Deforestation Trends in the Congo Basin

Reconciling Economic Growth and Forest Protection

WORKING PAPER 3 | Transport

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Africa Region
THE WORLD BANK

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ACRONYMS

AICD	Africa Infrastructure Country Diagnostic
CEMAC	Economic and Monetary Community of Central Africa
CICOS	International Commission for the Congo-Oubangui-Sangha Basin (Commission Internationale du Bassin Congo-Oubangui-Sangha)
CPIA	Country Policy and Institutional Capacity
ECCAS	Economic and Monetary Community of Central Africa
GHG	greenhouse gas
HFLD	high-forest / low deforestation
IWRM	integrated water resources management
LIC	low-income country
NEPAD	New Partnership for Africa's Development
OAU	Organization of African Unity
RAI	rural accessibility index
SSA	Sub-Saharan Africa
UAR	Union of African Railways
UNFCCC	United Nations Framework Convention on Climate Change
VOC	vehicle operating cost

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Reconciling Economic Growth and Forest Protection that was conducted by a multidisciplinaryteam under the leadership of the World Bank at the request of the COMIFAC (Regional Commission in charge of Forestry in Central Africa) to strengthen the understanding of the deforestation dynamics in the Congo Basin.

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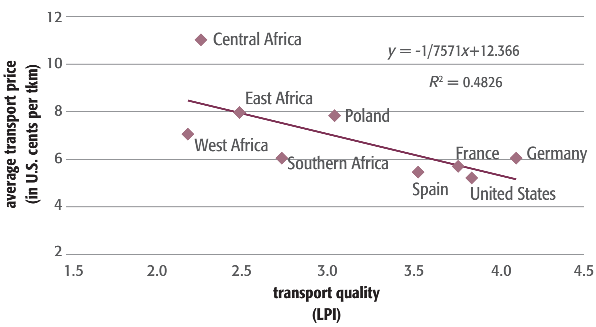
EXECUTIVE SUMMARY

THE CONGO BASIN SUFFERS FROM AN EXTREMELY POOR TRANSPORTATION INFRASTRUCTURE...

Transportation in Congo Basin countries is poor in quality and expensive (see figure 1).

Figure ES-1: Transport Service in Central Africa: Expensive and Low Quality



Source: Teravaninthorn and Raballand 2008.

Roads: The paved road density in the Congo Basin is among the lowest in the world with only 25 kilometers (km) of paved road for each 1000 km2 of arable land, compared with an average of 100 km in the rest of Sub-Saharan Africa (SSA).

Railways: The railroad network is largely disconnected. A legacy of the colonial era, it was mainly built to facilitate the extraction of natural resources (mostly timber and minerals), not to support the movement of people and goods.

Rivers: Despite a huge reserve of potentially navigable waterways (25,000 km), only three principal routes are currently used, with all converging at the Matadi port. The network was mostly developed during the colonial era and has dramatically declined since the 1950s.

Transportation costs: High transportation costs in the Congo Basin can be mostly attributed to operating costs, which result from the deteriorated infrastructure. Custom regulations, access restrictions, and oligopolistic structures also inhibit the emergence of new and more efficient operators. Countries become trapped in vicious cycles where inefficient systems sustain low-quality services and high transport prices.

...WHICH IMPEDES ECONOMIC GROWTH

This poor transportation network hampers economic growth in the Congo Basin by creating barriers to exchanges and trade not only with international markets but also internally on domestic markets. This situation literally creates multiple land-locked economies with limited to no exchanges among themselves.

The agriculture sector is particularly affected, with a severe connection gap between producers from rural areas and consumers in growing urban centers. In the Democratic Republic of Congo, it is estimated that only 33 percent (7.6 out of 22.5 million hectares) of all non-forested suitable arable land is less than 6 hours from a major market; that proportion is as low as 16 percent in the Central African Republic (1.3 out of 7.9 million hectares). This distance makes it difficult to rely on markets for either inputs or outputs, and generally pushes farmers to rely on self-subsistence agriculture. As a result, the growing markets within the region are mostly fed by food commodity imports, which deteriorate the national agriculture trade balance.

The same applies to many other sectors, including extractive sectors (forests, mining) but also sectors that rely on good mobility of people and goods.

NEW DEVELOPMENT PLANS

The infrastructure gap in the Congo Basin is widely acknowledged, and various entities are drafting plans and strategies to fill this gap, including the Program of Infrastructure Development in Africa from the African Union/NEPAD, the Consensual Road Network from Economic and Monetary Community of Central Africa (ECCAS), and the River Transportation plan from International Commission for the Congo-Oubangui-Sangha Basin (CICOS).

These plans define priority investments based on the development of corridors and growth poles. As such, they are primarily designed to unlock the potential of extractive industries. While these corridors are certainly of major importance, the challenge is to strike the appropriate balance with the development of a rural road network that would unlock the Congo Basin's agricultural potential.

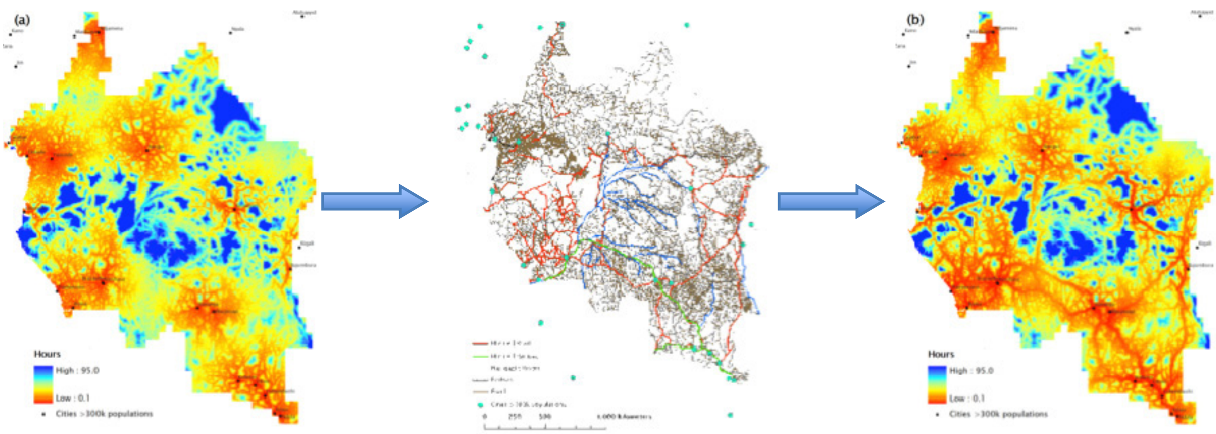
NEW PLANS—NEW THREATS ON FORESTS

Over the past decades, natural forests have been protected, by and large, by the region's poor transport infrastructure. The foreseeable development of road networks in the region is likely to be accompanied by adverse impacts on forests. While the direct impact of road construction on rainforests can be quite limited, indirect and induced impacts could represent a major threat by significantly changing economic dynamics in newly accessible areas.

The Congo-BIOM model was used to compute the likely impact of all road and railways projects for which financing has already been secured. It simulated changes in average travel time to the closest city along with the changes in internal transportation costs (see figure 2).

These changes are correlated to producer prices for agricultural output. The model shows that when agricultural products can reach urban markets at a lower price because of lower transportation costs, consumers tend to buy more domestically grown products (through import substitution). This, in turn, encourages producers to increase their production. Additionally, the price of such inputs as fertilizers tends to go down, increasing agricultural productivity. Typically, a new equilibrium is reached with a larger volume of regionally grown agricultural products and lower prices compared to the

Figure ES-2: Impact of Change in Transportation Infrastructure on Travel Time and Costs



Transport time with existing infrastructure (circa 2000)

Planned infrastructure (roads in red, rail in green)

Transport time with new infrastructure

Source: IIASA 2010.

initial situation. The reduction of domestic transportation costs also improves the international competitiveness of agricultural and forestry products. The model shows that if new transport infrastructure is indeed built, then the Congo Basin will export more sugarcane and palm oil. Another associated effect would be the expansion of illegal logging activities—with substantial impacts.

These developments that result from enhanced transportation infrastructure in the Congo Basin—unless associated with accompanying measures—will all result in more pressures on forested lands, leading to substantial impacts on deforestation and/or forest degradation.

RECOMMENDATION

Extremely weak transport infrastructure in the Congo Basin constitutes a major barrier to economic development. Countries, as well as regional entities, are strongly committed to fill this infrastructure gap. Induced impacts related to infrastructure can potentially create major pressures on forests. Future investments should focus on the following approaches:

- *Improve transportation planning at local, national, and regional levels.*

  Locally: Areas that are directly served by improved transportation facilities will become more competitive for various economic activities such as agricultural expansion, including palm oil plantations. Local participation in transportation planning will help ensure that economic opportunities are maximized. Mitigation measures at the local level may include clarifying land tenure or integrating the transportation project into a broader local development plan. Such plans may include the protection of forest banks along roads, rivers, or railways to avoid unplanned deforestation. Defined up front and in a participatory manner, these restrictions would get more backing from the various stakeholders.

  Nationally and regionally: The corridor approach shows that improving transportation services (for example, freight management in harbors) or infrastructure (facilitating river or rail transportation) may have a wider macroeconomic impact at the regional level. Planning at the national and regional levels, through a corridor approach, could help identify adequate mitigation measures, such as zoning reforms (establishing permanent forest areas), law enforcement (ensuring the respect of zoning decisions), land tenure clarification, and controlling the expansion of agriculture.

- *Foster multi-modal transport networks.* As countries plan for transport development, it is important that they consider the pros and cons of roads and alternative transport modes, such as navigable waterways and railroads, not only in terms of economic returns but also in terms of environmental impacts. For instance, with more than 12,000 km of navigable network, the Congo Basin could benefit from a potentially highly competitive waterway system.
- *Properly assess the impacts of transportation investments before they occur.* Transportation development (be it new infrastructure or rehabilitation of existing assets) will reshape the economic profile of the areas served by transportation and increase pressure on forest resources. Currently, most environmental impact studies or safeguard reviews fail to fully capture the long-term indirect effects on deforestation. New assessment methods, based on economic prospective analysis, could help prioritize infrastructure investments with low foreseen impacts on forests.

INTRODUCTION

The Congo Basin is among the most poorly served areas in terms of transport infrastructure in the world, and it faces a challenging environment with dense tropical forests crisscrossed by numerous rivers that require construction of numerous bridges. Given such complexities, constructing transport infrastructure as well as properly maintaining it is certainly a key challenge for the Congo Basin countries. Recent studies indicate that investment required per kilometer of new roads is substantially higher than in other regions of SSA and the same applies for maintenance.

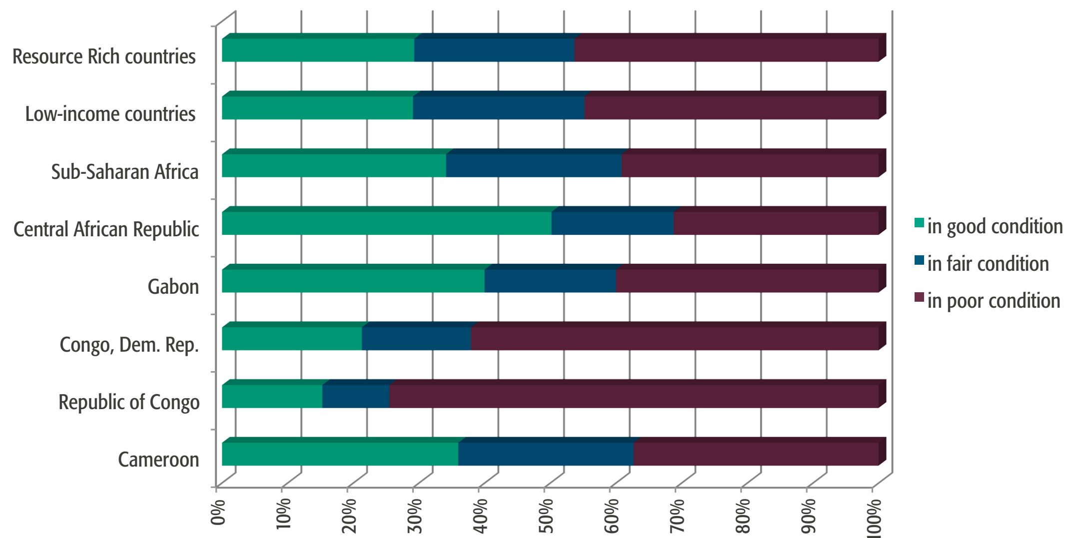
Transport infrastructure assets in poor condition.[1] The physical capital of transport infrastructure is deteriorated in the Congo Basin. The ratio of classified roads in good and fair conditions range from 25 percent in Republic of Congo to 68 percent in the Central African Republic,[2] which is globally lower than the average for low-income countries (LICs) and resource-rich countries (see figure I-1). Other transportation assets (railways and river system) are also limited: the railway network is essentially a legacy of the colonial era and mainly used for mineral transportation, while the river system is basically only marginal.

Overall poor transportation quality. In addition to globally poor transport infrastructure, the region's transportation system is negatively impacted by poor regulations, inefficient institutions, powerful cartels, and coercive transport associations. As a result, the

1 All the data used in this section are based on the Africa Infrastructure Country Diagnostic (AICD) reports and database. The AICD, spearheaded by the World Bank, has provided a comprehensive assessment of the needs for physical infrastructure (as well as associated costs) in SSA. It has collected detailed economic and technical data on each of the main infrastructure sectors, including energy, information and communication technologies, irrigation, transport, and water and sanitation.

2 The good performance in the Central African Republic hides the fact that, in reality, most of the classified roads are paved roads, which only represent a third of the total roads. Only 2 percent of the classified unpaved roads meet the standard of good and fair conditions.

Figure I-1: Condition of Road Transport Infrastructure



Source: AICD database 2011.

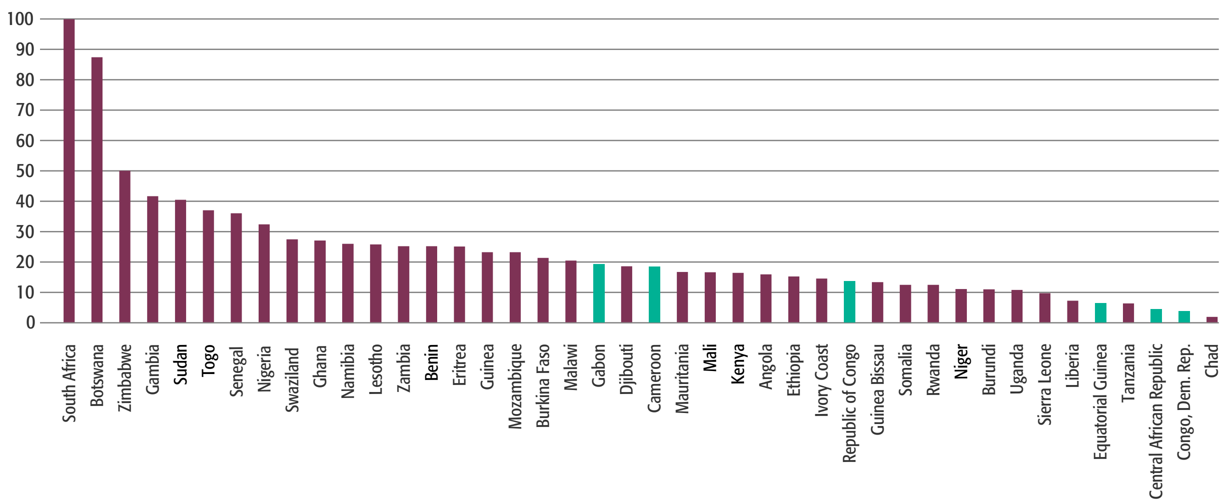
transport system in the Congo Basin is characterized by poor quality of roads. This index[3] has been calculated for all SSA countries, normalized to 100 for the highest-quality road transport (in South Africa).

This poor transportation infrastructure is a critical barrier to econoomic growth and poverty reduction in the Congo Basin. This poor transportation infrastructure, along with inadequately developed logistics, is adversely affecting economic growth by increasing transportation costs and transport delays as well as limiting private sector development and market access. Good transport infrastructure is crucial, as it underpins economic growth. Experience shows that increasing the stock of infrastructure by one percent can add up to one percent to gross domestic product. It has been found to have "normal" rates of return in developed countries, extraordinarily high rates of return in industrializing countries, and moderate rates of return in underdeveloped countries. In the Congo Basin, where both intra- and intercountry trade is still very low, transport infrastructure development is essential for private sector development and integration of markets, without which Congo Basin countries' economy is unlikely to move away from the agrarian to the industrial or knowledge-based economy.

Ambitious plans to cope with the infrastructure gaps. Infrastructure needs are significant in the Congo Basin countries, particularly in terms of transport infrastructure. Countries, as well as regional entities—African Union, ECCAS, and CEMAC—have high on their agendas the need to urgently fill the transport gap in order to unleash economic development potential: there is strong evidence of increased country budget allocation to transport sector (both investment and, to a lesser extent, recurring costs) and major "grand plans" set up by regional institutions.

3 The Road Transport Quality index is based on a formula combining the following parameters: Q = Road quality index for a country; P = Percent of roads that are paved in a country; G = GDP per capita in a country (an index of capacity to maintain roads); and C = The World Bank's Country Policy and Institutional Capacity index for transparency, accountability, and corruption in country j (a proxy for delays and costs inflicted on truckers).

Figure I-2: Road Transport Quality Index for SSA Countries



Source: AICD database 2011.
Note: Congo Basin countries are highlighted in yellow..

CHAPTER 1

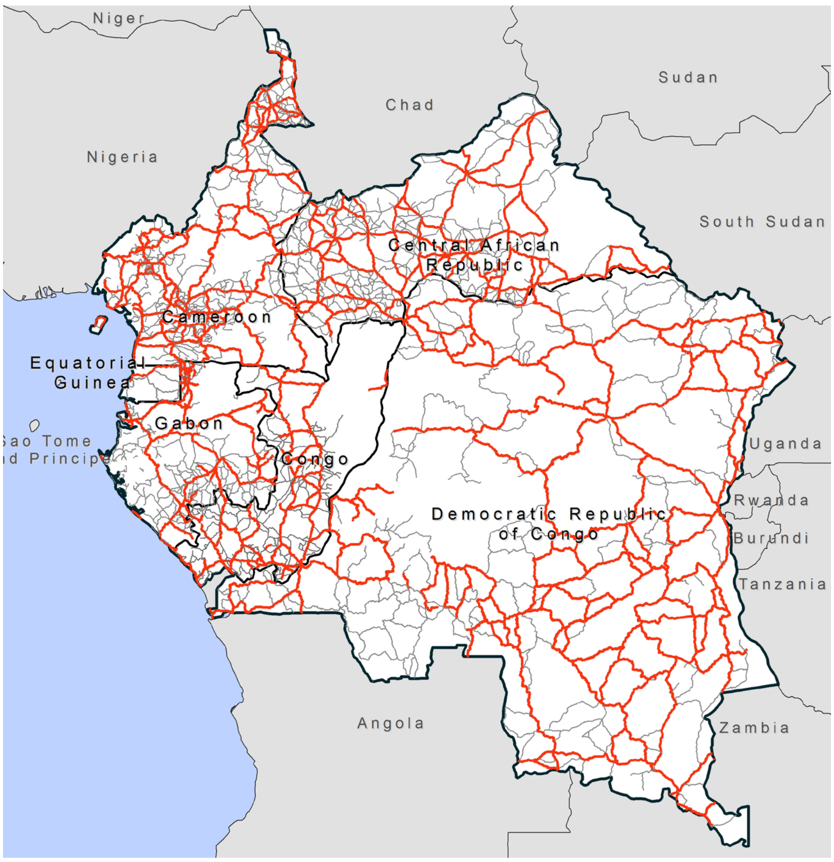
Transport Infrastructure: An Insufficient and Deteriorated Network

STRUCTURAL WEAKNESSES OF TRANSPORT INFRASTRUCTURE

Road Transportation Network

A sparse road network. The road density in the six Congo Basin countries is particularly low (between 17.3 km per 1,000 km2 in the Democratic Republic of Congo; 71.7 km per 1000 km2 in Cameroon), when compared to the SSA average of 149 km per 1,000 km2 (see figure 1.1-a). However, as shown by figure 1.2, the discrepancy between Congo Basin countries and other Sub-Saharan Africa countrieb is not that wide when density per habitant is compared (see figure 1.1-c). The low road density in the Congo Basin countries seems partly offset by the low population density in most of the countries (and particularly in the rural areas). In Gabon, for example, even though the population density is 5.620 people per km2, the population is highly concentrated in the few urban centers (1,342 per km2), and, hence, road density per habitants is high.

Figure 1.1: Congo Basin: Road Network



Road Infrastructure (Major roads: early to mid 2000s)

Type — Primary and Secondary — Other Major roads

Figure 1.2 Total Road Network Per Land Area (km/1000 km²)

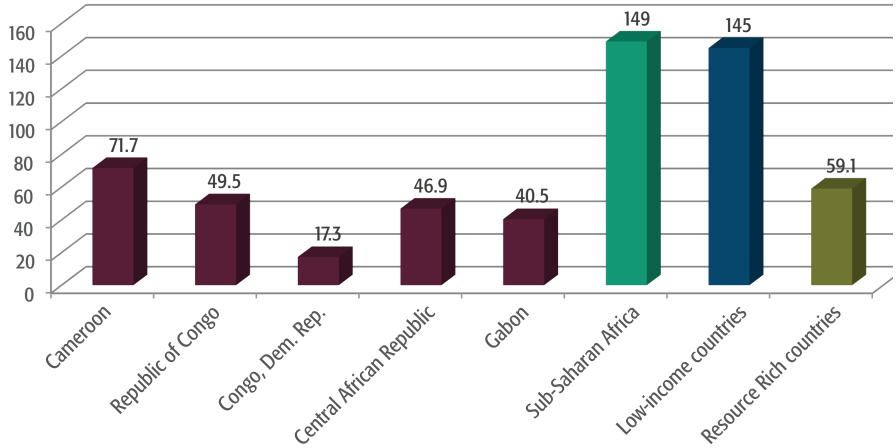
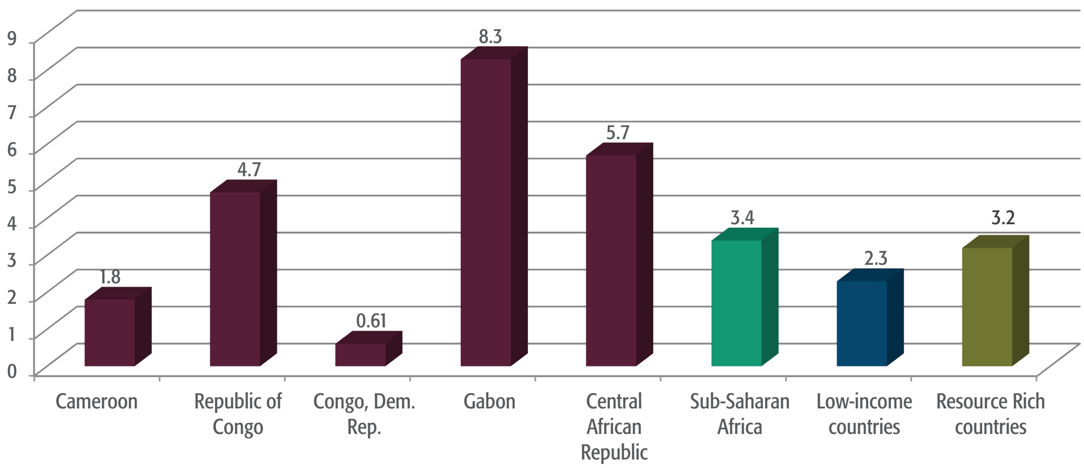


Figure 1.3 Total Road Network Per Population (km/1000 persons)



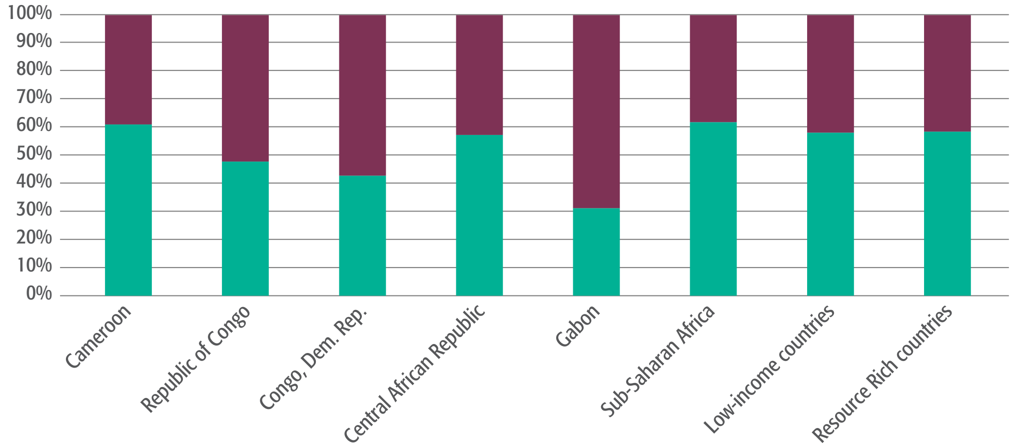
Source: AICD database, 2011.

Majority of the roads are unpaved. Except for Cameroon and Gabon (with respectively 61 percent and 57 percent of paved road), the other Congo Basin countries have most of their roads unpaved, with an extreme situation in the Central African Republic, where less than a third of the roads is actually paved (see figure 1.4).

Within the Congo Basin, the tertiary road network is particularly deficient and the rural accessibility—as measured by the percent of persons within a two-kilometer walking distance from an all-season road4—is limited. The rural accessibility index (RAI) in the Congo Basin ranges from one-quarter to one-third of the rural population, with the exception of the Central African Republic, where it is more than half of the population (see figure 1.5). This situation is particularly damaging for the agriculture sector, where farmers are trapped in a subsistence system with limited and disrupted access to market for both product sales and input purchases.

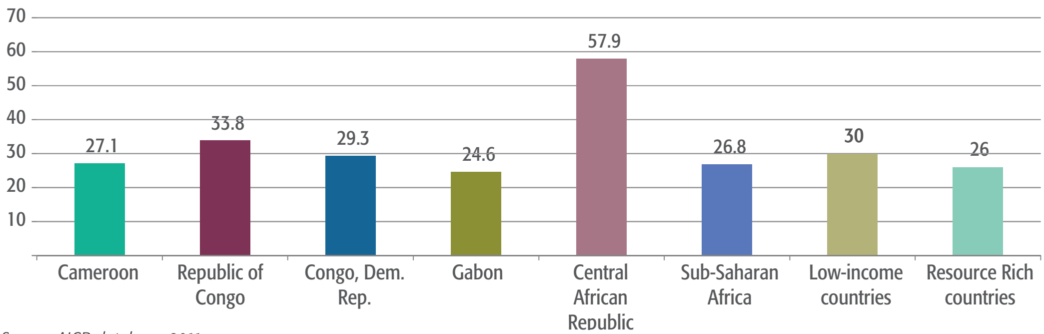
4 This is commonly known as the rural accessibility index (RAI) and is estimated by using a geographic information system model of Africa's road network and the geographical distribution of population.

Figure 1.4: Ratio of Paved to Unpaved Roads



Source: AICD database, 2011.

Figure 1.5: Rural Accessibility



Source: AICD database, 2011.

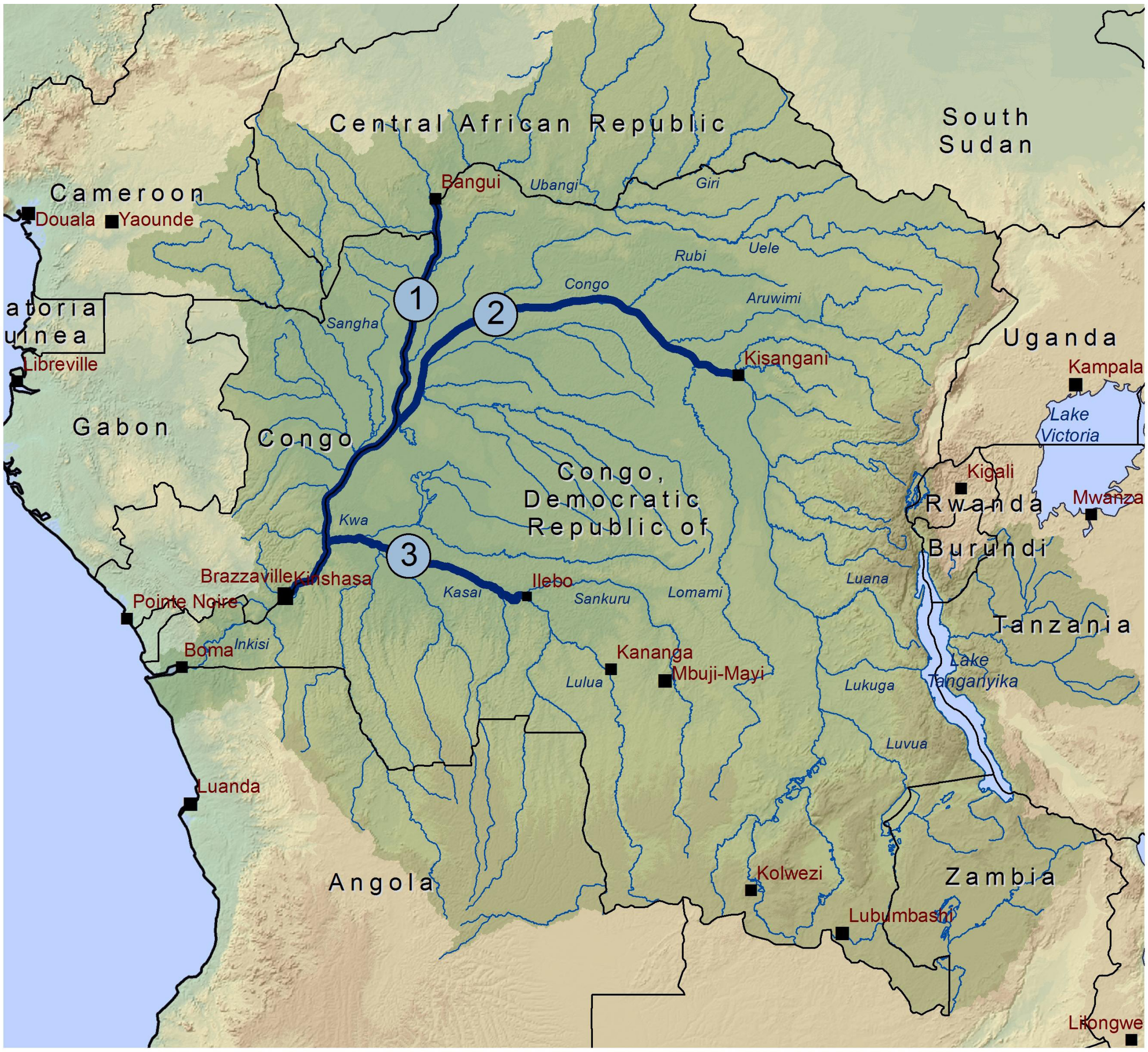
Transport infrastructure has been poorly maintained. In most Congo Basin countries, the road network has fallen into an advanced state of disrepair due to poor upkeep over the past decades (in some countries, protracted civil war exacerbated the lack of maintenance). Until recently, the budget allocated to road infrastructure has been excessively low, and the financial mechanisms (fonds routiers) in place to support road maintenance have been suboptimal.

River Transportation Network

The Congo Basin has a navigable network of 12,000 km, covering nearly four million km^2 in nine countries. The three principal routes—all of which converge on the downstream terminus at Kinshasa on the Malebo Pool— run from Kisangani, from Ilebo on the Kasai, and from Bangui on the Ubangi (see figure 1.6). The amount of goods transported by water (mainly agricultural products, wood, minerals, and fuel) is very modest, usually not reliable year-round.

In principle, the waterway system could significantly contribute to a multi-modal transport network serving the region, particularly given low associated transport costs of US$0.05 per ton-kilometer versus US$0.15 per ton-kilometer for road or rail freight in Central Africa, albeit at significantly lower speeds. In practice, however, the river transportation falls short of the role it could play in overall economic development of the Congo Basin. In fact, since the 1950s, river transportation has actually declined because of an outdated and insufficient infrastructure, inadequate maintenance,

Figure 1.6: River Transportation Network in the Congo Basin



Major Waterways

1 Bangui-Kinshasa 2 Kisangani-Kinshasa 3 Illebo-Kinshasa

Source: CICOS 2009.

poor regulatory framework, and numerous nonphysical barriers to movement. As a result, despite vast potential, the waterway system remains a marginal transport mode in the Congo Basin.

A new commission has been set up to foster development of river transportation. Recognizing this untapped potential, the governments of Cameroon, Central African Republic, Democratic Republic of Congo, and the Republic of Congo have found it imperative to jointly manage the resources of the Basin. In 1999, under the authority of the Executive Secretary of the Economic and Monetary Community of Central Africa (ECCAS), the four governments established the International Commission for the Congo-Oubangui-Sangha Basin (Commission Internationale du Bassin Congo-Oubangui-Sangha [CICOS]). The immediate objective of CICOS is to improve cooperation among its member states through improved communication via the Congo River and its tributaries; a longer-term objective is to promote integrated water resources management (IWRM) in order to enhance development and alleviate poverty in the member states.

Railways Network

Rail networks are underdeveloped. Railway lines generally link ports with regional hinterlands, with very limited regional integration potential: the pattern of railway development in the Congo Basin countries is no different from the overall network in Africa, which has historically not been designed to support inter-country trade. The total railway network in the Congo Basin countries is 7,579 km, out of which more than a third is not fully operational (see table 1.1). Rail networks in the Democratic Republic of Congo and Cameroon are comparatively better developed than other Congo Basin countries.

The network was centered on minerals—at the expense of passengers. The railway network is primarily used for transporting minerals and petroleum products (see table 1.2). It is indeed a legacy of the colonial era, primarily put in place to move extracted natural resources rather than to move people or foster integrated development of the country. This historic trend tends to persist: the Trans-Gabonais, which opened in 1987, was also built primarily to transport minerals. As a result, only a very marginal portion of the total transport task covers passenger transport (see table 1.1), and recent statistics show that the average passengers on railway transportation tend to decline globally.

Railway potential has not been fully tapped. While many railway systems once carried a high share of their countries' traffic, their market shares have declined, assets steadily deteriorated, and quality of service fallen over the years. Conflict has rendered some sections of

Table 1.1: Rail Networks in Selected Congo Basin Countries.

		Transport task (million units)		Proportion of total task (%)		Passenger (number /year)	
		Passenger-km	Net tonne-km	Passenger	Freight	2000	2005
Cameroon	CAMRAIL	308	1,119	22	78	1,266	1,053
Congo, Dem. Rep.	CFMK	3	57	5	95	155	33
	CFU	N/A	N/A	N/A	N/A		
	SNCC	70	444	14	86	1,307	359
Republic of Congo	CFCO	167	264	39	61	546	628
Gabon	SETRAG	87	2,208	4	96	237	218

Source: Bullock, 2009.

Table 1.2: Freight Composition as Percent of Total Tonnage

Congo Basin Countries	Company	Timber	Cement & Construction Material	Fertilizers	Petroleum Products	Ores & Minerals	Agricultural Products	Others	Total
Cameroon	Camrail	37	2	4	26	–	19	12	100
Republic of Congo	CFCO	41	2	1	12	1	2	41	100
Congo, Dem. Rep.	CFMK	11	6	–	4	24	–	55	100
Congo, Dem. Rep.	SNCC	2	3	–	8	85	–	2	100
Gabon	SETRAG	30	–	–	–	60	–	10	100

Source: Bullock, 2009.

the network unusable. At the same time, the enhancement of the road network has allowed road systems to capture higher-value general freight, thereby limiting rail traffic to bulk mineral and agricultural freight as well as semi-bulk freight, such as fuel. The consistent decline in revenue has delayed the maintenance and replacement of deteriorating track and rolling stock. The railway network in the Congo Basin is largely underperforming; it is expected to make only a minor contribution toward solving the transport problems confronting the region.

A HIGHLY DISCONNECTED REGIONAL NETWORK

The regional corridors are deteriorated. Only half of the major trade corridors in the Congo Basin countries are in good condition, leading to high costs for freight tariff (by far the highest cost in the SSA). In addition, the trade density is low.

This situation negatively impacts the Central African Republic—the only landlocked country in the Congo Basin—in particular. Although the Central African Republic heavily relies on its regional corridors for the efficient movement of goods and people, it does not have a single all-season road corridor to its coastal port gateways. Furthermore, its neighbors tend not to prioritize the maintenance of their portions of the corridors that connect the Central African Republic to main gateways; the Douala-Bangui and Point Noire–Brazzaville–Bangui corridors are still not fully paved. Cameroon's segment of the Point Noire–Brazzaville–Bangui corridor (308 km) is entirely unpaved, as is 1,000 km on the Congolese side. Some sections of the Douala-Bangui corridor (about 250 km in Cameroon and 210 km in the Central African Republic) are just being upgraded (as a part of the Economic and Monetary Community of Central Africa [CEMAC] Transport Transit program).

The multi-modal potential has deteriorated. Traditionally, the regional transport industry in Central

Table 1.3: Africa's Key Transport Corridors for International Trade

Corridors	Length (km)	Roads in good conditions (%)	Trade density (US$ million/km)	Implicit speed (km/hour)	Freight tariff (US$/tonne-km)
Western	2,050	72	8.2	6	0.08
Central	3,280	49	4.2	6.1	0.13
Eastern	2,845	82	5.7	8.1	0.07
Southern	5,000	100	27.9	11.6	0.05

Source: Bullock 2009.

Note: Implicit speed includes time spent stationary at ports, border crossings, and other stops.

Table 1.4: Road Quality and Traffic for Corridors Linking Bangui to Gateways

Corridors	Condition (%)				Type (%)		
	Good	Fair	Poor	Unknown	Paved	Unpaved	Unknown
Douala to Bangui	53.9	23.4	22.7	0	68.6	31.4	0
Cameroon	29.6	35.7	34.7	0	52.1	47.9	0
Central African Republic	100	0	0	0	100	0	0
Douala to Ndjamena	18.9	24.5	56.6	0	67.3	32.7	0
Cameroon	18.9	24.5	56.6	0	67.3	32.7	0
Pointe Noire to Brazzaville to Bangui	29.1	18.9	45.2	7	68.8	25.2	6
Cameroon	55.6	38.8	0	6	0	100	0
Central African Republic	99.2	0	0	1	99.2	0.8	0
Republic of Congo	0	21.3	69.4	9	27.9	62.8	9.2

Source: Bullock 2009.

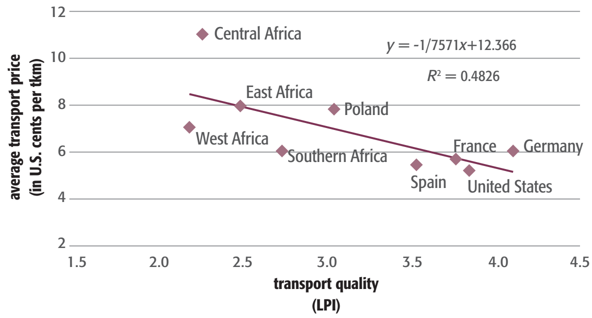
Africa, particularly with respect to transit traffic, has been shared between the road and road–rail corridors originating from the gateway port of Douala and the rail–river–road corridors between Pointe-Noire (the Republic of Congo) or Matadi (the Democratic Republic of Congo) and Bangui in the Central African Republic (rail–river) up to N'Djaména in Chad. However, the rail–river corridor has lost all of its market share of the Chadian trade since the early 1990s and has become marginal for the Central African Republic trade (except for oil products through Matadi).

Although the situation is particularly critical for the Central African Republic, one can argue that the poor transportation connectivity tends to create landlocked economy even within countries: this is particularly true in the continent-like the Democratic Republic of Congo. Access to markets is challenging and leads rural populations to rely on a subsistence economic model, with limited options for trade outside of their immediate neighborhoods.

TRANSPORTATION SYSTEM: HIGH PRICE, LOW QUALITY

Transportation prices in Africa are much higher than anywhere else. Transport services in Central African countries are among the least-performing in the world, with very high cost and low quality (as measured by Logistic Performance Index) (see figure 1.7). The

Figure 1.7: Transport Service in Central Africa: Expensive and Low Quality



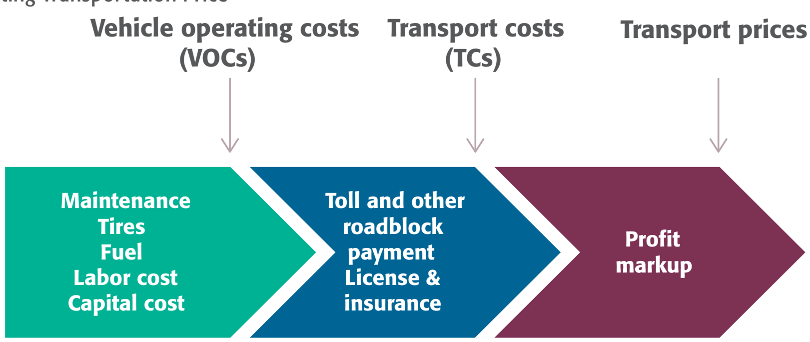
Source: Teravainthorn and Raballand 2008.

ECCAS[5] reports that the freight transportation cost from Douala to N'Djaména is US$6,000 per ton and takes 60 days, while it is only US$1,000 and takes 30 days from Shanghai to Douala. The rail freight rate in the Democratic Republic of Congo is nearly three times the rate charged elsewhere in southern Africa.

Transportation price results from a combination of factors. There are several factors that influence transportation price (see figure 1.8). While vehicle operating costs (VOCs)—which directly correlates to the quality of the road infrastructure and the types of vehicles—constitute a major portion of the transportation costs, transportation prices can be strongly influenced by other factors, such as inefficient logistics, weak regulatory framework and institutions, etc. The actual

5 Agreed Steering Program for Transport in Central Africa (Plan Directeur Consensuel pour le Transport), ECCAS 2004.

Figure 1.8: Factors Affecting Transportation Price



Source: Teravainthorn and Raballand 2008.

transportation price in a given countryis largely determined by the share of the aforementioned factors and varies significantly from one country to another.

- *Poor infrastructure condition maximizes maintenance costs.* Poor road conditions generate high-variable operating costs, as they increase fuel consumption, maintenance costs, and shorten the average lifetime of vehicles (and parts). In the Democratic Republic of Congo, for example, only 5 percent of the 58,000 km of national highways are paved. The cost imposed by poor road infrastructure is one of the main reasons why freight costs are so high in the Democratic Republic of Congo. Despite the existence of a relatively robust trucking industry—and the competition is fierce—freight costs continue to remain high due to poor road infrastructure and dilapidated transport networks.
- Underperforming logistics. Congo Basin countries are among the most logistics-unfriendly countries when it comes to transportation services. Poorly functioning ports and slow customs clearance, in particular, are significant constraints in Cameroon and the Democratic Republic of Congo. The cost of transporting a container between Douala and Bangui is 4.94 US$/km, while it is only 1.38 US$/km from Maputo to Johannesburg. The current system also favors the use of large fleets, which consist mostly of poorly maintained old trucks.
- *Overregulated transport market.* Regulatory frameworks in the Congo Basin countries are particularly complex. Such complexity has created space for all kinds of rent-seeking activities, such as corruption, protectionism, and cartels. The perverse incentive structure created by the complex regulatory framework is the major barrier to entry and has dwarfed competition. Lack of entry of new operators has inhibited the emergence of a more efficient supply chain sought by both importers and exporters.

Moving a ton of freight along intraregional corridors in the Central African region costs twice as much (between US$230 and $650) as in the southern Africa region (between US$120 and $270), where distances are significantly longer (Dominguez-Torres and Foster 2011). In the early 1990s, the cost of a bag of cement purchased in the provincial capital of Kisangani doubled by the time it reached the sub-regional capital of Buta some 250 km to the northwest along the trans-African highway—and the roads have only deteriorated since then. The landlocked status amplifies the burden of transportation costs. Expensive road transport costs along the Bangui-Douala corridor account for the bulk of the cost of importing to the Central African Republic. Inland transport costs, at about US$3,500 to $4,500 per container, account for more than 65 percent of the total cost of importing.

The structure of the prices for transport in the Congo Basin shows that even if improvements of roads can be expected to reduce both the vehicle operating and maintenance costs, more needs to be done to significantly and lastly reduce the transportation cost, specifically through easing of regulations and control of transport cartels.

CHAPTER 2

Poor Transport Infrastructure Has "Protected" the Forests

TYPOLOGY OF IMPACTS OF TRANSPORT INFRASTRUCTURE ON FORESTS

Many studies have shown a positive correlation between road infrastructure development and deforestation.[6] Roads are one of the most robust predictors of tropical deforestation: roads accelerate forest fragmentation and reduce forest regrowth. The development of transportation infrastructure (namely, roads and railways) has both direct and indirect impacts on forests. Direct impacts are usually limited and only encompass a strip of a few meters on each side of the transport line (that is, the security lane that needs to be deforested). However, the overall long-term impacts in terms of deforestation could be of much greater magnitude and could extend over a long period of time, especially if forest governance is weak, local law enforcement is poor, and livelihood opportunities of adjacent communities are limited. In addition, road construction/improvement causes forest degradation because it increases the accessibility of remote areas, allowing logging and hunting.

Although it is widely recognized that transport infrastructure undoubtedly tends to increase pressure on forests and leads to deforestation and forest degradation, the magnitude and trend of this phenomenon vary with parameters, such as type of infrastructure, population density, and type of forest ecosystems. In addition, governance issues can also play a part.

6 Some of the many studies on the topic include Cropper, Puri, and Griffiths 2001; Chomitz et al. 2007; Fearnside 2008; Kaimowitz and Angelsen 1998; Pfaff et al. 2007; Soares-Filho et al. 2005; and Zhang et al. 2005.

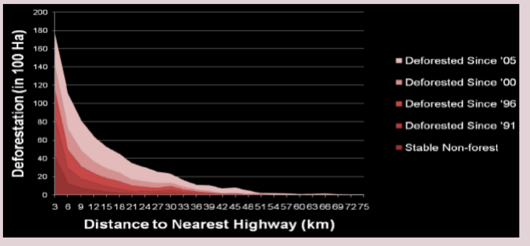
- *Population density.* Often, as population grows, demand for agricultural land and product increases. Such increases could lead to expansion of agricultural fields into areas previously occupied by forests. The rate of deforestation could grow significantly if population growth is coupled with the demand for agriculture land and fuel.
- *Transport infrastructure opens access to forest frontiers, which are often colonized by the most vulnerable people in search for subsistence land.* In Central Africa, major causes of deforestation and forest degradation are directly linked to the rural population density near the forest. The frequency of deforestation rapidly decreases with the distance from roads. In Brazilian Amazon, a 30 percent of forest loss was found within 10 km of roads, a 20 percent loss between 11 and 25 km, and a 15 percent loss from 26 to 50 km (Laurance et al. 2001). Less research work has been done on this issue in the Congo Basin: a modeling work conducted in southern Cameroon (Mertens and Lambin 1997) shows that 80 percent of total deforestation occurs within a distance of less than 2 kilometers of roads and that beyond a distance of 7.5 kilometers, deforestation ceases.
- *Type of infrastructure. Indirect impacts are usually of greater magnitude along a road than along a railway.* Similarly, studies in the Amazon have shown that impacts along paved roads, in terms of deforestation, are greater: 70 percent of deforestation occurs within 50 km of paved roads and, at most, 7 percent along unpaved roads (IPAM 2000).

- *Medium/long-term impacts.* Direct immediate impacts of transport infrastructure are usually limited to a few-meter-strip on each side of the transport line. Box 2.1 illustrates the situation in Latin American and highlights the temporal sequence: deforestation extends over a long period of time and full impacts can only be measured on a medium/long-term basis.
- *Governance.* Evidence from Belize shows that deforestation trends can be managed by integrated infrastructure planning and local development; however, in areas with weak forest governance and poor law enforcement, indirect impacts are usually out of control and new transport infrastructure tends to be accompanied with an explosion of illegal activities (illegal logging, mining…) that cause major damage to forests.

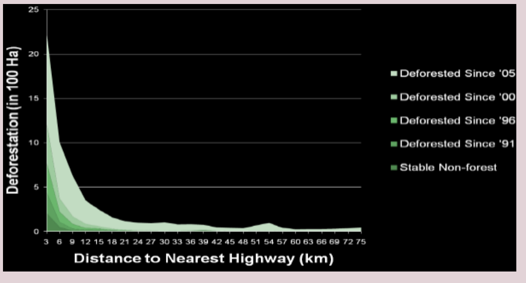
Box 2.1: Temporal Sequence of Forest Loss in Latin American Countries

The figures below illustrate the deforestation dynamics around roads in Brazil (Acre), Peru (Madre de Dios), and Bolivia (Pando) over a 15-year period following the creation of a new road.

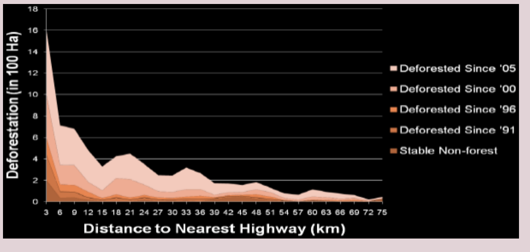
In all cases, clearing started in the areas adjacent to the roads, with the most rapid rate of clearing occurring within the first 10 km from the road. Beyond this initial distance, the patterns and rates vary quite significantly from one case to another. The 10 km pattern is especially true for Acre and Madre de Dios, where road paving is relatively advanced. Unlike in Acre and Madre de Dios, in Pando, forests along the dirt roads are beginning to be cleared. The area cleared, however, is quite minor, and distance from the road appears to be somewhat less significant. Findings suggest that paved roads increase connectivity and offer greater accessibility, facilitating greater clearing. Flows of people and goods will accelerate across the landscape, increasing the likelihood of dramatic future changes in forest cover.



Acre, Brazil



Madre de Dios, Peru



Pando, Bolivia

Source: Southworth et al. 2011.

Box 2.2: Connectivity between Provincial Capitals

In the case of the Democratic Republic of Congo, the provincial capitals of the countries are not connected by roads; most of them are connected to the country capital, Kinshasa, by a deficient air transport system. Lack of connectivity is a main bottleneck for economic development, as it has resulted in the isolation of provinces and has hindered the smooth exchange of goods and commodities. Even the countries with sea access are not in a position to achieve greater mobility of goods and people because of a highly disconnected transport network. Countries with access to ports, too, have yet to reap the benefits of transport efficiency; they are in the same situation as their landlocked counterparts.

Provincial capital	Road	River	Air
Matadi	√		
Mbandaka		√	
Kisangani		√	√
Bandundu		√	
Kananga			√
Mbuji-Mayi			√
Lubumbashi			√
Kindu			√
Goma			√
Bukavu			√

Transport Options between Kinshasa and the Provincial Capitals

POOR TRANSPORT INFRASTRUCTURE HAS "PRESERVED" FORESTS

Lack of Connectivity: Major Obstacle to Economic Development

There is considerable economic research to show that inadequate infrastructure impedes economic growth. Evidence (Aschauer 1989) shows a statistical linkage between transport infrastructure stock and economic growth. In China, for instance, the transport network growth has been one of the major engines of economic growth (Zhang 2009). It influences economic structure and performance by opening up markets.

The mobility of goods and people is challenged by a highly disconnected transport network in the Congo Basin. As illustrated in box 2.2, in the Democratic Republic of Congo only one provincial capital is connected to Kinshasa (the country capital) via roads; the others rely only on river and air transport. This situation is highly detrimental to trade, as the quality of infrastructure is indeed an important determinant of trade performance (Nordås and Piermartini 2004). Recent studies show that trade is highly sensitive to transport prices (a 10-percent drop in transport prices increases trade by 25 percent), and in many countries, high transportation prices constitute a higher barrier to trade than do import tariffs and trade restrictions. In addition, poor transport infrastructure increases time-related uncertainty and risks, and studies show that the travel delay caused by poor road infrastructure is negatively correlated with the transport price. Hummels et al. (2007) calculate tariff equivalent costs of time delays. They show that avoiding a day of delay would be worth 2 percent of the value of a shipment of road vehicle. The delays caused by poor transport infrastructure impact the trade volume as well. Djankov, Freund, and Pham (2006) estimate the trade impediment of an additional day in transit. Findings show that an additional day in transit reduces trade volume by more than 1 percent.

Deficient networks have been a major bottleneck for a transition from subsistence agriculture to a more market-oriented model. Poor infrastructure has made any transition to a more intensive form of forest-based farming virtually impossible. Feeder roads in the humid forest are difficult to maintain under wet conditions and are in many areas inaccessible during the rainy season. In the Democratic Republic of Congo, even though river transport proves to be one of the most efficient means of transport, its operation is highly constrained because of the fluctuating water level: it only works intermittently, when water levels are appropriate for operation. Furthermore, limited storage and processing capacities prevent subsistence farmers from waiting for the dry season to access markets and sell their products at a higher price. As a result, lack of road infrastructure, associated with poor storage capacities, has so far constricted farmers' profitability, as it increases the transaction costs and cuts off farmers' participation in the broader economy. It has also dwarfed competition, growth, and adversely affected both profitability and food security of subsistence farmers.

Food security becomes an issue when people are forced to depend entirely on local production. Even a relatively unsatisfactory growing season could jeopardize food security, as people will have no way to benefit from surpluses in other parts of the country. Lack of reliable road infrastructure increases the vulnerabilities of farmers to climatic shocks but could also protect them from other external shocks (for example, price volatility).

Suitable lands are mostly inaccessible. A large portion of potentially suitable land in the Congo Basin tends not to be converted into production, as the net profits are likely to be negative once transport costs are considered. A recent study[7] has identified potentially suitable and accessible land. The possibly suitable land was classified based on the travel time to the next significant market, defined as a city of at least 50,000 inhabitants, with a cutoff of six hours to market. As shown in the table below, Latin America clearly has a great advantage infrastructure-wise, with more than 75 percent of its non-forested suitable land at less than six hours from a market town. Consequently, despite Latin America having about 40 percent less land available than does SSA, the regions have roughly the same amount of non-forested suitable land (about 94 million hectares [ha]) when the criterion on access to market is taken into account. The situation is even worse in the Congo Basin countries. In the Democratic Republic of Congo, it is estimated that only 33 percent (7.6 out of 22.5 million ha) of the non-forested suitable land is at less than six hours from a major market; that proportion is as low as 16 percent in the Central African Republic (1.3 out of 7.9 million ha).

7 Deininger et al. 2011, based on IIASA 2010.

Improved infrastructure is a prerequisite for boosting minerals exploitation. Poor infrastructure has generally been a major obstacle in the development of mining operations in the Congo Basin; however, with the high demand for minerals as well as the high prices, incentives to develop new mineral deposits with a new generation of deals increase. In fact, over the past few years, a trend has grown toward investors offering to build associated infrastructures, such as roads, railways, power plants (including large dams), ports. In Gabon, the Belinga iron ore reserves have been put under contract for development by China National Machinery and Equipment Import and Export Corporation, and this contract includes building the related infrastructure. In Cameroon, an Australian company (Sundance) has been allotted exploration rights that would—should the project be approved—develop an iron-ore mine and the related infrastructure, which also falls within the dense tropical forests that cover the southern portion of the country. These new deals largely take the burden off the host countries, which generally lack the

Table 2.1: Potential Supply of Non-cultivated Non-forested Low-Population-Density (< 25 persons/km^2) Land, Applying an Access to Market Criterion (million ha)

	Total Area	Area < 6 hours to market	% Area < 6 hours to market
Sub-Saharan Africa	201.5	94.9	47.1%
Latin America and Caribbean	123.3	94	76.2%
Eastern Europe and Central Asia	52.4	43.7	83.4%
East and South Asia	14.3	3.3	23.1%
Middle East and North Africa	3	2.6	86.7%
Rest of world	51	24.6	48.2%
Total	445.6	263.1	59.0%

Source: Deininger et al. 2011, based on IIASA 2010.

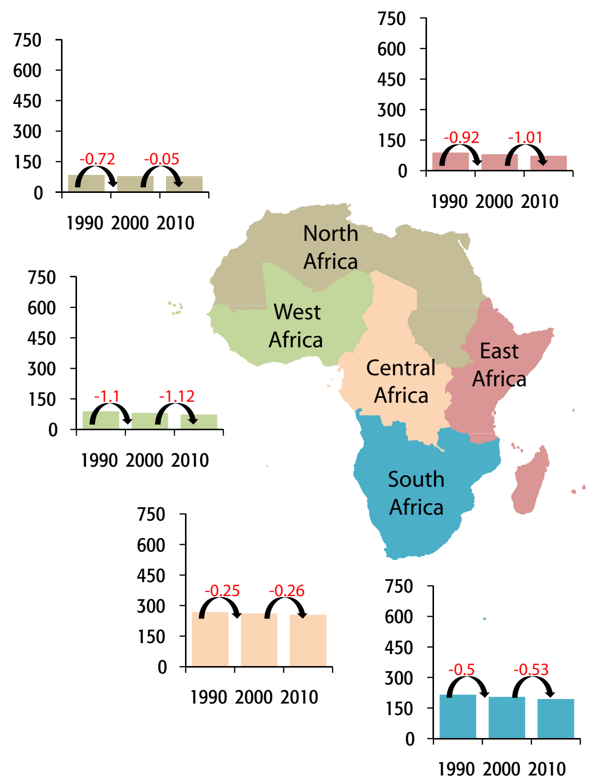
finances to cover such investment needs. Such "new deals" would circumvent one of the major weaknesses of the Congo Basin countries for the development of the mining operations.

Deforestation Rates in the Congo Basin Are Among the Lowest

Deforestation rates in Congo Basin are among the lowest, even in Africa. In the Congo Basin, tropical forests have been "passively" protected because some of the major drivers of deforestation—agricultural expansion, infrastructure, and mining development—remained dormant over recent decades for such reasons as political instability, protracted insurgency, etc. Figures indicate that Central Africa's rates are not only well below those of the major negative contributors to world total forest area but are also below the deforestation rates experienced by most other African regions. Area-wise, Central Africa loses about 40 percent less forest each year than does Southern Africa, 25 percent less than West Africa, and 15 percent less than East Africa, and represents less than one-fifth of the total forest area lost every year on the continent (see table 2.2 and figure 2.1).

Tropical forests have mainly been "passively" protected. In the six Congo Basin countries, the overall current deforestation and forest degradation rates are very moderate. In Central Africa, annual net deforestation and degradation were respectively 0.09 percent and 0.05 percent between 1990 and 2000 (figure 2.2). Poor transportation systems and political instability were some of the major barriers to economic development in the subregion. Farmers were trapped into subsistence agriculture with low inputs. and the enormous extractive resources could not be exploited. As a consequence, over the past decades, Congo Basin forests have been largely protected and are considered to be among the best preserved tropical forests in the world. However, deforestation in the Congo Basin has accelerated in recent years. Deforestation and forest degradation have been largely associated with expansion of subsistence activities (that is, agriculture and energy) and are concentrated around densely populated areas.

Figure 2.1: Changes in Forest Area in Main Regions in Africa on 1990–2010 period



Note: For the purpose of this analysis,

Central Africa includes Burundi, Cameroon, the Central African Republic, Chad, the Democratic Republic of Congo, Equatorial Guinea, Gabon, Republic of Congo, Rwanda, Saint Helena, Ascension and Tristan da Cunha, São Tomè and Príncipe;

East Africa: Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Mayotte, Réunion, Seychelles, Somalia, Uganda, United Republic of Tanzania;

North Africa: Algeria, Egypt, Libyan Arab Jamahiriya, Mauritania, Morocco, Sudan, Tunisia, Western Sahara;

Southern Africa: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe;

West Africa: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo

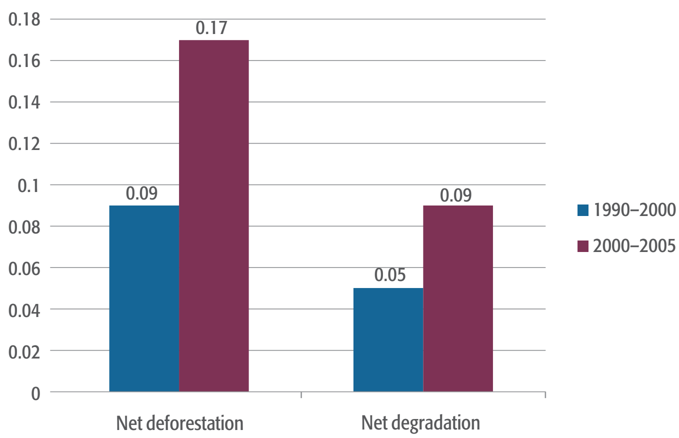
Source: authors, from FAO (2011)

Table 2.2: Changes in Forest Area in Africa and in the Main Negative Contributors to World Total Forest Area, 1990–2010

Subregion	Forest area (thousand ha)			Annual change (thousand ha)		Annual change rate (%)	
	1990	2000	2010	1990–2000	2000–2010	1990–2000	2000–2010
Central Africa	268,214	261,455	254,854	-676	-660	-0.25	-0.26
East Africa	88,865	81,027	73,197	-784	-783	-0.92	-1.01
North Africa	85,123	79,224	78,814	-590	-41	-0.72	-0.05
Southern Africa	215,447	204,879	194,320	-1,057	-1,056	-0.50	-0.53
West Africa	91,589	81,979	73,234	-961	-875	-1.10	-1.12
Total Africa	749,238	708,564	674,419	-4,067	-3,414	-0.56	-0.49
Southeast Asia	247,260	223,045	214,064	-2,422	-898	-1.03	-0.41
Oceania	198,744	198,381	191,384	-36	-700	-0.02	-0.36
Central America	96,008	88,731	84,301	-728	-443	-0.79	-0.51
South America	946,454	904,322	864,351	-4,213	-3,997	-0.45	-0.45
World	4,168,399	4,085,063	4,032,905	-8,334	-5,216	-0.20	-0.13

Source: FAO 2011.

Figure 2.2: Average Annual Deforestation and Forest Degradation Rates, 1990–2000 and 2000–2005



Source: De Wasseige et al. 2012.

CHAPTER 3

Future Developments of Transportation: A Threat for the Congo Basin Forests?

Underachievement in infrastructure is severe in the Congo Basin. The urgent need to “transform Africa’s infrastructure” critically applies to the Congo Basin countries, which rank among those with the lowest level of adequate infrastructure. Ambitious plans are being prepared at the regional and continental levels while individual countries also tend to give higher priority to both infrastructure construction and rehabilitation.

TRANSPORTATION ENHANCEMENT: AT THE TOP OF THE POLITICAL AGENDA

A Priority for Congo Basin Countries

Significant progress is being made by countries to rehabilitate their road infrastructure. Over the past few years, most Congo Basin countries have set ambitious goals in terms of infrastructure and particularly transportation infrastructure to drive economic growth and development. In most cases, these goals have translated into major increases in their national budget allocations to the transport sector: a large portion is targeted to investments, as the top priority really focuses on construction and rehabilitation of roads and—to a lesser extent—railways. In the Republic of Congo, where the transportation system is by far the most deteriorated, the public financing to the transport sector has increased by 31.5 percent between 2006 and 2010, with an allocation of 19.6 percent of public resources. This effort has been particularly targeted to the road subsector, whose budgetary allocation has increased by 77 percent during the same period. These resources, along with external ones, have been used to support flagship investments.

Significant progress has also been made to mobilize external resources to support the reconstruction of the road network. In the Democratic Republic of Congo, for instance, the reconstruction of the road network has been clearly set as a top priority immediately after the end of the armed conflict. The Democratic Republic of Congo has secured major financial commitments from multilateral and bilateral donors as well as China. These funds cover many of the country’s major road corridors: the route between Matadi (the port) and Kinshasa was recently rebuilt, and there are plans underway to reconstruct and resurface the major east–west and north–south corridors. China is currently financing a trans-Congo highway, providing access to rich mineral and timber resources. Consequently, recent road quality indicators suggest that the state of the country’s limited paved network (fewer than 3,000 km) has improved. Nevertheless, the unpaved roads—which at more than 30,000 km still represent the vast majority of the network—are in serious disrepair.

Maintenance remains a challenge. A key issue going forward will be not only to reconstruct the road network but also to create a sustainable basis for funding its maintenance. The climatic and ecological conditions are particularly severe in the Congo Basin, contributing to rapid alteration of the infrastructure capital. Thus, the road network requires substantial financing for maintenance. Given the vast geographical expanse of the network, the Democratic Republic of Congo would need to spend almost US$400 million a year just to keep its transport infrastructure in usable condition, a figure that represents more than 5 percent of the country's GDP. Securing resources for maintenance clearly represents a huge challenge, as does spending those funds effectively. In many countries, road funds have been created to respond to this challenge. Particular attention should be given to these road funds so that they can ensure an efficient and effective use of resources collected to cover appropriate road maintenance services.

Many Regional and Continent-wide Programs

The transportation network is currently highly fragmented. A regional approach has the potential to reduce the cost of infrastructure development, as well as to improve the overall functioning of the system and to optimize the potentialities of the transport corridors within and outside the region.

Road corridors. Taking into account the crucial challenge, numerous plans and programs are underway to transform transportation infrastructure in the Congo Basin, both at the continent level (under the auspices of the African Union and NEPAD) and at the regional level (under the leadership of the regional economic entities—ECCAS and CEMAC) (see annex1 and box 3.1).

Expansion of railways network. There have been many proposals, some dating back a century, to create new routes for landlocked countries and to integrate the isolated networks. The most ambitious proposal came in 1976, when the Union of African Railways (UAR) prepared a master plan for a pan-African rail network that included 18 projects requiring 26,000 km of new construction, many of which had been proposed for several decades. This plan—designed to create a grid to support intra-African trade development and regional economic integration—was approved by the Organization of African Unity (OAU) in 1979, but few, if any, of the proposed links have left the drawing board. The UAR is now concentrating on a 2001 revised master plan containing a subset of 10 corridors. In 2005, the UAR further simplified this plan with its adoption of three major transcontinental routes: Libya-Niger-Chad-Central African Republic-Republic of Congo-Democratic Republic of Congo-Angola-Namibia (6,500 km), Senegal-Mali-Chad-Djibouti (7,800 km), and Kenya-Tanzania-Uganda-Rwanda-Burundi-Democratic Republic of Congo with possible extensions to Ethiopia and Sudan (5,600 km) (Bullock 2009).

Box 3.1: The Consensual Road Network for Central Africa

The region needed a reference network to establish its infrastructure investment program. Therefore, a long process has been followed during many years, as shown by the following milestones:

- In 1988, the ECCAS Head of State Conference created officially the "community road axis."
- In 2000, the ECCAS Head of State Conference adopted a priority network for Regional integration (n° 9/00/CEMAC-067-CM-04 dated July 20, 2000)
- In 2005, states from ECCAS decided to codify the development corridors.
- In June 2007, the ECCAS Head of State Conference approved the final version of the prioritized projects.
- In June 2011, a donor roundtable was held to agree on the founding of the plan.

The Consensual Road Network for Central Africa comes from the shared will to have, at the regional level, a common and agreed basis for transportation improvements. In March 2006, transportation experts validated the Consensual Road Network for Central Africa and its codification, the Development Corridors and, then, the projects in the first, second, and third priorities. The Consensual Road Network for Central Africa includes the inter-states liaisons and the inter-connection network.

River transportation. In line with the African Union's decision to promote the creation or reinforcement of intergovernmental agencies in order to improve cooperation between the states, CICOS was created on November 6, 1999, to help manage the water resources in the Congo–Oubangui–Sanga Basins and to facilitate the river transportation on those waterways. With the support of African Development Bank and African Water Facility, CICOS launched an action plan for 2009–2010 in order to prepare a Strategic Action Plan for developing river transportation. CICOS aims to provide the region with the institutional tools and the planning arrangements to improve and develop river transportation in the Congo Basin.

POTENTIAL IMPACTS OF TRANSPORTATION INFRASTRUCTURE DEVELOPMENT ON FOREST COVER

Poor transportation infrastructure has so far "protected" the tropical forests in the Congo Basin; however, it seems clear that with the ongoing transport infrastructure development and upkeep, the region is expected to see an upswing in deforestation. The partial equilibrium model GLOBIOM (IIASA 2010) has been used to assess the potential impacts of transportation developments based on the planned infrastructure for which funding has already been secured.

A Modeling Approach: CongoBIOM

A modeling approach has been elaborated to investigate the effect of the predicted main future drivers of deforestation in the Congo Basin, both internal and external, on land-use change and on resulting greenhouse gas (GHG) emissions by 2030. In fact, the high-forest / low deforestation (HFLD) profile of the Basin countries justified the use of a prospective analysis to forecast deforestation, as historical trends were considered inadequate to properly capture the future nature and magnitude of the drivers of deforestation. Accordingly, a macroeconomic approach, based on the Global Biomass Optimization model (GLOBIOM) was taken in order to sufficiently account for global parameters (see box 3.2 and Annex 2).

Box 3.2: Brief Presentation of the GLOBIOM

GLOBIOM is designed for the analysis of land use changes around the world.[1] The biophysical processes modeled (agricultural and forest production) rely on a spatially explicit data set which includes soil, climate/weather, topography, land-cover/use,[2] and crop management factors. Harvesting potentials in cropland are computed with the EPIC model (Williams 1995), which determines crop yields and input requirements based on relationships between soil types, climate, hydrology, etc. Timber-sustainable harvesting potential in managed forests is computed from the G4M model's forest-growth equations. The GLOBIOM draws on extensive databases for initial calibration of the model in the base year, technical parameters, and future projections. In order to reproduce the observed quantities for the reference year (2000), the GLOBIOM is calibrated by employing the Positive Mathematical Programming (Howitt 1995), which consists of using the duals on the calibration constraints to adjust the production cost. This process is supposed to correct the model's problems of specification and the omission of other unobservable constraints that face production. It is used to calibrate the crop, sawn-wood, wood-pulp, and animal calories production.

GLOBIOM is a global simulation model that divides the world into 28 regions. One such region considered under the GLOBIOM is the Congo Basin (the six highly forested countries covered by the study). It is important to look at the rest of the world when studying land-use change in a region because local shocks affect international markets and vice versa. Moreover, there are important leakage effects. Bilateral trade flows are endogenously computed between each pair of regions, depending on the domestic production costs and the trading costs (tariff and transportation costs).

1 Concept and structure of GLOBIOM are similar to the U.S. Agricultural Sector and Mitigation of Greenhouse Gas model.

2 The land-cover data for 2000 are taken from the GLC2000

GLOBIOM is a partial equilibrium model, which is an economic model that incorporates only some sectors of the economy. Like all models, GLOBIOM simplifies a complex reality by highlighting some variables and causal relations that explain land-use change based on a set of assumptions about agents' behavior and market functioning. GLOBIOM only includes the main sectors involved in land use (that is, agriculture, forestry, and bioenergy). It is an optimization model that searches for the highest possible levels of production and consumption, given the resource, technological, and political constraints in the economy (McCarl and Spreen 1980). The demand in the GLOBIOM is exogenously driven—that is, some projections computed by other teams of experts on population growth, GDP growth, bioenergy use, and structure of food consumption are used to define the consumption starting point in each period in each region. Then, the optimization procedure ensures that the spatial production allocation minimizes the resources, technology, processing, and trade costs. Final equilibrium quantities result from an iterative procedure between supply and demand, where prices finally converge to a unique market price. Box 3.2 provides a detailed description of the GLOBIOM.

Based on an adaptation of GLOBIOM, the CongoBIOM has been elaborated. The Congo Basin region was specifically created within the GLOBIOM, and additional detail and resolution for the Basin countries were included. Land-based activities and land-use changes have been modeled at the simulation-unit level, which varies in size between 10 x 10 km and 50 x 50 km. Internal transportation costs have been computed based on the existing and planned infrastructure network; protected areas and forest concessions have been delineated, and available national statistics have been collected to inform the model (IIASA 2011; Mosnier et al. 2012).The calibration of the CongoBIOM was done on the data collected in the various six countries by a team of international and national experts.

The CongoBIOM was used to assess the impacts of a series of "policy shocks" identified by Congo Basin country representatives. The methodological approach was first to investigate what could be the reference level of emissions from deforestation in the Congo Basin without further measures to prevent or limit deforestation. Complementary scenarios were tested in addition to the baseline with different assumptions about global meat and biofuel demand, internal transportation costs, and crop yield growth. The selection of the policy shocks was based on a literature review and was validated during two regional workshops with local experts. Policy shocks were chosen to describe impacts from both internal and external drivers: external (S1): increase in international demand for meat; (S2): increase in international demand for biofuel factors of deforestation and internal; (S3): improved transport infrastructure; (S4): decrease in fuelwood consumption; and (S5): improved agricultural technologies. The objectives of the modeling exercise were: (1) to highlight the mechanisms through which deforestation could occur in the Basin (driven by both internal and external drivers); and (2) to test the sensitivity of deforested area and GHG emissions from deforestation with respect to different drivers. Table 3.1 describes the different scenarios used as well as the main results.

The quantitative outputs of the model presented in Table 3.1 should be taken with extreme caution and used, rather, as a comparative basis between the different scenarios. Validation of these input data would require additional statistics at a finer resolution level and would ideally be available for several years.

Hypothesis under the "Improved Transport Infrastructure" Scenario

The scenario S3: "Improved Transport Infrastructure" is based on the assumption that with the return of political stability and new economic potentialities (i.e. agriculture, mining), both the new transport infrastructure development and the repair of existing infrastructure will increase by many fold. The model includes the projects for which the funding is certain (see list in annex 1). This planned transport infrastructure information provided by the ministries for Cameroon, the Central African Republic, and Gabon, and by the World Bank for the Democratic Republic of Congo and Republic of Congo (AICD) was used in the model to forecast the impact.

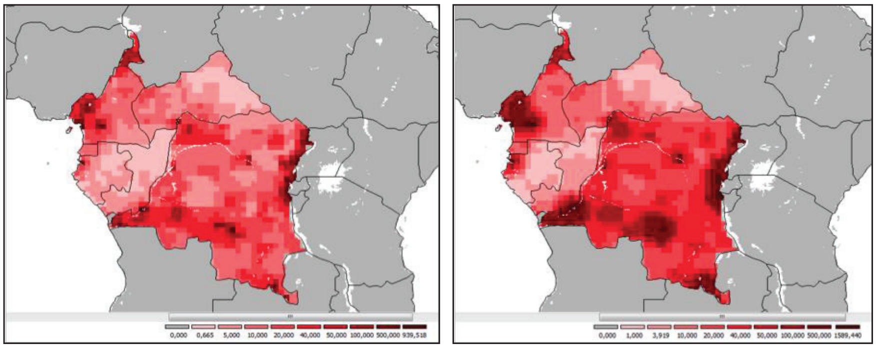
Table 3.1: Policy Shocks Tested with CongoBIOM and Main Results

Scenarios	Description	Main Results
Baseline	Business as usual using standard projections of main model drivers.	Deforestation rate close to the historical rate of deforestation over 2020 to 2030 (0.4 Mha per year). Productivity gains avoid about 7 Mha of cropland expansion (the equivalent of the projected cropland expansion).
S1: Meat	Business as usual with a higher global meat demand. In the scenario, the demand of animal calories increase by 15 percent compared to FAO projection in 2030.	The Congo Basin countries remain marginal in meat production. The average deforested area over the 2020–2030 period still increases by 20 percent in the Congo compared to the base Basin. As the global price for meat and animal food increases, food and feed imports are reduced and local production increases—leading to deforestation.
S2: Biofuels	Business as usual with a higher global first-generation biofuel demand. The scenario on the biofuel consists to double the demand for biofuels of first generation compared to the initial projection of the POLES model in 2030.	The Congo Basin countries remain marginal in global biofuels feedstock production. The average deforested area over the 2020–2030 period still increases by 36 percent in the Congo Basin compared to the base. As the global price for oil palm and agriculture product increases, food imports are reduced and local production of oil palm and food increases—leading to deforestation.
S3: Infrastructures	Business as usual with planned transportation infrastructures included. Return of political stability, good governance, and new projects induced a multiplication of projects to repair existing transport systems and contribute to a new transportation. The model has included all the projects for which the funding is certain.	Calories intake per capita increases by 3 percent compared to the base scenario. The Congo Basin improves its agricultural trade balance with an increase in exports and a reduction in food imports. Total deforested area becomes three times as large (+234 percent) and emissions from deforestation escalate to more than four times as large.
S4: Fuelwood	Business as usual with a decrease in fuelwood consumption per inhabitant from 1 m^3 to 0.8 m^3 per year.	Within the 0.4 Mha deforested per year on the baseline, fuelwood counts for 30 percent. A 20 percent decrease in fuelwood consumption induces therefore a 6 percent decrease in total deforestation compared with the business-as-usual scenario.
S5: Technological change –Increase in agriculture productivity	Business as usual with increased crop productivity. The model assumes that this increase is proportional across all management systems and does not involve higher producing costs for farmers (modeling, for example, agricultural mechanization or subsidies of better seeds). The yields are doubled for food crops and increased by 25 percent for cash crops.	Calories intake per capita increases by 30 percent and imports are reduced. Increase in emissions from deforestation by 51 percent over the 2020–2030 period because consumption increases faster than that of crop productivity.

***Source**: IIASA 2011.*

As illustrated in the section on "Impacts of transport on Forests" under chapter 2, the preservation of the forest cover along transport axes largely depends on population density. It is critical to include the distribution of the population as well as the prospects for growth during the simulation period because with the increase in population, dynamics of forest access and resource extraction will change. Therefore, population growth parameters were integrated in the Congo-BIOM model. In the Congo Basin, population is expected to double between 2000 and 2030, with an average annual growth rate of 3.6 percent between 2000 and 2010

Figure 3.1: Population Density Simulation in 2000 and 2030 (projected)



Population density (persons/km²) in 2000 | Population density (persons/km²) in 2030

Source: IIASA 2011.

and 2.2 percent between 2020 and 2030—leading to a total population of 170 million inhabitants by 2030.

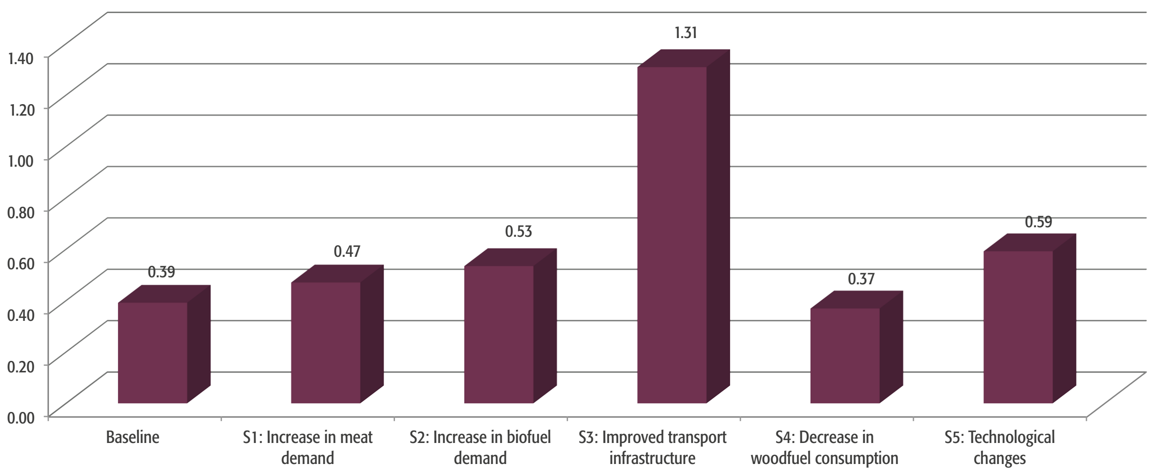
Urbanization trends have also been computerized. As in other developing regions, the urbanization process is expected to intensify in the Congo Basin. From United Nations estimates (2009), the number of cities in the Basin with more than 1 million inhabitants should jump from four in 2000 to eight in 2025, with 15 million inhabitants in the city of Kinshasa alone. North and Southwest Cameroon and the eastern Democratic Republic of Congo border will continue to register high population densities.

Impacts of Transportation Development on Forest Cover: Results from CongoBIOM

While acknowledging the limitation of any modeling exercise,[8] one can, however, recognize that the CongoBIOM can be helpful to investigate, ex ante, how changes in transport structure can impact forest cover under different scenarios. Under this specific activity,

8 "All models are wrong—but some are useful" (George P. E. Box).

Figure 3.2: Results of the Shocks in Terms of Areas Annually Deforested under the Different Scenarios, 2010–2030



Source: IIASA 2011.

the model was been elaborated and used to help decision makers better understand the causal chain that leads to deforestation: it used quantified method to help increase qualitative understanding. The quantified results of the model are, however, presented in the below paragraphs. These quantified results should be used with great caution based on the multiple limitation of the modeling exercise.

According to the CongoBIOM, the impact of the scenario "Improved Transport Infrastructure," as planned under the various plans and programs, is foreseen to be, by far, the most damaging to forest cover. The model shows that the total deforested area is three times higher than in the business-as-usual. Among the multiple scenarios explored, the "Transportation Scenario" emerged as the one causing the highest rate of deforestation (see figure 3.2).

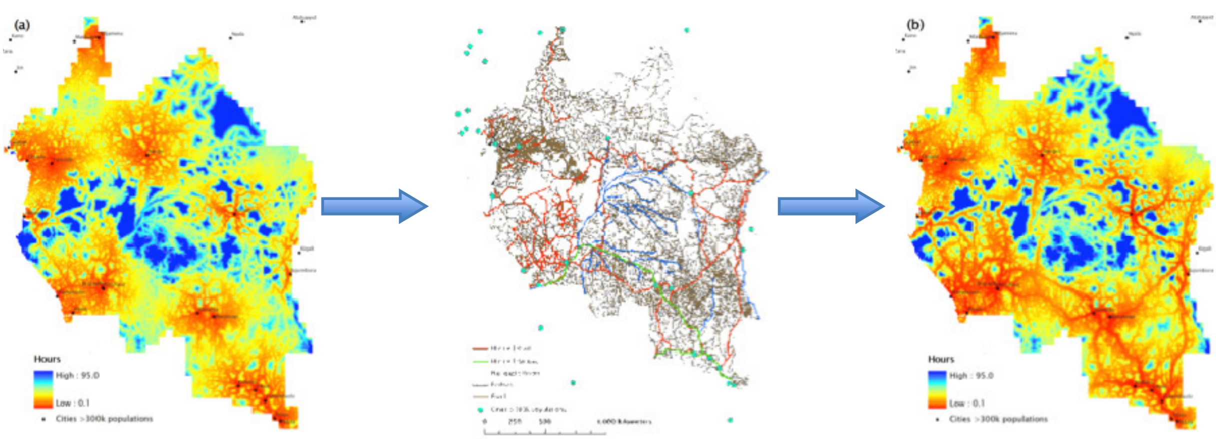
However, as described in the previous section on "Typology of Impacts," most of the impacts do not result from the infrastructure development itself but from the indirect impacts associated with economic activities unlocked through an enhanced access to markets and a higher connectivity.

Improved transportation infrastructure lowers transportation costs. The CongoBIOM computerizes current transportation costs throughout the Congo Basin into a spatially explicit data set. The internal transportation cost has been estimated on the basis of the average time needed to go from each simulation unit to the closest city above 300,000 people in 2000 (including cities in neighboring countries) based on the existing transportation network of roads, railways, and navigable rivers, the elevation, the slope, the boundaries, and the land cover (see Annex 2 on modeling). On average, considering the infrastructure existing in 2000, internal transportation costs are the lowest in Cameroon and the highest in the Democratic Republic of Congo, where they can lead to a doubling of initial production costs.

The "Improved Transportation" scenario uses the same methodology and parameters, and computerizes the internal costs with planned infrastructure for the 2020–2030 simulation period. The transportation costs are expected to reduce in the same magnitude as the transportation time[9] (see figure 3.3. below).

9 Authors are aware of the limitation of such an assumption, as the literature presents various examples where this direct correlation between time and costs does not apply; however, in absence of stronger assumption, this one has been applied.

Figure 3.3: Impact of Change in Transportation Infrastructure on Travel Time and Costs



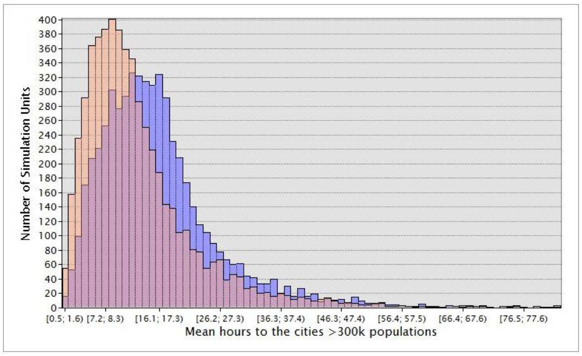
Transport time with existing infrastructure (circa 2000)

Planned infrastructure (roads in red, rail in green)

Transport time with new infrastructure

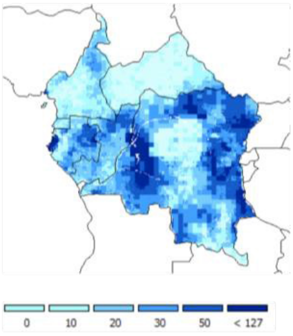
Source: IIASA 2010.

Figure 3.4: Improvements of accessibility due to the planned infrastructure construction in the six Congo Basin countries.



Note: Red = projected accessibility, blue = current accessibility (in hours).
Source: IIASA 2010.

Figure 3.5 : Internal transportation cost reduction deriving from infrastructure improvements per simulation unit (in US$/ton).



Note: Dark blue indicates the highest transportation cost reduction.

Figure 3.4 shows for each simulation unit the variation of accessibility to city under the "Enhanced Transportation" scenario: most simulation units benefit a shorter mean time to access a mid-size city (300,000 habitants). Figure 3.5 highlights the variation between internal transportation costs with existing infrastructure and internal transportation costs after implementation of planned improvements to infrastructure.

Improved transportation changes rural economic equilibrium. Reduction in the transportation costs can lead to significant changes in economic equilibrium of a rural area and dynamic of agricultural development: the causal chain that the model is highlighted here:

Improved infrastructure→
Increase in agriculture production→
Increased pressure on forests

Enhanced transportation network tends to reduce the price of the agricultural products to the consumer while producer prices net of transport costs tend to increase. This leads to an increase of the consumption (often through substitution phenomenon[10]) which, in turn, encourages producers to produce more. Typically, a new equilibrium would be reached with a larger volume and lower price compared to the initial situation. Under the scenario "Improved Infrastructure,"[11] the Congo-BIOM projects a 12 percent increase in the total volume of crops produced and a decrease in the price index for local crops, following infrastructure improvements in the Congo Basin. Figure 3.5 shows the projected deforestation "hot spots" due to agricultural expansion.

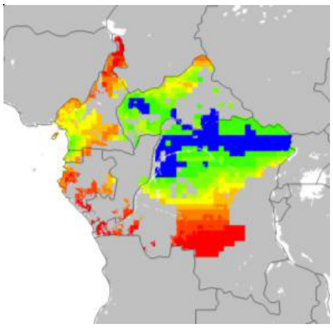
The impact varies with the different crops. Infrastructure improvement has a greater impact on crops with low unit price: since transportation costs depend on the volume, not the value of a crop, the lower the unit price of a crop, the higher the share of the internal transportation costs in total production costs. As a result, the model indicates a decrease in price for cassava and sugarcane; however, this does not apply to maize. The graphs below highlight the areas with the highest yield for different crops (sugarcane, cassava, and corn). Figures show that the highest yields occur in the Democratic Republic of Congo for the two crops, contrary to corn (maize) where the highest yields are achieved in the northern part of the region, in the Central African Republic, and north Cameroon (figure 3.6) the areas with high yield for sugarcane and cassava tend to be the most exposed to deforestation..

International competitiveness of agricultural and forestry products also benefits from reduction of

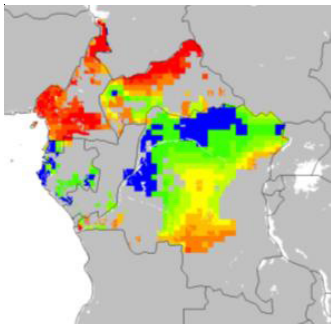
10 Consumers in the Congo Basin are increasingly reliant on imported agricultural products. Reduction in "prices to consumer" can drive the consumption of locally grown products.

11 Without any changes on the other parameters.

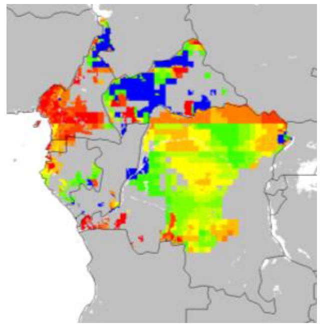
Figure 3.6: Yield of Major Crops in the Congo Basin



a. Sugarcane yield, high input



b. Cassava yield, low input



c. Corn yield, low input

Source: IIASA 2010.
Note: Red = low, blue = high.

transportation costs; however, this may not be as much as the Congo Basin countries usually argue. In fact, despite huge potential in terms of land availability and suitability for biofuels, simulation under the CongoBIOM indicates that the poor business climate would still place Basin countries in a disadvantaged position in comparison to other large basins. The recent moratorium on new biofuel plantations in Indonesia, however, seems to indicate that new trends could be foreseen under effects of international leakages.

Illegal logging. In many areas, the opening of new roads is immediately associated with increase in illegal activities and illegal logging in particular. The domestic demand for wood (both for construction and energy), while long overlooked, is now recognized as more important than the supply to international markets: this leads to increased pressure on forest resources. Without a proper governance system, uncontrolled activities tend to explode.

RECOMMENDATIONS: HOW TO RECONCILE TRANSPORTATION ENHANCEMENT AND FORESTS PROTECTION IN THE CONGO BASIN

Infrastructure deficit in the Congo Basin is among the most severe in the world. Physical capital of transport infrastructure is critically deteriorated in the Congo Basin: most of the indicators, both in terms of infrastructure quantity and quality, rank among the lowest in the world. This situation has resulted in a fragmentation of economies and very limited exposure to trade and exchanges, both internally and externally.

Addressing the infrastructure gap in Africa is high on the agenda at country, regional, and continental levels. The infrastructure deficit is widely acknowledged as one of the major barriers to economic growth and development, and ambitious plans are now being prepared at the regional and continental levels to address this gap. Individual countries also tend to invest more national resources (along with external financing support) to both infrastructure construction and rehabilitation.

Transport infrastructure development is likely to have significant impacts on forests in the Congo Basin. As the Congo Basin countries are planning for transformational investments in infrastructure, it is critical that they identify ways that will reconcile transportation enhancement and forest preservation. The Congo Basin countries are entering a transitional path and are committed to close the infrastructure gap to realize their potential in terms of economic growth and development. The infrastructure capital will significantly increase and improve in the next decades. The Basin countries need to identify investments as well as policies that minimize the impacts associated with transport infrastructure on primary forests. While the international community now recognizes that forests (and particularly tropical forests) are a key element in the fight against global warming, transport development in the Congo Basin should be defined in a way that will respond to the urgent need to unlock development potential through an integration of fragmented economies and to limit adverse impacts on natural forests. The REDD+[12] mechanism—under discussion among the parties of the UNFCCC (United Nations Framework Convention on Climate Change)—has the potential to generate significant financial flows to accompany developing countries to sustain economic development, while reducing pressures on their natural forests. The below section provides some recommendations and guidance as well as insights on how the future REDD+ mechanism could be used to support the new development paths that would accompany the development of transport infrastructure in the Congo Basin to minimize adverse impacts on natural forests.

Promote an Integrated Approach for Transport Infrastructure Development

In all Congo Basin countries, one sees a lack of land-use planning and intersectoral coordination to ensure sustainable development at the local and national levels. As a result, numerous conflicts have been noted between and among conservation priorities, mining and logging concessions, and livelihoods of the local populations.

A comprehensive land-use planning exercise, to be conducted in a participatory manner, should determine the different land uses to be pursued on the national territories. Once completed, this land plan would distinguish the forest areas that need to be preserved and those that could potentially be converted to other uses. While planning transport development, particular attention should be given to "high-value forests" in terms of biodiversity, watershed, and cultural values.

Trade-offs among different sectors and within sectors need to be clearly understood by stakeholders so that they can define robust development strategies at the national level. For example, in the Congo Basin, there are large amounts of non-forested land with high potential in low-population density areas, which implies that there is no need, in principle, to draw on currently forested areas to satisfy the future demand for agricultural commodities. However, past trends show that forested areas may be more vulnerable to agriculture expansion. So, if forests are to be protected, pro-active measures need to be set up by the governments. This type of exercise requires a strong coordination among the different line ministries and potential arbitrage at the highest levels to reconcile potential conflicting uses of lands. One output of such an exercise could be the identification of major development corridors and growth poles that could be developed in a coordinated manner, with the involvement of all governmental entities along with private sector and civil society.

While such a land-use planning exercise need to be conducted at the country level (and even at the provincial level) to define country-specific priorities in line with national strategies, the benefit of regional integration is also undoubtedly huge for all the Congo Basin countries. As such, the corridor approach has also been adopted by the Economic Community of Central African States at the regional level to foster synergies and economies of scale amongst their member states.

Due consideration is to be given to the development of local development plans for areas affected by the new transport infrastructure. Developing transportation infrastructure while mitigating deforestation requires a thorough reflection on the development model at all levels. In fact, areas that are directly served by improved transportation facilities will become more competitive for various economic activities (such as agricultural expansion, including palm-oil plantations). Local participation in transportation planning will help ensure that economic opportunities are maximized. Consultation with the local population affected by the transport development and definition of a consensual local development plan should be part of the preparation: it will help clarify land tenure issues as well as potential economic opportunities related to the new infrastructure. Mitigation measures at the local level

12 REDD+ means "Reducing greenhouse emissions from Deforestation, forest Degradation, considering also the role of conservation, sustainable forest management and enhancement of forest carbon stocks" in developing countries.

may include clarifying land tenure or integrating the transportation project into a broader local development plan. Such plans may include the protection of forest banks along roads, rivers, or railways to avoid unplanned deforestation.

Foster Multi-modal Transport Network

While much focus is given to roads, other modal systems can support economic growth in the Congo Basin. For instance, with more than 12,000 km of navigable network, the Congo Basin could benefit from a potentially highly competitive waterway system: such a transport system is characterized by low associated costs (of US$0.05 per ton-km versus $0.15 per ton-km for road or rail freight in Central Africa). However, the river transportation falls short of the role it could play in overall economic development of the Congo Basin. In fact, since the 1950s, river transportation has actually declined because of an outdated and insufficient infrastructure, inadequate maintenance, poor regulatory framework, and numerous non-physical barriers to movement. As a result, despite vast potential, the waterway system remains a marginal transport mode in the Congo Basin.

While roads usually come with significant associated adverse impacts on natural forests, the impacts of waterway systems are usually minimal. The same applies to railway systems to a lesser extent. While countries plan for transport development, they must consider alternate modes and the pros and cons of different modes, not only in terms of economic returns but also in terms of environmental impacts.

Properly Assess Ex Ante Impacts of Transport Investments

Transport development (whether new infrastructure or rehabilitation of existing) will reshape the economic profile of the areas it impacts and will consequently increase pressure on forest resources, if any. It can lead to deforestation through conversion of natural forests into agricultural lands or to forest degradation through widespread illegal logging activities.

A robust ex ante assessment of the potential indirect and induced impacts of transport development can help design the mitigation measures that should be associated to reduce adverse impacts on forest resources. Such an exercise should be an integral part of the design phase of the infrastructure investments; however, currently only the direct environmental impacts of investments are assessed. So far, neither the environmental impact studies nor the safeguard mandatory reviews are considering the long-term indirect effects on deforestation. Therefore, there is a need to develop a new set of instruments that would help capture the impact of increasing economic competitiveness in the areas served by new transportation infrastructure. To do so, a robust economic modeling exercise (that is, economic prospective analysis) should be undertaken as part of any infrastructure investment preparation. This would ensure that transportation investments are designed consistently with a low-impact economic development.

Enforce Forest Protection and Manage Forest–Agriculture Frontier

Enhancement of transport infrastructure will undoubtedly increase the pressure in forest–agriculture frontier. The agriculture frontier will be contained only if an appropriate mix of institutional, technological, and economic factors is put in place. Studies in the Amazon indicate that zoning enforcement has been the most economically efficient way to control the agricultural expansion on forested lands. In other areas, payments of economic services seem to provide adequate incentives. In all cases, technological improvements are needed to allow the farmers to maintain or to increase their production without converting new lands.

Institutional capacities, particularly at the decentralized level, will have to be strengthened in order to properly enforce monitoring and control activities. Check points will have to be established and properly run on the transport axis, particularly to combat illegal logging and poaching. In addition, compliance with land-use plans will have to be respected. Such activities can only be effectively implemented at a decentralized level, with human resources adequately trained and equipped.

Enforcement measures will have to go hand in hand with the promotion of more intensive agricultural practices as intensification, while increasing the productivity, is likely to lead to more conversion of forested lands in a context of a growing demand for agricultural products (both internal and potentially external) and unemployment. Examples from the Amazon show that growth poles are not systematically to be associated with post-transportation infrastructure deforestation: accompanying mitigation measures, such as land management governance at the local level, can substantially contain the pressures on forest areas.

CONCLUSION

Congo Basin countries are faced with the considerable challenge to reconcile infrastructure development and forest preservation. This implies the dual challenge of developing local economies through an improved infrastructure while limiting the negative impacts of growth on the region's natural capital—particularly forests.

Infrastructure development is crucial to help the local population out of poverty. In spite of the region's great potential in terms of exploitation and development, the national poverty line hovers between a third and two-thirds of the population in different countries of the Basin, access to food is majorly inadequate, and undernourishment is highly prevalent. Transportation infrastructure is among the most deteriorated in the world creating, within the region, de facto a juxtaposition of landlocked economies that make farmers considerably vulnerable to poor harvests. Looking ahead, the Congo Basin population is expected to double between 2000 and 2030, leading to a total of 170 million people by 2030—people who need of food, energy, shelter, and employment. In order to deal with that domestically increased demand, infrastructure must be developed strategically. That means not only an improved transport infrastructure but also improved storage capacities and better access to local markets to allow for higher efficiency in domestic supply chains.

Passive protection of forests due to low infrastructure development so far. Due to the decrease of quality in the regional transport networks and the remoteness of most of the forested area, forests have been passively protected. Most notably, after independence from colonial regimes, the region has seen a strong decline in infrastructure quality. This former shortcoming can today be turned into an advantage. The countries are now at a crossroads: in the upcoming years, more economic development is expected, and it could be channeled in a more sustainable way.

New environmental finance mechanisms can help Congo Basin countries to transition toward a forest-friendly development path. Environmental finance includes climate funding for adaptation and mitigation efforts in general and REDD+ in particular, but also financing for biodiversity, wetlands, or soil restoration. This new, dedicated focus on forest protection within international climate agreements—in combination with the availability of new financial resources—moves sustainable forest management up in the political agenda and has facilitated in many countries a dialogue among forest agencies and those ministries and entities that regulate broader industrial and agricultural development.

Payments for environmental services and REDD+ funding in particular could be used to finance structural changes and reforms in a cross-sectoral approach. In this context, performance-based payments for forest-friendly infrastructure development could be used. When accessing these new resources, countries may consider a number of issues in order to prioritize activities and effectively allocate these new funds. It is, therefore, up to national governments to define how these various mechanisms fit into their own development; how to best use such resources; whether and how to meet the relevant criteria of funds or mechanisms; and how to assess the benefits and risks associated with particular funds, including the costs of putting into place relevant information and institutional conditions.

Even though the precise nature of REDD+ funding remains uncertain, there are sources available now that countries can use for no-regret measures, such as forest-conscious infrastructure reforms.

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ANNEXES

Annex 1

NEW TRANSPORT INFRASTRUCTURE DEVELOPMENT AND REPAIR OF THE EXISTING INFRASTRUCTURE

LIST OF PROJECTS USED FOR THE SIMULATION

WORLD BANK

Project name/ID	Implementation date	Total Cost (US$ millions)	Description	Road names	Length (Km)	Works	Status
PMURR (Volet routes 1390 km)	2002–2008	$152.77	Transport, roads, electricity and water, urban infrastructure, health, social protection	Mpozo-Sonabata Bridge	261	Rehabilitation of paved roads	100% finished
				Kenge-Kikwit-Batshamba	346	Rehabilitation of paved roads	95% finished
				Batshamba-Tshikapa	258	Opening up of unpaved roads	Steps canceled
				Tshikapa-Kananga	254	Rehabilitation of Tshikapa bridge	100% finished
				Kananga-MbujiMayi	183	Opening up of unpaved roads	Works abandoned at RN1 and Mbuji-Mayi crossings
				MbujiMayi-Mweneditu	158	Maintenance of paved roads	
				Mweneditu Nguba	769	Construction of paved road	Not envisaged within the framework of the PMURR
				Nguba- Lubumbashi	184	Rehabilitation of paved roads	70% finished
PUSPRES (Volet routes 1779 km)	2005–2010	$93.34	Rehabilitation of priority infrastructure of transport, rehabilitation of urban functions in 4 major cities and 8 urban centers, support to based communities, Ministry of Finance, Institutional Strengthening	Mbujimayi-Kasongo-Bukavu	1020	Opening up of unpaved roads	Execution: Physical-12.7%. Financial-74%
				Kisangani-Niania-Beni	751	Opening up of unpaved roads	Execution: Physical-78%. Financial-80%
				Port de Matadi-Pont Mpozo	8	Rehabilitation of paved roads	100% finished
PUAACV (Volet routes 600 km)	2005–2010	$33.44	Support to medium size cities, rehabilitation of administrative centers of provinces, opening up of roads and institutional strengthening of provinces	Lubumbashi-Kasomeno-Kasenga	208	Opening up of unpaved roads	Execution: Physical-63%. Financial-89%
				Akula-Gemena-Mbari	168	Opening up of unpaved roads	Execution: Physical-12%. Financial-42.6%
				Mbari-Libenge et Boyabo-Zongo	224	Opening up of unpaved roads	Execution: Physical-40%. Financial-41.5%
PRO ROUTES (1800 km)	2008-2013	$123.00 (World Bank $50 and DFID $73)	n/a	Kisangani-Buta-Bunduki and Dulia-Bondo	650	Reopening	0%
			n/a	Uvira-Fizi-Kalemie-Pweto-Kasomeno	1150	Dirt road	0%

AFRICAN DEVELOPMENT BANK

Project name/ID	Implementation date	Total Cost (US$ millions)	Description	Road names	Length (Km)	Works	Status
Rehabilitation of Nsele-Lufimi and Kwango-Kenge roads Project	2005–2010	$52.45	Rehabilitation of Nsele-Lufimi et Kwango-Kenge roads Study on the planned Loange-Mbuji Mayi road construction	Nsele-Lufimi	95	Rehabilitation of paved roads	0%
				Kwango-Kenge	73	Rehabilitation of paved roads	0%
				Rural roads within Kwango-Kenge	140	Dirt road construction	0%
				Loange-Mbujimayi	601	Paved road construction	0%

EUROPEAN UNION

Project Name/ID	Implementation date	Total Cost (euro millions)	Description	Roads names	Length (Km)	Works	Status
Programme d'appui à la réhabilitation (PAR II)+ avenants n° 1 et n° 2 (volet routes)	Jul-03	97.64	Rehabilitation of roads infrastructures and adduction of clean water, building operational capacities of OdR, of OVD and Regideso	Sonabata-Lufimi-Kenge	343	Preservation of RN1	
				Lufimi-Kwango	57	Rehabilitation of paved roads	Ongoing
				Mongata-Bandundu-Mpoko	281	Opening up of unpaved roads	28% finished
				RN1-Mpoko-Bandundu-Weti-Mbandaka	809	Opening up of unpaved roads	
				Gemena-Zongo	224	Mechanized rehabilitation of national roads and priority dirt roads	100% finished
				Gemena-Mobanza-Businga-Lisala-Bumba-Bunduki et Kananga-Tshikapa	907	Opening up of unpaved roads	0%
East Congo Program (PEC) Program of Rehabilitation and Reinsertion after war in the Eastern Provinces in the Democratic Republic of Congo	Aug-06	65.00	Rehabilitation of roads infrastructures and adduction of clean water, building operational capacities of OdR, of OVD and Regideso	Fr Burundi-Kivimvira-Uvira-Kamanyola-Bukavu-Kavumu and Sake-Kanyabayonga, Oso-Biruwe and Osokari-Walikale	373	Rehabilitation and maintenance of roads. Reopening and maintenance of unpaved roads	0%
				Kamanyola-Bukavu, Fizi-Minembwe, Kavumu-Nyabibwe-Minova and Biruwe-Osokari, Rutshuru-Bunagana, Kanyabayonga-Beni-Kasindi, Beni-Eringeti	710		
				Uvira-Fizi and Fizi-Minembwe	173		0%
				Mbau-Kamango and Kamango-Nobili	76		60% finished
				Kisangani-Lubutu	204	Reopening up of paved roads	Just started
				Sake-Walikale	287	Maintenance of unpaved roads	0%
				Iga Barrière-Nioka	96	Rehabilitation of road	8% finished

BELGIUM

Financement BELGE : Volet Routes, Voiries et pistes Rurales							
Project Name/ID	Implementation date	Total Cost (US $millions)	Description	Roads names	Length (Km)	Works	Status
Programme d'Urgence pour la RDC 2006–2008 (Volet routes)	2006-2008	2.30	Improve access to water, sanitation of priority zones, and opening up of these zones in major cities	Boma-Tshela	117	Rehabilitation of paved roads	Ongoing

UNITED KINGDOM

Project Name/ID	Implementation date	Total Cost (US$ millions)	Description	Roads names	Length (Km)	Works	Status
Réhabilitation de la route Kisangani-Ubundu	2004	$7.00	Rehabilitation of the road Kisangani-Ubundu by the HIMO method	Kisangani-Ubundu	129	Opening up of unpaved roads	

GERMANY

Project Name/ID	Implementation date	Total Cost (US$ millions)	Description	Roads names	Length (Km)	Works	Status
Réhabilitation route Punia-Kowe	2007–2008	$0.60	Rehabilitation of the road and construction of 24 bridges	Punia-Kowe			97%
Réhabilitation de 13 ponts sur la route Punia-Matumba et route Kindu-Kikombo	2007–2008	$0.15	Rehabilitation of bridges	Punia-Matumba, Kindu-Kikombo			52%
Volet AAA : Reconstruction d'infrastructure en HIMO	2005–2008	$9.01	Rehabilitation of the road	Walikale-Lubutu	250		

Annex 2

GLOBIOM MODEL—FORMAL DESCRIPTION

Objective function

$$\text{Max } WELF_t = \sum_{r,y}\left[\int \phi^{\text{demd}}_{r,t,y}\left(D_{r,t,y}\right)d(\cdot)\right] - \sum_{r}\left[\int \phi^{\text{splw}}_{r,t}\left(W_{r,t}\right)d(\cdot)\right] \tag{1}$$

$$- \sum_{r,l,\tilde{l}}\left[\int \phi^{\text{lucc}}_{r,l,\tilde{l},t}\left(\sum_{c,o,p,q} Q_{r,t,c,o,l,\tilde{l}}\right)d(\cdot)\right]$$

$$- \sum_{r,c,o,p,q,l,s,m}\left(\tau^{\text{land}}_{c,o,p,q,l,s,m} \cdot A_{r,t,c,o,l,s,m}\right)$$

$$- \sum_{r}\left(\tau^{\text{live}}_{r} \cdot B_{r,t}\right) - \sum_{r,m}\left(\tau^{\text{proc}}_{r,m} \cdot P_{r,t,m}\right)$$

$$- \sum_{r,\tilde{r},y}\left[\int \phi^{\text{trad}}_{r,\tilde{r},t,y}\left(T_{r,\tilde{r},t,y}\right)d(\cdot)\right].$$

Exogenous demand constraints:

$$D_{r,t,y} \geq d^{\text{targ}}_{r,t,y}. \tag{2}$$

Product balance

$$D_{r,t,y} \leq \sum_{c,o,p,q,l,s,m}\left(\alpha^{\text{land}}_{t,c,o,l,s,m,y} \cdot A_{r,t,c,o,l,s,m}\right) + \alpha^{\text{live}}_{r,t,y} \cdot B_{r,t} \tag{3}$$

$$+ \sum_{m}\left(\alpha^{\text{proc}}_{r,m,y} \cdot P_{r,t,m}\right) + \sum_{\tilde{r}} T_{\tilde{r},r,t,y} - \sum_{\tilde{r}} T_{r,\tilde{r},t,y}.$$

Land use balance

$$\sum_{s,m} A_{r,t,c,o,l,s,m} \leq L_{r,t,c,o,l}. \tag{4}$$

$$L_{r,t,c,o,l} \leq L^{\text{init}}_{r,t,c,o,l} + \sum_{\tilde{l}} Q_{r,t,c,o,\tilde{l},l} - \sum_{\tilde{l}} Q_{r,t,c,o,l,\tilde{l}} \tag{5}$$

$$Q_{r,t,c,o,l,\tilde{l}} \leq L^{\text{suit}}_{r,t,c,o,l,\tilde{l}} \tag{6}$$

Recursivity equations (calculated only once the model has been solved for a given period)

$$E_{r,t,e} = \sum_{c,o,l,s,m}\left(\varepsilon^{\text{land}}_{c,o,l,s,m,e} \cdot A_{r,t,c,o,l,s,m}\right) + \varepsilon^{\text{live}}_{r,e,t} \cdot B_{r,t} \tag{7}$$

$$+ \sum_{m}\left(\varepsilon^{\text{proc}}_{r,m,e} \cdot P_{r,t,m}\right) + \sum_{c,o,l,\tilde{l}}\left(\varepsilon^{\text{lucc}}_{c,o,l,\tilde{l},e} \cdot Q_{r,t,c,o,l,\tilde{l}}\right). \tag{8}$$

Irrigation water balance

$$\sum_{c,o,l,s,m} \left(\varpi_{c,l,s,m} \cdot A_{r,t,c,o,l,s,m} \right) \leq W_{r,t}. \tag{9}$$

Greenhouse gas emissions account

$$E_{r,t,e} = \sum_{c,o,l,s,m} \left(\varepsilon^{\text{land}}_{c,o,l,s,m,e} \cdot A_{r,t,c,o,l,s,m} \right) + \varepsilon^{\text{live}}_{r,e,t} \cdot B_{r,t} + \sum_{m} \left(\varepsilon^{\text{proc}}_{r,m,e} \cdot P_{r,t,m} \right) + \sum_{c,o,l,\tilde{l}} \left(\varepsilon^{\text{lucc}}_{c,o,l,\tilde{l},e} \cdot Q_{r,t,c,o,l,\tilde{l}} \right). \tag{10}$$

Variables

D	demand quantity (tons, m^3, kcal)
W	irrigation water consumption (m^3)
Q	land use/cover change (ha)
A	land in different activities (ha)
B	livestock production (kcal)
P	processed quantity of primary input (tons, m^3)
T	interregionally traded quantity (tons, m^3, kcal)
E	greenhouse gas emissions (tCO2eq)
L	available land (ha)

Functions

φ^{demd}	demand function (constant elasticity function)
φ^{splw}	water supply function (constant elasticity function)
φ^{lucc}	land use/cover change cost function (linear function)
φ^{trad}	trade cost function (constant elasticity function)

Parameters

τ^{land}	land management cost except for water (\$/ha)
τ^{live}	livestock production cost (\$/kcal)
τ^{proc}	processing cost (\$/unit (t or m3) of primary input)
δ^{targ}	exogenously given target demand (for example, biofuel targets; EJ, m^3, kcal)
α^{land}	crop and tree yields (tons/ha, or m^3/ha)
α^{live}	livestock technical coefficients (1 for livestock calories, negative number for feed requirements [t/kcal])
α^{proc}	conversion coefficients (—1 for primary products, positive number for final products, for example, GJ/m^3)
L^{init}	initial endowment of land of given land use/cover class (ha)
L^{suit}	total area of land suitable for particular land uses/covers (ha)
ω	irrigation water requirements (m^3/ha)
ε	emission coefficients (tCO_2eq/unit of activity)

Indexes

r	economic region (28 aggregated regions and individual countries)
t	time period (10-year steps)
c	country (203)

o simulation unit (defined at the intersection of 50 × 50 kilometer grid, homogeneous altitude class, slope class, and soil class)

l land cover/use type (cropland, grassland, managed forest, fast-growing tree plantations, pristine forest, other natural vegetation)

s species (37 crops, managed forests, fast-growing tree plantations)

m technologies: land use management (low input, high input, irrigated, subsistence, "current"); primary forest products transformation (sawn wood and wood pulp production); and bioenergy conversion (first-generation ethanol and biodiesel from sugarcane, corn, rapeseed, and soybeans; energy production from forest biomass—fermentation, gasification, and CHP)

y outputs (Primary: 30+ crops, sawlogs, pulpwood, other industrial logs, woodfuel, plantations biomass. Processed products: forest products (sawn wood and wood pulp), first-generation biofuels (ethanol and biodiesel), second-generation biofuels (ethanol and methanol), other bioenergy (power, heat, and gas)

e greenhouse gas accounts: CO_2 from land use change; CH4 from enteric fermentation, rice production, and manure management; N_2O from synthetic fertilizers and from manure management; and CO_2 savings/emissions from biofuels substituting fossil fuels

Table A.1 Input Data Used in the CongoBIOM Model

Parameter	Source	Year
Land characteristics	Skalsky et al. (2008), FAO, USGS, NASA, CRU UEA, JRC,	
IFPRI, IFA, WISE, etc.		
Soil classes	ISRIC	
Slope classes		
Altitude classes	SRTM 90m Digital Elevation Data (http://srtm.csi.cgiar.org)	
Country boundaries		
Aridity index	ICRAF, Zomer et al. (2008)	
Temperature threshold	European Centre for Medium Range Weather Forecasting (ECMWF)	
Protected area	FORAF	
Land cover	Global Land Cover (GLC 2000) Institute for Environment and Sustainability	2000
Agriculture		
Area		
Cropland area (1000 ha)	Global Land Cover (GLC 2000) Institute for 2000 Environment and Sustainability	2000
EPIC crop area (1000 ha)	IFPRI–You and Wood (2006)	
Cash crop area (1000 ha)	IFPRI–You et al. (2007)	2000
Irrigated area (1000 ha)	FAO	Average 1998–2002
Yield		
EPIC crop yield (T/ha)	BOKU, Erwin Schmid	
Cash crop yield(T/ha)	IFPRI- You et al. (2007)	2000
Average regional yield (T/ha)	FAO	Average 1998–2002
Input use		
Quantity of nitrogen (FTN) (kg/ha)	BOKU, Erwin Schmid	
Quantity of phosphorous (FTP)(kg/ha)	BOKU, Erwin Schmid	
Quantity of water (1000 m³/ha)	BOKU, Erwin Schmid	
Fertilizer application rates	IFA (1992)	

Parameter	Source	Year
Fertilizer application rates	FAOSTAT	
Costs for 4 irrigation systems	Sauer et al. (2008)	
Production		
Crop production (1000 T)	FAO	Average 1998–2002
Livestock production	FAO	Average 1998–2002
Prices		
Crops (USD/T)	FAO	Average 1998–2002
Fertilizer price (USD/kg)	USDA (http://www.ers.usda.gov/Data/FertilizerUse/)	Average 2001–05
Forestry Area under concessions in Congo Basin (1000 ha) Maximum share of sawlogs in the mean annual increment (m^3/ha/ year) Harvestable wood for pulp production (m^3/ha/year) Mean annual increment (m^3/ha/year)	FORAF Kindermann et al. (2006) Kindermann et al. (2006) Kindermann et al. (2008) based on the Global Forest Resources Assessment (FAO 2006a)	
Biomass and wood production (m^3 or 1000 T)	FAO	2000
Harvesting costs	Kindermann et al. (2006)	
Short rotation plantation	Havlik et al. (2011)	
Suitable area (1000 ha)	Zomerat et al. (2008)	2010
Maximum annual increment (m^3/ha)	Alig et al. (2000); Chiba and Nagata (1987); FAO (2006b); Wadsworth (1997)	
Potential NPP	Cramer et al. (1999)	
Potentials for biomass plantations	Zomer et al. (2008)	
Sapling cost for manual planting	Carpentieri et al. (1993); Herzogbaum GmbH (2008)	
Labor requirements for plantation establishment	Jurvélius (1997)	
Average wages	ILO (2007)	
Unit cost of harvesting equipment and labor	FPP (1999); Jirouš ek et al. (2007); Stokes et al. (1986); Wang et al. (2004)	
Slope factor	Hartsough et al. (2001)	
Ratio of mean PPP adjustment	Heston et al. (2006)	
GHG emissions		
N_2O emissions from application of synthetic fertilizers (kg CO_2/ha)	IPCC Guidelines (1996)	
Fertilizer application rates	IFA (1992)	
CO_2 savings/emission coefficients	CONCAWE/JRC/EUCAR (2007), Renewable Fuels Agency (2009)	
Above- and below-ground living biomass in forests (tCO_2eq/ha)	Kindermann et al. (2008)	
Above- and below-ground living biomass in grassland and othernatural land (tCO_2eq/ha)	Ruesch and Gibbs (2008) (http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html)	
Total non-carbon emissions (million metric CO_2 equivalent)	EPA (2006)	
Crop carbon dioxide emissions (tons CO_2/hectare)	EPA (2006)	
GHG sequestration in SRP (tCO_2/ha)	Chiba and Nagata (1987)	
International Trade		
MacMap database	Bouet et al. (2005)	
BACI (based on COMTRADE)	Gaulier and Zignago (2009)	
International freight costs	Hummels et al. (2001)	

Parameter	Source	Year
Infrastructure		
Existing infrastructure	WRI; Referentiel Geographique Commun	
Planned infrastructure	National statistics from Cameroon, Central African Republic, and Gabon and AICD (World Bank) for Democratic Republic of Congo, and Republic of Congo	
Process		
Conversion coefficients for sawn wood	4DSM model—Rametsteiner et al. (2007)	
Conversion coefficients for wood pulp	4DSM model—Rametsteiner et al. (2007)	
Conversion coefficients and costs for energy	Biomass Technology Group (2005); Hamelinck and Faaij (2001); Leduc et al. (2008)	
Conversion coefficients and costs for ethanol	Hermann and Patel (2008)	
Conversion coefficients and costs for biodiesel	Haas et al. (2006)	
Production costs for sawn wood and wood pulp	Internal IIASA database and RISI database (http://www.risiinfo.com)	
Population		
Population per country (1,000 inhabitants	Russ et al. (2007)	average 1999–2001
Estimated total population per region every 10 years between 2000 and 2100 (1,000 inhabitants)	GGI Scenario Database (2007)—Grubler et al. (2007)	
0.5 degree grid	GGI Scenario Database (2007)—Grubler et al. (2007)	
Population density	CIESIN (2005)	
Demand		
Initial food demand for crops (1000 T)	FBS data—FAO	average 1998–2002
Initial feed demand for crops (1000 T)	FBS data—FAO	average 1998–2002
Crop requirement per animal calories (T/1,000,000 kcal)	Supply Utilisation Accounts, FAOSTAT	average 1998–2002
Crop energy equivalent (kcal/T)	FBS data—FAO	
Relative change in consumption for meat, animal, vegetable, milk (kcal/ capita)	FAO (2006a) World agriculture: toward 2030/2050 (Tables: 2.1, 2.7, 2.8)	
Own price elasticity	Seale, Regmi, and Bernstein (2003)	
GDP projections	GGI Scenario Database (2007)	
SUA data for crops (1,000 tons)	FAO	
FBS data	FAO	
Bioenergy projections	Russ et al. (2007)	
Biomass and wood consumption (m^3/ha or 1,000 T/ha)	FAO	

DATABASES

In order to enable global biophysical process modeling of agricultural and forest production, a comprehensive database—integrating information on soil type, climate, topography, land cover, and crop management—has been built (Skalsky et al. 2008). The data are available from various research institutes (NASA, JRC, FAO, USDA, IFPRI, etc.) and were harmonized into several common spatial resolution layers, including 5 and 30 arcmin as well as country layers. Consequently, Homogeneous Response Units (HRU) have been delineated by including only those parameters of landscape, which are almost constant over time. At the global scale, we have included five altitude classes, seven slope classes, and six soil classes. In a second step, the HRU layer is merged with other relevant information, such as a global climate map, land category/use map, irrigation map, and so on, which are actually inputs into the Environmental Policy Integrated Climate model (Williams 1995; Izaurralde et al. 2006). The Simulation Units are the intersection between country boundaries, 30 arcmin grid (50 × 50 kilometers), and Homogenous Response Unit.

MAIN ASSUMPTIONS FOR THE BASELINE

Population growth: The regional population development is taken from the International Institute for Applied Systems Analysis (IIASA)'s SRES B2 scenario (Grübler et al. 2007). World population should increase from 6 billion in 2000 to 8 billion in 2030. In the Congo Basin, the model uses an average annual growth rate of 3.6 percent between 2000 and 2010 and 2.2 percent between 2020 and 2030, leading to a total population of 170 million people in 2030. The model uses the spatially explicit projections of population by 2010, 2020, and 2030 to represent the demand for woodfuel. No difference is made between rural and urban markets.

Exogenous constraints on food consumption: From the intermediate scenario of the SRES B2, GDP per capita is expected to grow at an average rate of 3 percent per year from 2000 to 2030 in the Congo Basin. FAO projections are used for per capita meat consumption. The model considers a minimum calorie intake per capita in each region and disallows large switches from one crop to another. The model currently restricts coffee and cocoa production to Sub-Saharan Africa. Initial demand for these crops is set at the observed imports in 2000 and is then adjusted for population growth. This assumption means tat neither price changes nor income changes influence demand for coffee and cocoa.

Demand for energy: The model makes the assumption that woodfuel use per inhabitant remains constant, so that woodfuel demand increases proportionally to population. Bioenergy consumption comes from the POLES model (Russ et al. 2007) and assumes that there is no international trade in biofuels.

Other assumptions: The baseline is a situation where technical parameters remain identical to the 2000 level; new results are driven only by increases in food, wood, and bioenergy demand. There is no change in yields, annual increments, production costs, transportation costs, or trade policies. Subsistence farming is also fixed at its 2000 level. No environmental policies are implemented other than the 2000 protected areas. This baseline should be regarded as a "status quo" situation that allows us to isolate the impacts of various drivers of deforestation in the Congo Basin in the different scenarios.

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