropower. The total installed operational capacity of hydropower was reported at 6,490 MW, 39 % (2,540 MW) of which is located in DRC (see table 9.2).

The installed capacity represents only a small fraction of the estimated hydropower potential in the Congo Basin. Studies examining the potential for hydropower generation, point to the Congo Basin, and the Inga rapids in particular, as the most important potential source of hydropower development on the African continent. Currently, the Inga hydropower station comprises a 358 MW plant (Inga I) that was commissioned in 1972 and a 1,424 MW plant (Inga II) that began operating in 1982 (both are currently reported to be operating at less than half their installed capacity). The overall hydropower generating capacity of the Inga site has been estimated at 44-60 GW and the interest to build a third Inga site (Inga

III) and develop a pan-Africa electricity exporting project has long existed. Plans are currently underway with Westcor (Western Power Corridor (PTY) Limited) to begin construction for Phase I of Inga III in 2010, with full commissioning of Phase I anticipated in 2015 at a base power of 5,000 MW. An ambitious undertaking, this project is at the center of the NEPAD Infrastructure Program and represents a serious potential source of revenue for potential shareholders, including an estimated \$ 424 million annually for the government of DRC after payment of capital debts during years 1 to 5. Revenues are expected to increase to \$ 594 million and finally to \$ 678.8 million in subsequent years (Westcor, 2008).

Other hydropower (proposed and actual) developments of note are:

- The Imboulou hydropower dam on the Léfini River in the Republic of Congo. Construction of the facility began in 2005 and was expected to take 5 - 6 years. It is expected to have an installed capacity of 120 MW.^{5,6}

⁵ <http://www.mbandi.com/indy/powr/af/co/p0005.htm> (accessed 24 Feb. 2009)

⁶ http://www.fwt.fichtner.de/php/main/page/php/referenzen.php/ukat_id/6/kat_id/3/idc1/27/z1/2/map/1/sprache/e/li/0re (accessed 24 Feb. 2009)

Table 9.2: Hydropower capacity in the Congo Basin at the end of 2005

| | Net installed capacity of electric generating plants | | Production of hydropower electricity. |
|--------------|--|------------------|---------------------------------------|
| | Total (all types) MW | Hydropower MW | MWH |
| Angola | 525 | 390 | 1,747 |
| Burundi | 33 | 32 | 99 |
| Cameroon | 875 | 805 | 3,913 |
| CAR | 43 | 22 | 84 |
| ROC | 93 | 92 | 355 |
| DRC | 2,573 | 2,540 | 7,395 |
| Gabon | 420 | 175 | 814 |
| Rwanda | 39 | 35 | 130 |
| Tanzania | 549 | 329 | 1,778 |
| Zambia | 2,260 | 2,245 | 5,834 |
| Total | 6,990 | 6,490 | 21,335 |

Source: United Nations, 2005. All figures are estimates by the Statistics Division of the UN Secretariat.

- The Belinga dam, Gabon. The Kongou Falls, on the Ivindo River have been earmarked as the site for this dam (Stella, 2007). The proposed Belinga dam would generate power for the Belinga Iron Ore Project. Environmental groups are concerned that if the dam is constructed at the Kongou Falls in Ivindo National Park, it will have a negative impact on the biodiversity and natural resources and have requested the dam be moved instead to Tsengué-Lélédi Falls. Civil society groups are also concerned about the imbalance of benefits for the Gabonese people. Currently Gabon's primary hydropower sites are located at Tchimbélé, in Monts de Cristal National Park (69 MW) (supplying electricity to Libreville) and Kinguélé (58 MW) on the M'Bei River.⁷
- The Ruzizi III dam in DRC would be situated 25 km downstream from Ruzizi I and II, already located at the outlet from Lake Kivu. Ruzizi I and II are operated by a tri-national company (Burundi, Rwanda and DRC). Electricity production is insufficient to meet the needs of the adjacent areas. A further dam, Ruzizi III, is planned to meet the shortfall
- The Lom Pangar dam in Cameroon. The two main hydro stations, Song-Loulou (384 MW) and Edéa (264 MW) located on the Sanaga River, have experienced significant reductions in power generation due to reservoir sedimentation, poor maintenance and dry seasons exacerbated by drought (Hathaway and Durrell, 2005). Construction of the Lom Pangar dam would help regulate flow of the Sanaga and increase and secure constant power output from two downstream dams. This would be the

fourth dam built to help regulate the Sanaga River. The project has been delayed due to pressure from environmental groups who claim it will submerge part of the Deng Deng Forest Reserve, a refuge for endangered animals such as chimpanzees, elephants, gorillas, and black rhinoceros. Concern has also been expressed about Cameroon's heavy reliance on hydropower when drought is already an issue.^{8,9}

Climate models for Africa are far from clear (Schiermeier, 2008) and so too are the effects that climate change will have on large hydropower schemes. Mukheibir (2007) is of the opinion that an increase in the average annual rainfall in the Congo Basin would lead to increased generation potential but notes this could also have negative impacts of increased flooding and associated large sediment loads which would be detrimental to large dams. By contrast Paeth and Thamm (2007) modeled climate scenarios for Africa and indicate that there could be a reduction in precipitation in the Congo Basin by up to 500 mm (20-40 % of the annual sum) which could seriously limit the hydropower potential of the region.

Although Africa's great rivers are considered "under-dammed" by global standards, many of the big dams constructed have been built at the expense of rural communities and important ecosystems. In response to such concerns, guidelines and improved practices for decision making and risk assessment have been put forward by the World Commission on Dams and the Dams and Development Project.¹⁰

⁷ <http://www.internationalrivers.org/en/africa/belinga-dam-gabon> (accessed 24 Feb. 2009)

⁸ <http://africanpress.wordpress.com/2008/02/02/delay-in-construction-of-lom-pangar-dam-slows-project-to-upgrade-aluminium-smelter/> (accessed 24 Feb. 2009)

⁹ [http://www.internationalrivers.org/en/africa/drought-could-cripple-cameroon %E2%80%99s-hydro%E2%80%93heavy-energy-sector](http://www.internationalrivers.org/en/africa/drought-could-cripple-cameroon%E2%80%99s-hydro%E2%80%93heavy-energy-sector) (accessed 24 Feb. 2009)

¹⁰ <http://www.dams.org/>.

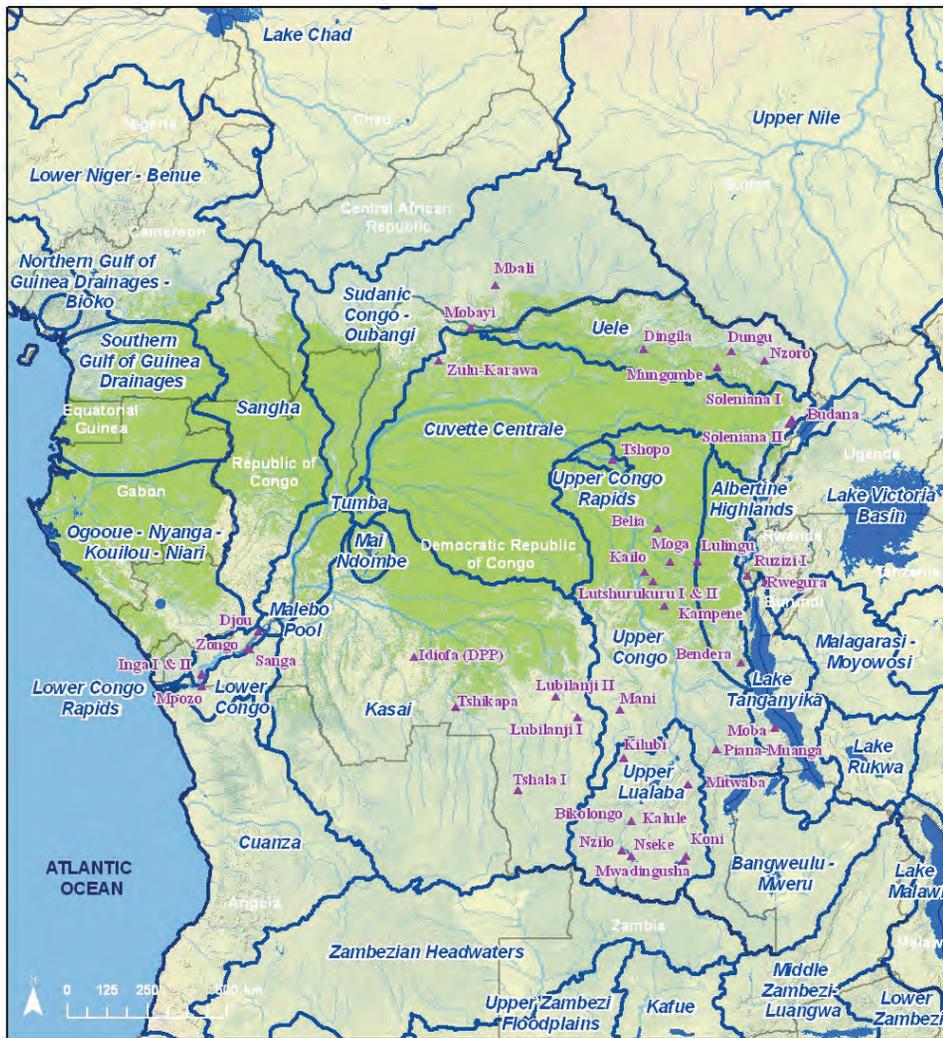
The forested region of Central Africa is characterized by a large diversity of freshwater system types and habitats, from the large delta of the Niger River, to the extensive swamp forests and associated lateral lakes of Central Congo, to the powerful rapids of the Lower Congo, to the web of marshes and lakes along the Upper Lualaba.

Several authors have defined freshwater biogeographic provinces for Africa based on freshwater fish (Lévêque, 1997; Roberts, 1975; Thieme *et al.*, 2005). Each province encompasses freshwater systems sharing a relatively similar fish fauna. The boundaries largely correspond with the catchments of major river systems, which provide the natural routes for gene flow for freshwater fishes (Stiassny *et al.*, 2007). The major ichthyofaunal provinces in the region are the Congo, Lower Guinea, and Nilo-Sudan. These provinces are further subdivided into freshwater ecoregions, which also largely follow river basin divides and are intended to describe broad patterns of species composition and associated ecological and evolutionary processes (figure 9.5; Abell *et al.*, 2008; Thieme *et al.*, 2005).

The diversity of habitats in the region is matched by high species diversity. However, taxonomic surveys are lacking for much of Central Africa and new species are continually being discovered (Lévêque *et al.*, 2005; Lundberg *et al.*, 2000). For fish species, it is considered the third richest tropical river basin, following the Amazon and Orinoco Basins. Over 550, 700, and 150 fish species are currently described from the Lower Guinea, Congo, and Niger Delta, respectively; with new species being described every year (Stiassny *et al.*, 2007; Teugels and Guégan, 1994; Thieme *et al.*, 2005). The rivers and streams of Lower Guinea and the Congo have high levels of fish endemism (estimated at 50 % and 80 %, respectively). About fifteen strictly aquatic mammals live in the waters of Central Africa; including several that are endemic (e.g., the aquatic genet (*Osbornictis piscivora*), Ruwenzori otter shrew (*Micropotamogale ruwenzorii*), and giant otter shrew (*Potamogale velox*)). The region also has a rich herpetofauna – upwards of 280 aquatic frogs, and about twenty aquatic snakes, turtles and crocodiles are known. Data on aquatic invertebrates are particularly scarce; however, available data suggests that the region harbors areas of high invertebrate biodiversity. Kalkman *et al.*, (2008) identified the Guinean-Congolian region as having the greatest diversity and number of range-restricted

species of Odonates (dragonflies) in Africa. The richest areas for dragonflies are the Cameroonian highlands and Lower Guinean lowland forests (Kalkman *et al.*, 2008). Diversity of freshwater crabs appears to be highest in the lower parts of the Congo Basin and the upper reaches, including those draining from Rwanda and Burundi (Groombridge and Jenkins, 1998). Southeast Nigeria, southern Cameroon, and Gabon also host three endemic genera and more than 10 endemic species of freshwater crabs (Cumberlidge, 1998). Aquatic mollusks are very poorly known - about 100 snails (gastropods) have been described from the Congo Basin, of which about half are considered to be found only there (Brown, 1994); a contemporary region-wide estimate of aquatic mussels does not exist, though there are historical and more recent syntheses for parts of the region (e.g., Graf and Cummings, 2006; Pilsbry and Bequaert, 1927).

Despite the lack of reasonably comprehensive georeferenced species data, several studies have highlighted freshwater biodiversity hotspots in the region (Groombridge and Jenkins, 1998; Kamdem-Toham *et al.*, 2003; Thieme *et al.*, 2005). Common among these are the Lower Congo rapids for their rheophilic and endemic fish and mollusks; the *Cuvette centrale* and associated marshes and swamp forest for high fish richness and endemism; floodplain lakes and marshes of the plateau region of the Upper Lualaba for fish endemism; several crater lakes in Cameroon with highly endemic aquatic faunas; several rivers of the Lower Guinea province including the Ogooué, Kouilou-Niari, and Cross Rivers for high richness and endemic fish and crabs; and the Niger Delta with five monotypic fish families. Additional areas will be added and the boundaries of existing hotspots will be modified as new data on the biodiversity of the region become available.



Sources: WWF, TNC, SDSU, CICOS.
 Figure 9.5: Freshwater ecosystems



Photo 9.7: Riparian forests have specific floral compositions.

Box 9.3: The Lower Congo River

In 2005 the American Museum of Natural History's Congo Project received funding from the US National Science Foundation to undertake an ichthyofaunal survey and inventory of the lower Congo River (<http://research.amnh.org/ichthyology/congo/index.html>). The project which is an ongoing international, multidisciplinary collaboration is combining traditional taxonomy and survey methods and the latest molecular techniques with state-of-the-art remote sensing technologies and *in-situ* geomorphological analysis. Results to date reveal the lower Congo River to be a site of unexpectedly high fish biodiversity forged by an uniquely complex physical regime. By integrating analyses of hydraulic conditions and channel morphology with metapopulation analyses of fish species in the lower Congo the project aims to elucidate the underlying processes driving speciation and diversification in the river.

Near the twin capitals of Kinshasa and Brazzaville, the lower Congo River spills out over a rocky sill at the southern edge of Stanley Pool and cascades down through the gorges of the Crystal Mountains. This relatively short stretch of the river, fed by a discharge of 23,000-50,000 m³/s is punctuated by some of the most spectacular rapids, pools and runs on Earth. Unlike most of the rest of the river, the lower Congo downstream of Pool Malebo to the port town of Matadi, is highly channel-constrained with a peculiarly complex hydrology that appears to have isolated it from the remainder of the Basin. Channel topology itself is highly heterogeneous, punctuated by underwater canyons of extreme depth. Water velocities are also extreme, even in areas without surface rapids, and recent measurements taken with pirogue-deployed Acoustic Doppler Current Profilers (ADCP) have revealed complex flow patterns within the water column including shifting counter directional flows and descending and ascending "walls" of fast moving water. Analysis of remotely sensed data provides an additional view of the numerous macrohabitats and channel features that characterize this hydrologically complex stretch of river. Using the latest remote sensing technologies, and with intensive on-the-ground sampling and analysis, a much clearer picture is beginning to emerge of how the geomorphological template of the river has played a major role in isolating fish populations.

To date the project has documented the presence of over 300 fish species and of these upward of 80 appear to be endemic to the lower Congo region. These are unexpectedly high levels of species richness and endemism for a 350 km stretch of river, by way of comparison the entire Upper Nile from its headwaters to the junction with the Blue Nile at Kartoum, a stretch well over 1,400 km in length, harbors around 115 fish species of which only 16 are known endemics. Clearly the lower Congo, with its unique hydrological regime, represents a model system for exploring the interplay of complex hydraulic conditions, channel features of extreme depth, and patterns of species richness and drivers of local endemism.

Relationship between Forests and Hydrological Goods and Services

Forest Cover and Watersheds

Water resources are regional services that are strongly influenced by their ecosystem. Vegetation is often the primary influence of these ecosystem effects on hydrological services (Brauman *et al.*, 2007). In a forest ecosystem, forests influence the hydrological cycle by regulating the quantity and timing of water and nutrients being added to the system. The extent to which ecosystems are affected is dependent on the size and distribution of different ecosystems within a catchment system

as well as the frequency, duration and intensity of climatic events. Andreassian (2004) argues that larger forests, such as the Amazon or Congo Basin play a critical role in both controlling the quantity and quality of water circulating in a watershed or river basin as well as influencing climate at the global level. In the following section we examine local and regional interactions between forests and water resources.

The Role of Forests in the Congo Basin Water Balance

Relative to other comparable forested regions, far less research has gone into understanding the relationship between forests and water in the Congo Basin (box 9.4). However, studies from

other areas can provide insight into how forest cover may affect water systems. The common perception is that "forests are good for water," acting like sponges to absorb high rainfalls and releas-

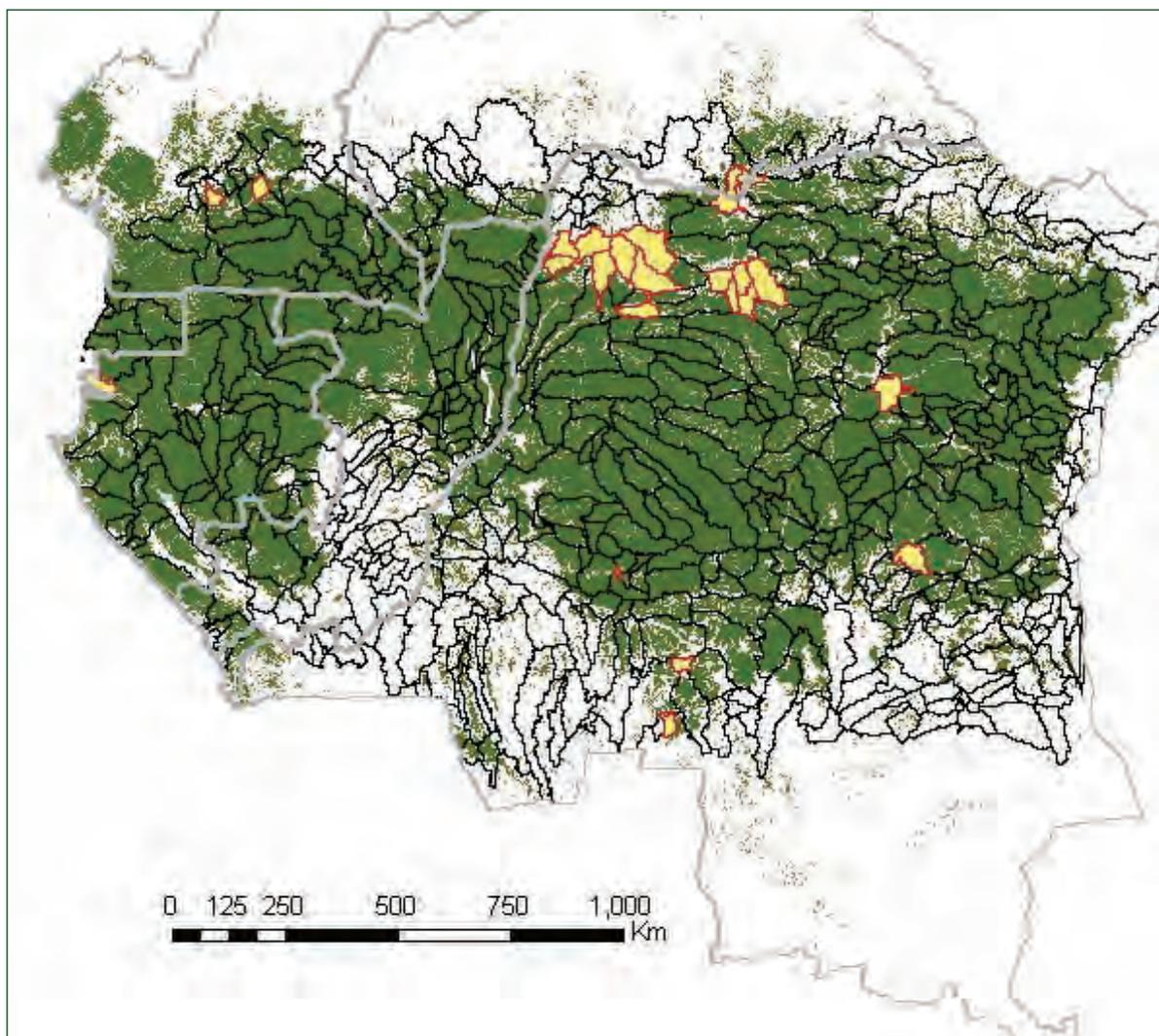
ing water slowly through drier periods. While it is generally accepted that forests improve water quality, moderate peak flows and sequester carbon dioxide, trees can also use more water than other vegetation types and so the net water balance may mean that less water is provided to downstream areas than for other land covers (Dudley and Stolton, 2003; Bruijnzeel, 2004; Brauman *et al.*, 2007). This increased water use is due to the larger rooting depth of trees (compared with grassland or agricultural crops) allowing them to access water from a greater portion of the soil profile, and sometimes even from the sub-soil. Forest also presents a rougher surface than shorter crops, thus increasing the efficiency of gas exchanges with the atmosphere (Brauman *et al.*, 2007).

Evidence of the greater water use of forests has been accumulated mainly from studies where forests have been cleared and net water supply has increased, albeit in a much more irregular flow distribution pattern. These studies are almost exclusively for montane forests. No reported declines in annual streamflow totals following lowland tropical forest removal have been found in the literature. For montane forests controlled experiments comparing water yield before and after deforestation, show that in all cases the removal of more than 33 % of forest cover results in significant increases in overall annual streamflow during the first 3-years, with changes in water yield roughly proportional to the fraction of biomass removed (Bruijnzeel, 2004). The reverse effect has been observed: in a review of 14 comparative experiments in the tropics to find that after afforestation or planting trees in agricultural fields there was approximately a three-fold increase in water infiltration. Elsewhere it has been shown that afforestation will reduce local water yields and flow, but these effects are likely to be small unless the area reforested is large (Van Dijk and Keenan, 2007). In studies on smaller tropical wa-

tersheds, deforestation has been shown to increase discharge and runoff (Sahin and Hall, 1996).

Mature tropical rainforest deforestation has the potential to degrade the regulation of hydrological flows through changes in evapotranspiration, canopy interception, surface runoff and groundwater recharge. Reductions in evapotranspiration (the process of direct evaporation and transpiration by plants that transfer water to the atmosphere) with increasing deforestation can impact hydrological flows by warming the surface, inhibiting convection and changing regional precipitation and cloud cover. Most evidence of these impacts has been witnessed in smaller river basins, where in many cases the effects of land cover change on hydrological processes are not measurable until at least 20 % of a catchment has been converted, although this threshold may vary between 15 to 50 % (Stednick, 1996). The effects of land conversion on evapotranspiration may be less for conversions between primary and secondary forests, as opposed to cropland or shrub land.

The results of local, short-term studies provide important information but can not necessarily be extrapolated to the larger scales and time frames of relevance when discussing vast river systems like the Congo Basin. A study by Costa *et al.*, (2003) in a large Amazonian river basin found that changes in land cover had a significant impact on discharge, although not precipitation. In the Congo, the effects of deforestation on rates of evapotranspiration are expected to be particularly significant because a large portion of rainfall, (between 75-95 %), comes from recycling moisture from the region's forests (Brinkman, 1983). A recent study mapping forest clearing over the last decade for the entire Congo Basin (Hansen *et al.*, 2008), at a spatial resolution that allows forest clearing to be examined on a per watershed basis, will provide important data for future studies (figure 9.6).



Sources: SDSU, USGS.

Figure 9.6: Watersheds with more than 50 percent forest cover in circa 1990 and a 5 percent loss in forest cover by circa 2000 are highlighted in yellow

Box 9.4: State of Knowledge

Compared to other vast river systems in the world, little information and research is available for the Congo Basin. Quantitative data on water resources within the Congo Basin has always been limited. The collection and management of information on water resources are difficult for numerous reasons, including:

- The dilapidated state, and low density, of data collection sites for hydrological, limnometric or meteorological information.
- Few stations are operational, most are manual and they are usually limited to large freshwater areas.
- The discontinuity in the hydroclimatological data series in the vast majority of hydroclimatological stations across the Basin. Very few continuous data sets, where continuous refers to constant data collection since pre-1960, exist. Even rarer are meteorological or hydrological stations with a continuous series of data for the past 100 years. The data that is most frequently presented have been collected through remote sensing.
- The lack of coordination between different sectors concerned with water resource management in all the riparian countries.

However some historic data are available for: the Congo from 1902 (station in Kinshasa), 1907 (station in Kisangani), and 1912 (station in Kindu); from 1911 for the Oubabgui (station in Bangui) and from 1948 on the Sangha river (at Ouesso). Daily water levels are measured at Bangui, Ouesso, Brazzaville and Kinshasa. The three organizations charged with monitoring flow in the Congo Basin are:

- The *Régie des Voies fluviales* (RVF) in DRC for the middle and upper portions of the river.
- The *Régie des Voies maritimes* (RVM) in DRC for the lower Congo.
- The *Service commun d'Entretien des Voies navigables* (SCEVN) in CAR and ROC for the Congolese section of the River and the Oubangui.

The African Monitoring of Environment for Sustainable Development program (AMESD; www.amesd.org/www.cicos.info) in Central Africa aims to develop a monitoring system for water resources in the Congo Basin. Implemented by CICOS for Central Africa, AMESD will utilize existing meteorological satellite data receiving stations in seven Central African countries, install additional environmental receiving stations in key organizations and built the capacities of regional experts with the aim of providing regular information on water levels and the water cycle (rainfall, runoff and evapotranspiration will be measured) (Ladel *et al.*, 2008). Two operational services will be developed: one to alert on low waters for navigation, and one to monitor the impact of deforestation and climate change, initially on the Oubangui sub-basin water resources.

Water Resource Management

The Congo Basin has abundant water supplies and great potential to develop further in the areas of hydropower, irrigation and navigation. In the past a piecemeal approach to water management focused solely on satisfying immediate demands for energy, agriculture or urban water supply. And in doing so it failed to take into account the potential environmental, social or long-term financial impacts. Conflict, lack of regulation and mismanagement has left more than half the rural population in Congo and DRC without access to clean drinking water and adequate sanitation facilities¹¹. The need to improve water management in the Basin is widely recognized both within individual countries and across the Basin as a whole.

In response to this need, an Integrated Water Resource Management (IWRM) approach has been adopted (box 9.5) by CICOS. This ap-

proach to planning and implementation simultaneously works to balance society's long-term needs for water, essential ecological processes and economic benefits. It is centered on maintaining the environment while also promoting sustainable development and encouraging democratic participation in governance. A better understanding of the relationship between forests and water resources, as well as an appreciation for the economic value of forests based on the water-related services they provide (see box 9.6) can be used to increase the incentive to maintain healthy forest ecosystems and conserve forest watersheds. Although a comprehensive economic assessment of the goods and services provided by water resources has never been attempted in the Congo Basin, it is clear that the economic value of water resources in the Congo Basin and the dependence of human populations on these resources are great.

¹¹ <http://www.unicef.org/infobycountry/centralafrica.html>

Box 9.5: Integrated Water Resource Management (IWRM)

The history of IWRM stems back to the United Nation's Mar del Plata Conference in 1977 which called for increased coordination between different sectors concerned with water management. In 1992, the International Conference on Water and the Environment reiterated the need for a more holistic approach to assure the sustainable use of water resources. The 2000 Millennium Development objectives called for IWRM to go further to incorporate interactions between surface water and underground water resources, as well as taking into consideration the limits of the environment and managing the demand for water.

IWRM is a process that promotes the co-ordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare on an equitable manner without compromising the sustainability of vital ecosystems. It is based on the following four Rio/Dublin principles:

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
3. Women play a central role in the provision, management and safeguarding of water.
4. Water has an economic value for all its competing uses and should be recognized as an economic good.

Photo 9.8: The Congo River in Kinshasa.



Understanding the role forests play in providing these benefits will support adopting an ecosystem approach to managing forests that involves evaluating the “trade-offs” between alternative management schemes. This can be complex because it is often difficult to assess the long-term impacts of actions such as deforestation or carbon sequestration on the ecosystem or the services it provides (Foley *et al.*, 2007; Jackson *et al.*, 2005). The variation in geographic scale of ecosystem services further adds to this complexity, with some services extending to cover whole watersheds. Additional research is needed to further explore the intricate relationship between changes in land cover and water resources in the Congo Basin, specifically from the perspective of the goods and services provided by water resources at different space and time scales. In addition to local and national governments there are two principal organizations concerned with managing the Congo Basin’s water resources: CICOS (see box 9.2) and the Authority of Lake Tanganyika.

CICOS recognizes that the management of vast river basins is dependant on many factors, including: the ecological nature of the basin, demographic and socioeconomic conditions, the historical context of the Basin, partnerships, regulating texts and laws, the engagement of governments, financial factors and planning. Given all of these different variables it is difficult to provide a comprehensive strategy of resource management for water resources in the Congo Basin; however, CICOS has identified some underlying principles that are necessary to implement effective resource management:

- implementation of a political process of transboundary cooperation between all the riparian countries;
- increased availability of pertinent data and information on water resources;
- application of institutional agreements for issues such as the division of costs, environmental regulations, environmental standards, etc;
- a clear definition of the role of the organization in charge of Basin management;
- strong leadership within the governing organizations;
- strong implication of stakeholders, including the public, in the development of management plans and the implementation of policies.

With funds from GTZ and the African Development Bank^{12,13} CICOS has been tasked with the preparation of a strategic action plan for integrated management of the Basin’s water resources. As part of this plan activities are likely to include the rehabilitation of an *in situ* hydrological network within the Basin (complementary with the AMESD satellite monitoring system), the creation of an information management system within the CICOS Secretariat and capacity building to implement activities in accordance with the principles and strategies agreed with the riparian countries. It is hoped that this approach will promote well-coordinated policies at the national, regional and transnational scales that seek to balance long-term water needs, essential ecological processes and economic gains.

¹² <http://www.engineeringnews.co.za/article/development-bank-funds-project-to-support-management-of-congo-river-2007-06-22> (accessed 24 Feb. 2009)

¹³ <http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/18950.htm> (accessed 24 Feb. 2009).

Box 9.6: Payment for Watershed Services

The ecosystem services delivered by a particular geographical location and habitat will provide benefit both to the location itself and to others at a distance. In current market conditions and governance structures, the costs of protecting these ecosystem services, in terms of proactive management or lost opportunities to carry out other activities, falls predominantly on those in the provider location. It is thus important when considering the ecosystem service of an area to identify the flows of benefits, so that the full value, in ecological terms, can be assessed. So, for example, forests provide services at the global level (regulating climate, sequestering and storing carbon dioxide, biodiversity, as a source of medicinal plants), at the national/regional level (e.g., timber resources, opportunities for eco-tourism), at the river basin level (e.g., clean water, regulated river flows (less floods, higher dry season flows), reduced sediment supply) and at the local level (e.g., timber, firewood, water, non-timber forest products).

Forests in many areas of the world are under pressure primarily due to the clearance of land for food production or timber extraction. There is much evidence that such activities cause the loss of a whole range of ecosystem services at all levels from global to local. Therefore, it is argued that those who would benefit from the protection of such services should contribute financially to their protection. This is one of the underlying principles of the global carbon market (although this also allows swapping of damaging behavior in one location for carbon storing actions in another). The idea of ecosystem service beneficiaries paying managers of the land elsewhere to protect those services either proactively, or through not taking some action (such as forest clearance for agriculture) is the concept behind payment for Environmental services (PES)(see also chapter 8 on PES in this report). At the watershed, or river basin level, this is often called payment for watershed services (PWS), although it can be argued that this is only a partial picture of the services delivered predominantly through transfers of water and mass (sediment, nutrients, contaminants).

It is now recognized globally that with ever increasing population and standards of living, the environmental resources of the planet are becoming stretched to, and sometimes, beyond, their limit; climate change is the obvious pressing example. Many governments, NGOs and scientists are now starting to advocate ecosystem approaches and PES schemes to protect and restore the environment to address such concerns.

