Deforestation Trends in the Congo Basin

Reconciling Economic Growth and Forest Protection

WORKING PAPER 1 | Agriculture

Joel Hourticq
Carole Megevand

with Eric Tollens
Johanna Wehkamp
Hari Dulal

APRIL 2013

Deforestation Trends in the Congo Basin

Reconciling Economic Growth and Forest Protection

WORKING PAPER 1 | Agriculture

Joel Hourticq
Carole Megevand

with Eric Tollens
Johanna Wehkamp
Hari Dulal

Africa Region
THE WORLD BANK

APRIL 2013

ACKNOWLEDGMENTS

This Working Paper 1: Agriculture is one of the outputs of the global study on "*Deforestation Trends in the Congo Basin: Reconciling Economic Growth and Forest Protection*", that was conducted by a multi-dispinary team 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.

This Working Paper was prepared by Joel Hourticq and Carole Megevand, with significant contributions from Eric Tollens, Johanna Wehkamp and Hari Dulal. The team is grateful for useful guidance provided by Christian Berger. The report was ably edited by Sheila Gagen. Maps and illustrative graphs were prepared by Hrishikesh Prakash Patel.

The study benefited from financial support from various donors, including: Norway through the Norwegian Trust Fund for Private Sector and Infrastructure (NTF-PSI), the Program on Forests (PROFOR), and the Trust Fund for Environmentally and Socially Sustainable Development (TFESSD).

CONTENTS

FIGURES

TABLES

BOXES

ACRONYMS

AGDP	agricultural gross domestic product
CAADP	Comprehensive Africa Agriculture Development Programme
CAR	Central African Republic
CCAFS	Climate Change, Agriculture and Food Security
CEMAC	Commission de la Communauté Economique et Monetaire de l'Afrique Centrale
CFA	Central African franc
CGIAR	(*formerly*) Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
COMIFAC	Central Africa Forests Commission
DRC	Democratic Republic of Congo
ECAM III	Troisième Enquête auprès des Ménages au Cameroun
ECCAS	Economic Community of Central African States
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FLEG	Forest Law Enforcement and Governance
FLEGT	Forest Law Enforcement, Governance and Trade Support Programme
GDP	gross domestic product
GHG	greenhouse gas
GHI	Global Hunger Index
ha	hectare
HFLD	High Forest Cover, Low Deforestation
HRU	homogeneous response unit
IFPRI	International Forest Policy Research Institute
IIASA	International Institute for Applied System Analysis
IITA	International Institute of Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
IRAD	Institute de Recherche Agricole pour le Dévelopment
kg	kilogram
km	kilometer
m^3	cubic meter
MDGs	Millennium Development Goals

NEPAD	New Partnership for Africa's Development (African Union)
NPCA	NEPAP Planning and Coordinating Agency
OECD	Organization for Economic Co-operation and Development
ORSTOM	Office de la recherche scientifique et technique outre-mer
pcAGDP	per capita agricultural gross domestic product
PES	payment(s) for environmental services
R&D	research and development
REDD+	Reducing Emissions from Deforestation and Forest Degradation+
ReSAKSS	Regional Strategic Analysis and Support System
SECID	South-East Consortium for International Development
SODECAO	Société de développement du Cacao
STABEX	Système de Stabilisation des Recettes d'Exportation
UNFPA	United Nations Population Fund
WDIs	World Development Indicators
WHO	World Health Organization
WWF	World Wildlife Fund

EXECUTIVE SUMMARY

Agriculture in the Congo Basin is largely dominated by traditional low input/low output subsistence systems. Plantations are not well developed except in Cameroon. Modernization of the agricultural sector has been hampered by many factors, including poor road infrastructure, poor public policies, and neglected R&D functions.

Despite its significance in terms of employment and contribution to the gross domestic product (GDP), the agricultural sector in Congo Basin countries is largely underperforming in comparison with those of other tropical regions, with poor results for most agricultural indicators (e.g., land productivity, work productivity, use of fertilizers, use of improved varieties). As a result, and despite huge potential, reliance on food imports is substantial.

PROMISING PROSPECTS FOR THE AGRICULTURAL SECTOR

The potential for agricultural development in the Congo Basin is significant. The region is among the areas with the greatest potential in the world for both expanding cultivation and increasing existing yields; market forces, driven by both internal (domestic and regional markets) and external drivers (growing international demand for food and energy) suggest that agriculture will, in the medium and long term, expand. However, it remains to be seen whether and to which extent this potential manifests over the course of the next decades. The below parameters are expected to positively influence the agricultural development in the Congo Basin.

Productivity gains. The Congo Basin is among the areas in the world with the greatest potential for increasing agricultural yields. Minimal interventions could transform agricultural productivity in these countries and increase the resilience of yields to climate change.

Land availability/suitability. The Congo Basin countries are estimated to represent about 40 percent of the uncultivated, unprotected land suitable for cultivation in Sub-Saharan Africa and 12 percent of such land available worldwide (IIASA 2010).

Water availability. Many parts of the world, especially in developing countries, are expected to experience water scarcity and stress in the future. In the context of a changing climate, the Congo Basin stands out as a sub-region in which water availability is likely to increase or at least be maintained. This resilience to climate change could provide the Congo Basin countries with a comparative advantage at the global level.

HOW COULD THIS AFFECT THE FOREST COVER?

Over the past decades, deforestation has been mostly driven by subsistence activities, as more than most of new agricultural land came at the expense of intact forests. As a result, it is highly correlated to population density and concentrates around urban centers and other densely populated areas.

Factors described above suggest that the agriculture sector could take off during the next decades. Unlocking this potential may lead to greater pressures on forests In-depth analytical work along with the IIASA model developed for the Congo Basin countries (CongoBIOM), helped better understand some potential impacts.

Forested versus non-forested lands. While the vast majority of suitable land (uncropped, unprotected areas) in the Congo Basin is currently covered by forests, the potential of suitable non-forested lands is also considerable and represents more than the area currently under production in most of the countries (i.e., the mean ratio of cultivated area to non-forested suitable area is 0.61 for the Congo Basin countries). This means that the Congo Basin could almost double its cultivated area without converting any forested areas.

Increase in land productivity—will it reduce or exacerbate the pressure on forests? Increase in land productivity is often seen as the most promising means to address both the food production and mitigation challenges. It is commonly assumed that producing more on the same amount of land will prevent the need to expand cultivated areas and thus help reduce forest conversion. However, models show that this logic is unlikely to hold unless certain accompanying measures are put in place. The CongoBIOM model suggests that intensification of land production in the Congo Basin will lead to an expansion of agricultural land because of a growing demand for food and an unconstrained labor force. Productivity gains make agricultural activities more profitable and thus tend to increase pressure on forested land, which is generally the easiest new land for farmers to access. Environmental degradation, land tenure, and customary rights issues associated with large-scale farmland acquisition are additional factors driving farmers into forested land.

Indirect effects of international agricultural patterns. The Congo Basin is not yet fully integrated into global agricultural markets, with the exception of coffee and cocoa. However, the CongoBIOM model suggests that the Congo Basin could be affected by global trends in agricultural commodity trade despite its marginal contribution to global markets. For example, the fact that the Congo Basin does not yet produce significant amounts of biofuel does not mean that it will not eventually be affected by the global expansion of biofuels: biofuel expansion in other regions of the world could reduce agricultural exports from main exporting regions and lead to increased deforestation in the Congo Basin through a substitution effect of import by local production.

RECOMMENDATIONS

Congo Basin countries need to identify new paths that can reconcile their urgent need to transform their agricultural sectors to feed their populations and potentially respond to international market signals with the preservation of their forest capital. Below are listed some policy recommendations, identified as credible options to limit deforestation while supporting agricultural development in the Congo Basin. These recommendations should be taken as general guidelines to spur more detailed policy discussions at the country level.

- Prioritize Agricultural Expansion in Non-forested Areas
- Enforce Forest Protection and Manage the Agricultural Frontier
- Clarify Land Tenure Governance
- Promote Climate-Smart Agriculture
- Empower Smallholder Farmers
- Promote a Sustainable Large-Scale Agribusiness Industry
- Foster Win-Win Partnerships between Large-Scale Operators and Smallholders
- Develop Transport Infrastructure
- Create Positive Incentives and Remove Potential Negative Incentives
- Reinvigorate Research and Development

INTRODUCTION

The Congo Basin represents 70 percent of the African continent's forest cover and constitutes a large portion of Africa's biodiversity. Cameroon, the Central African Republic, the Democratic Republic of Congo, Equatorial Guinea, Gabon, and the Republic of Congo share the Basin's ecosystem. It is the second largest tropical forest area in the world—of a total surface of 530 million hectares (ha) of land, 300 million are covered by forests. More than 99 percent of the forested area is primary or naturally regenerated forest (de Wasseige et al. 2012). The Congo Basin forest performs valuable ecological services, such as flood control and climate regulation at the local and regional levels. The wealth of carbon stored in the Basin's abundant vegetation further serves as a buffer against global climate change. In all six countries, forestry is a major economic sector, providing jobs and local subsistence from timber and non-timber products, and contributing significantly to export and fiscal revenues.

Agriculture is a vital yet neglected sector in the Congo Basin. Agriculture is by far the region's largest employer. In Cameroon, the Democratic Republic of Congo, the Central African Republic, and Equatorial Guinea, more than half of the economically active population is engaged in agricultural activities. Agriculture is also a significant contributor to GDP, particularly in the Central African Republic, the Democratic Republic of Congo, and Cameroon. Despite its importance, the agricultural sector has been neglected and underfunded for much of the past few decades. Most agriculture is small-scale, and the sector is dominated by traditional subsistence systems, with a few large commercial enterprises focused mainly on palm oil and rubber. Agricultural productivity in the region is very low compared with that of other tropical countries, and overall use of fertilizer is also low. As a result, reliance on food imports is substantial and increasing.

The potential for agricultural development in the Congo Basin is significant for many reasons. First, Congo Basin countries are endowed with much suitable and available land. Together, these countries have about 40 percent of the uncultivated, unprotected, low-population-density land suitable for cultivation in Sub-Saharan Africa and 12 percent of such land available worldwide. If only suitable nonforested areas are included, the Congo Basin still includes about 20 percent of the land available for agricultural expansion in Sub-Saharan Africa and 9 percent worldwide (Deininger et al. 2011). Second, the region has unconstrained water resources, which gives it an edge over other areas that may face water scarcity as a result of climate change. Third, and unsurprisingly, Congo Basin countries rank among the countries with the greatest potential in the world for increasing yields. Finally, the rapidly urbanizing populations and increasing international demands for food and energy could drive a dramatic demand for agricultural products from the Congo Basin. These factors combine to make agriculture a very promising sector.

Agricultural development is a central lever to help people out of poverty, as well as a key driver of deforestation. Congo Basin forests are home to about 30 million people, who struggle with poverty and strive for a more prosperous life. However, evidence from other tropical forest regions around the world suggests that a conventional path of economic development usually means rapidly increasing levels of loss of natural forests (the forest transition theory). This negative correlation seems especially pronounced in connection with agricultural development (Andersen et al., 2002; López and Galinato 2004; Walker, 1993). Future agricultural developments in the Congo Basin may well be at the expense of forests.

Forest-friendly agricultural development is a challenge for the region. Unlocking the agricultural potential of the Congo Basin could increase pressure on forests, particularly if investments in road infrastructure remove a long-lasting bottleneck to market access. Increasing agricultural productivity—often seen as a win-win solution that reduces pressure on forests—could actually drive more deforestation, A consensus exists that a new development approach needs to be defined that will reconcile the dire need for more agriculture in the Congo Basin with the preservation of the forest capital through a forest-friendly agricultural model.

This report describes some ways forest-friendly agricultural development could materialize in the Congo Basin. It is one of a series of reports prepared during a two-year attempt to analyze and better understand deforestation dynamics in the Basin. The report presents findings related to the agricultural sector in the Congo Basin and its potential impact on forest cover. It is based on an in-depth analysis of the sector, from previous trends through future prospects. It builds on results derived from a modeling exercise conducted by the International Institute for Applied Systems Analysis (IIASA) that scrutinized national, regional, and international trends in agricultural sectors and trade, and their impacts on Congo Basin forests.

The structure of the report is as follows:

- **Chapter 1** gives an overview of the agricultural sector in the six countries, including an analysis of the sector's impact so far on forest cover.
- **Chapter 2** describes the prospects for development of agriculture in the near future and the potential impacts on forest under a business-as-usual scenario.
- **Chapter 3** identifies potential key levers in agricultural policy that could enable forest-friendly agriculture. The chapter builds on the analysis of the previous chapters and recommends priority activities Basin countries can undertake to address the current and future drivers of deforestation.

1 CHAPTER 1

Agriculture in the Congo Basin: A Major But Neglected Sector

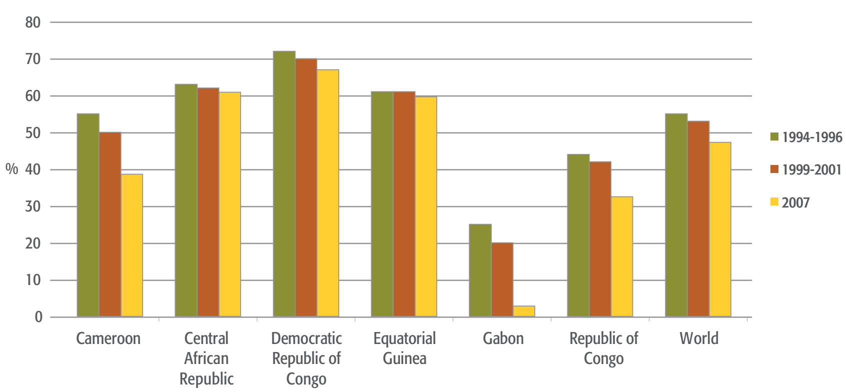
A KEY ECONOMIC SECTOR FOR THE CONGO BASIN COUNTRIES

Agriculture is an important segment of the economy, especially in terms of employment. Despite the rapid growth of the main cities and secondary urban centers in the Congo Basin, driven by robust rural-urban migration over the past few years, a large proportion of the population of the Congo Basin countries continues to live in rural areas (figure 1.1).[1] Most rural households rely primarily on agricultural activities for their livelihoods, and agriculture is by far the largest employer in the Basin (figure 1.2). In Cameroon, the Central African Republic, the Democratic Republic of Congo, and Equatorial Guinea, more than half of the economically active population is engaged in agricultural activities; however, all six countries show a declining trend in the share of employment in agriculture.

Agriculture is a significant contributor to GDP, especially in the Central African Republic, the Democratic Republic of Congo, and Cameroon. Agriculture's contribution to GDP remains high in the Central African Republic and the Democratic Republic of Congo, at 40–50 percent (figure 1.3). However in the Democratic Republic of Congo, an unstable political context has led to strong variability in the contribution of the agricultural sector to GDP over the past

1 Drivers for rural-urban migration in the recent past have not only been economic development and related employment opportunities and better services in urban centers but also insecurity in rural areas resulting from conflicts, particularly in the Democratic Republic of Congo, Republic of Congo, and the Central African Republic.

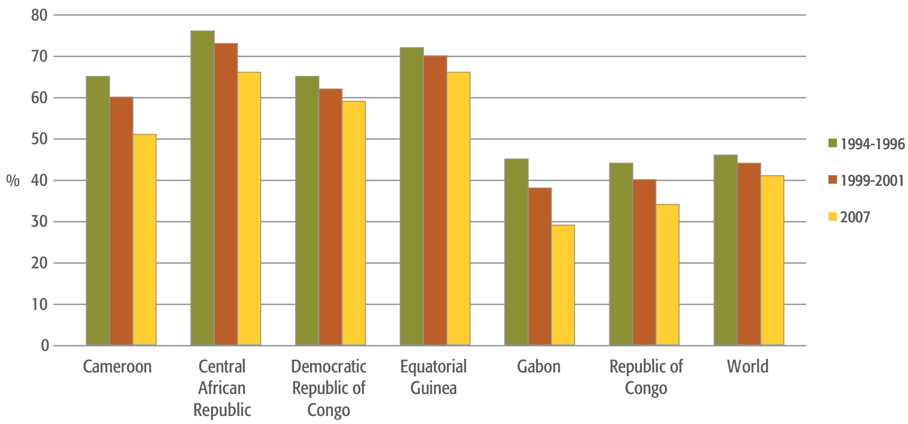
Figure 1.1: Share of Rural Population in Total Population, 1994–2007



Source: FAO 2009a.

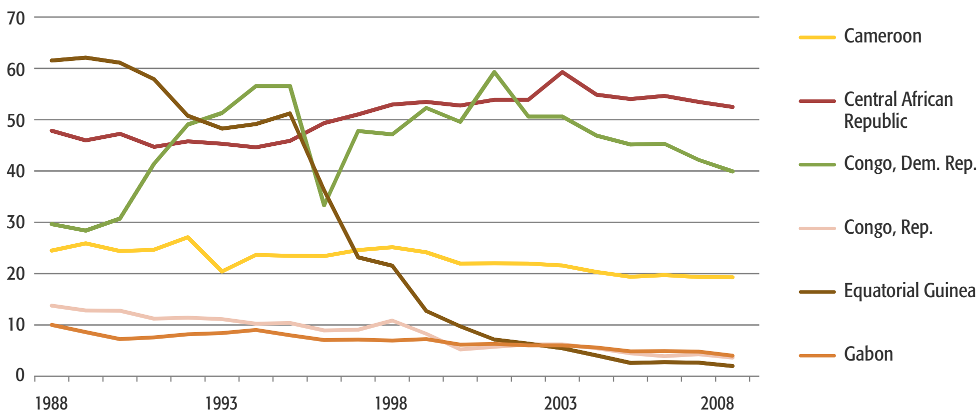
Note: The share of the rural population exceeds 60 percent in the Democratic Republic of Congo, the Central African Republic, and Equatorial Guinea. In the last, the population appears to be largely unaffected by rural-urban migration, despite the recent oil boom (which began in 1995) and the consequent dramatic drop in agriculture's relative contribution to GDP (note however that the share of the rural population graphed for that country is based on an estimated total population of 642,000, whereas the latest government census, published in 2004, claimed a total population of 1,015,000.) In Gabon, the vast majority of the population has concentrated in urban centers to access public services and participate in an economy largely based on the redistribution of resource extraction revenues. The same applies, to a lesser extent, to the Republic of Congo.

Figure 1.2: Share of Economically Active Population in Agriculture



Source: FAO 2009a.

Figure 1.3: Evolution of Agriculture's Contribution to GDP, 1988–2008



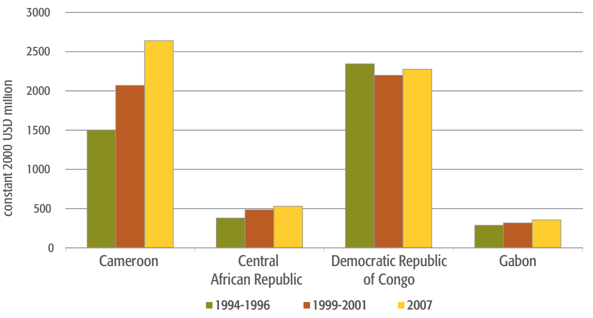
Source: World Bank 2010b.

two decades.[2] In the four oil-producing countries (Cameroon, Equatorial Guinea, Gabon, and Republic of Congo), the contribution of agriculture to GDP is much lower, although it remains around 20 percent for Cameroon. The contribution of agriculture to GDP in Equatorial Guinea dropped dramatically during the mid-1990s, owing to a sharp increase in oil revenues (total GDP increased by a factor of 60).

Cameroon's agricultural GDP has increased significantly, while that of the Central African Republic, the Democratic Republic of Congo, and Gabon has stagnated. The average annual growth in Cameroon's agricultural GDP (AGDP) has been quite strong at 4.8 percent (figure 1.4)—twice the total population growth rate. Because the population living from agriculture has not significantly changed over the period, the growth rate of the AGDP per capita of agricultural population (pcAGDP, figure 1.5) has been similar. In the Central African Republic, the AGDP growth has been weaker at 2.8 percent per year, but it has exceeded the total population growth rate, leading to an increase in the pcAGDP. In Gabon, the AGDP growth rate, at 1.8 percent, has been lower than the overall population

2 In the late 1980s to early 1990s, the sharp decline in the Democratic Republic of Congo economy resulted in agriculture representing an increasing share of GDP. Agriculture was then severely disrupted by the 1996 civil war. The recovery of agriculture's contribution to GDP following the war was more a reflection of the poor overall economic situation than an indication that agricultural output was growing. In fact, harvested area reached a peak just before the 1996 civil war, then dropped off dramatically, bottoming out in 2002. Since then, it has begun to recover, but at a slow pace.

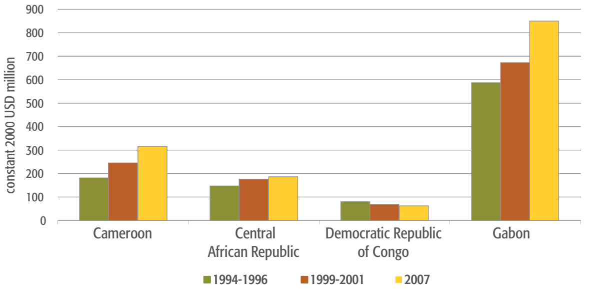
Figure 1.4: Evolution of AGDP, 1994–2007



Source: Calculations from FAO 2009a.

Note: No data available for the Republic of Congo and incomplete data for Equatorial Guinea.

Figure 1.5: Evolution of AGDP per Capita of Agricultural Population, 1994–2007



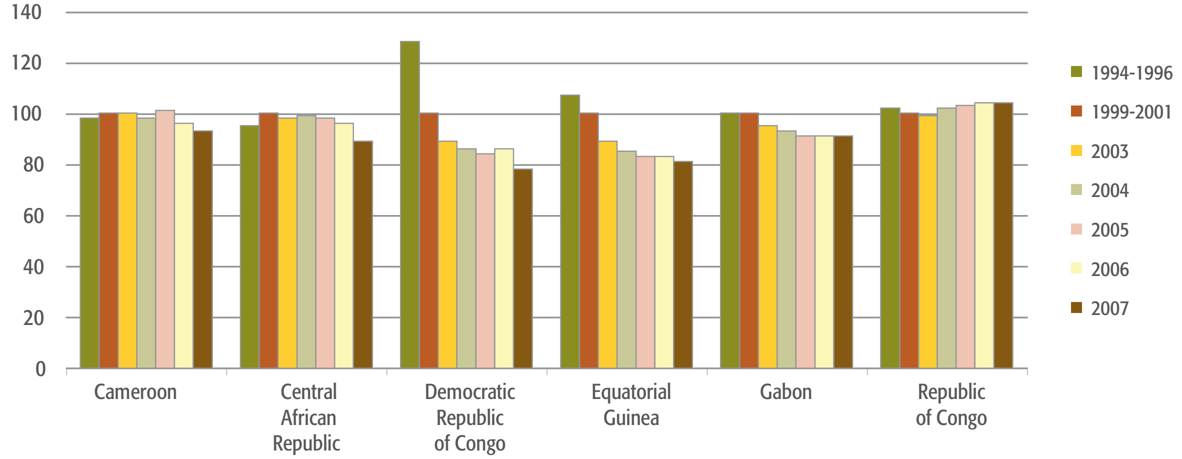
Source: Calculations from FAO 2009a.

Note: No data available for the Republic of Congo and incomplete data for Equatorial Guinea.

growth rate. However, as the population living from agriculture is reported to have decreased by 1.3 percent per year over the period, the pcAGDP has substantially increased. In the Democratic Republic of Congo, stagnation of the AGDP combined with an agricultural population growth of 2 percent per year has resulted in a decline in the pcAGDP of 2.1 percent per year. The pcAGDP in Gabon is the highest in the region, owing to a very limited rural population; it is estimated to be almost 14 times higher than that of the Democratic Republic of Congo, almost 5 times higher than that of the Central African Republic, and 2 to 3 times higher than those of Cameroon and Equatorial Guinea. Over the same period, another indicator—the index of per capita agricultural production[3]—has stagnated or decreased in all Congo Basin countries with the exception of the Republic of Congo (figure 1.6).

3 The Food and Agriculture Organization (FAO) index of agricultural production shows the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 1999–2001. Aggregate volume is based on the sum of price-weighted quantities of different agricultural commodities produced after deductions of quantities used as seed and feed weighted in a similar manner. Thus, it represents disposable production for any use except as seed and feed.

Figure 1.6: Congo Basin Countries' per Capita Agricultural Production Index, 1994–2007 (1999-2001=100)



Source: FAO 2009a.

DOMINATED BY TRADITIONAL SUBSISTENCE SYSTEMS

Agriculture in the Congo Basin is still largely dominated by traditional low input/low output subsistence systems, and tremendous gaps exist between actual and potential yields. This situation is directly linked to long-lasting state disengagement, especially in R&D and extension, and poor infrastructure. In addition, the poor business climate has handicapped both large and small-scale investments from the private sector.

The Congo Basin has two types of plantations. A few large commercial plantations, usually owned by multinational companies, are engaged in palm oil and rubber production (and bananas, in Cameroon), while smallholder plantations primarily produce cocoa, coffee, and palm oil. The agricultural sectors in the Central African Republic and Equatorial Guinea do not have large commercial plantations. Coffee and cocoa are predominantly smallholder crops in the Congo Basin, most actively in Cameroon. Most of the palm oil production is artisanal in the Central African Republic, Equatorial Guinea, the Republic of Congo, and the Democratic Republic of Congo (85 percent in the last). In Cameroon, industrial production of palm oil used to predominate, but artisanal production is expanding in response to the increasing demand for vegetable oil from the growing urban population, while industrial plantations are not maintained and some are abandoned.

Slash-and-Burn Agriculture

In the slash-and-burn system, smallholder families generally cultivate a maximum of 2–3 ha of traditional crops on a 2-year cultivation and 7–10-year fallow pattern.[4] The most demanding crops are grown first: maize with groundnuts, taro, and yams, generally followed by cassava and plantains.[5] These crops are grown mostly for own consumption, with surpluses sold in the market.[6] Cultural systems are highly integrated, with combinations of various crops and often multiple planting seasons, in an effort to guarantee household food security while mitigating risks (climate, diseases, etc.) and optimizing land productivity.

Shifting cultivation in the forest zone may become unsustainable because of population growth. As population density increases above 10–15 persons per square km, the length of the fallow period must be shortened, and as fallows shorten, the soil fertility of cleared land declines, resulting in reduced harvests, distress from food insecurity, conflicts, and some outmigration to other areas or urban centers. Studies show that the critical threshold of population density that results in a complete breakdown of the shifting cultivation system is 20–30 persons/km^2 (3–5 ha per person) (Tollens 2010). The most densely populated areas in the rainforest of Cameroon and the Democratic Republic of Congo (e.g., the Lisala and Bumba regions) have already reached a population density of 30 persons/km^2. This threshold, once achieved, usually triggers migration (mainly to urban centers) or transition to a more efficient agricultural system (through changes in practices).

Smallholders and Large Commercial Plantations

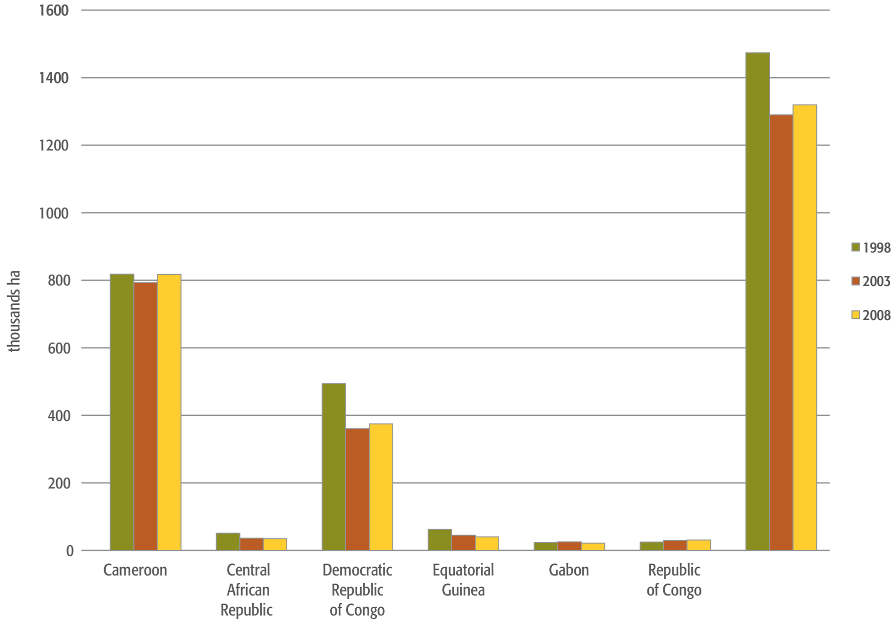
In the Congo Basin countries, the area under plantations has either stagnated or decreased; in the region as a whole, it is estimated to have decreased by about 10 percent over the period (figure 1.7). As a result, the share of plantation area in total cultivated land (table 1.1) remains rather modest: 10 percent or less in most Congo Basin countries. The percentage in Cameroon is 17.4 percent for historical reasons (an important tradition of both smallholder and commercial plantations, see box 1.1); in Equatorial Guinea it is 46 percent for structural reasons (very limited overall amount of cultivated land).

4 Because of the prevalence of the tse-tse fly, livestock production is marginal and limited to small ruminants, poultry, and pigs, essentially for own use.

5 Some other crops—such as beans, gourds, and vegetables—are grown in home gardens, along with fruit trees.

6 In some areas, upland rice is also grown as a cash crop.

Figure 1.7: Evolution of Total Plantation Areas, 1998–2008



Note: Although plantation development over the past decade has been particularly important in Cameroon, especially as regards cocoa (area has increased by 40 percent), bananas (+ 65 percent), and to a lesser extent oil palm (+ 13 percent), the total area under plantation in that country has stagnated because of the dramatic drop in coffee areas (-60 percent). In the Republic of Congo, areas under coffee and bananas are reported to have increased by about 130 percent and 60 percent, respectively, leading to an increase of about 25 percent in the total plantation area. However, that area remains at very modest levels.

Source: Calculations from FAOSTAT 2011.

Table 1.1: Total Plantation Areas and Share in Total Land under Cultivation, 2008

	Total plantation area (ha)	Average annual growth rate 1998–2008 (%)	Total land under cultivation (ha)	Share of plantations in total land under cultivation (%)
Cameroon	817,000	0	4,685,000	17.4
Central African Republic	34,900	-3.7	965,000	3.6
Democratic Republic of Congo	374,780	-2.7	5,860,000	6.4
Equatorial Guinea	40,000	-4.4	87,000	46.0
Gabon	21,200	-1.1	209,000	10.1
Republic of Congo	30,950	2.3	282,000	11.0
Total Congo Basin	1,318,830	-1.1	12,088,000	10.9

Source: Calculations from FAOSTAT 2011.

Box 1-1: Why Is Plantation Development More Important in Cameroon Than in the Other Congo Basin Countries?

Cameroon has a long tradition of growing cocoa and coffee as export crops, dating back to the colonial period. In addition, it is a politically stable country with the highest rural population density in the region, the best rural infrastructure, the best investment climate, and by far the most supportive government, with significant public expenditure allocated to the agricultural sector and public institutions dedicated to the promotion of specific agricultural value chains (e.g., Société de Développement du Cacoa for cocoa, SODECAO). This more favorable context has resulted in more investments by smallholders and commercial operators alike.

Coffee and Cocoa Plantations

Coffee and cocoa are overwhelmingly smallholder productions in the Congo Basin rainforest, on small plantations of 0.5–3 ha.[7] Cocoa and coffee production is of particular importance in Cameroon but less important (and more and more so) in the other countries (figures 1.8 and 1.9).

In Cameroon, where an estimated 600,000 cocoa farmers are operating, cocoa development is on the rise, promoted by SODECAO (the national specialized parastatal agency) and the Ministry of Agriculture, and financed through a levy on cocoa exports. Cocoa area is reported to have increased by 140,000 ha (about 40 percent) in Cameroon over the past decade, while it has decreased in all other countries. The artificial drying required for the cocoa beans uses significant amounts of fuel wood, which of course encourages forest degradation. More efficient drying ovens have been introduced and promoted using STABEX funding from the European Commission.

Coffee plantation areas are highly sensitive to world market prices. As a result of depressed market prices during the first half of 2000, coffee production (Robusta and Arabica) declined dramatically in all Congo Basin countries.[8] In Cameroon, the area under coffee is reported to have declined by 60 percent, and in the region as a whole it declined by half. However, increases in coffee areas can be seen as world prices pick up again.

7 There were a few large commercial coffee and cocoa plantations in the Democratic Republic of Congo, but almost all of them were abandoned after the first Zairianisation (expropriation) in 1973–74 and the pillages of 1991 and 1993.

8 Except in the Republic of Congo, where coffee area is reported to have more than doubled over the past 10 years.

Figure 1.8: Evolution of Cocoa Harvested Areas, 1998–2008

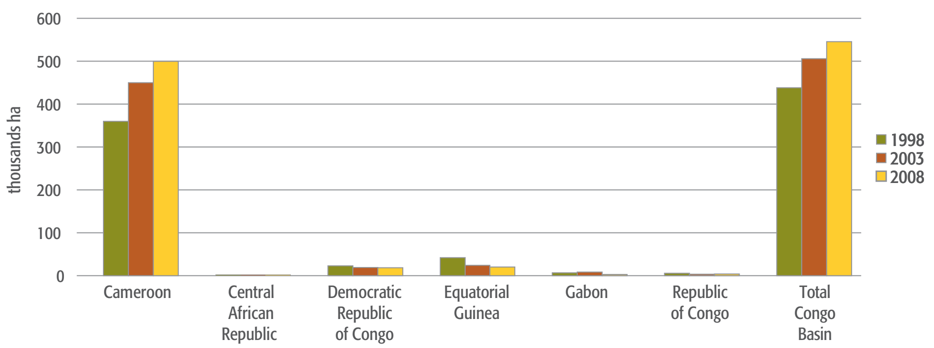
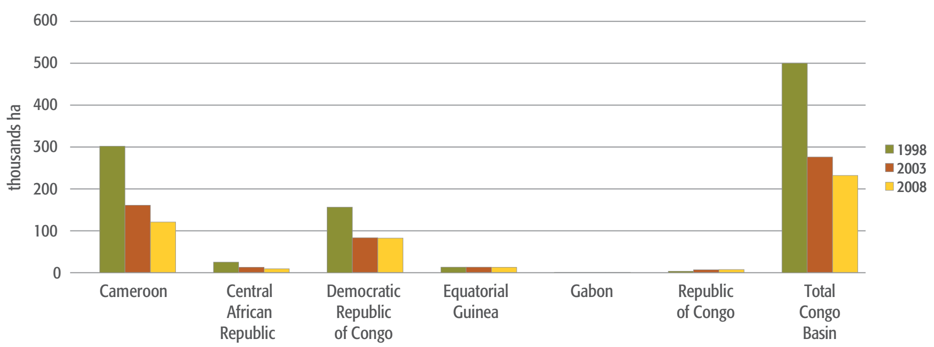


Figure 1.9: Evolution of Coffee Harvested Areas, 1998–2008



Source: Calculations from FAOSTAT 2011.

Agro-industrial plantations (oil palm, rubber, and banana)

Unlike coffee and cocoa, oil palm is cultivated in both smallholder plantations (100 percent of production in the Central African Republic, Equatorial Guinea, and the Republic of Congo; 85 percent in the Democratic Republic of Congo) and large estates operated by multinational companies (Gabon, Cameroon). Figures 1.10 and 1.11 show that the oil palm and rubber plantations are mainly located in Cameroon, the Democratic Republic of Congo, and Gabon, and that there are no large, active oil palm or rubber plantations in the Central African Republic, Equatorial Guinea, or the Republic of Congo.[9] In Cameroon and Gabon, all oil palm and rubber plantations currently in operation were created in the 1960s to 1980s as parastatal companies supported by international donors. They were privatized as part of the structural adjustment process in the 1990s and early 2000s. In the Democratic Republic of Congo, oil palm and rubber plantations have always been run by private companies.

Cameroon also has sizable and expanding commercial banana plantations (figure 1.12). The produced palm

9 In the Republic of Congo, the Ouesso Sangopalm plantation is abandoned.

Figure 1.10: Evolution of Oil Palm Harvested Areas, 1998–2008

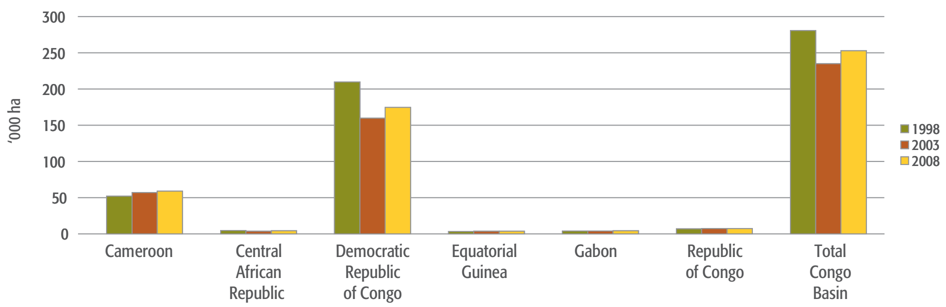


Figure 1.11: Evolution of Rubber Harvested Areas, 1998–2008

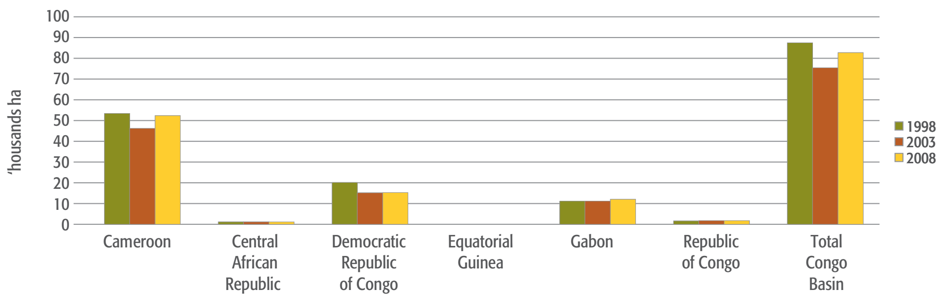
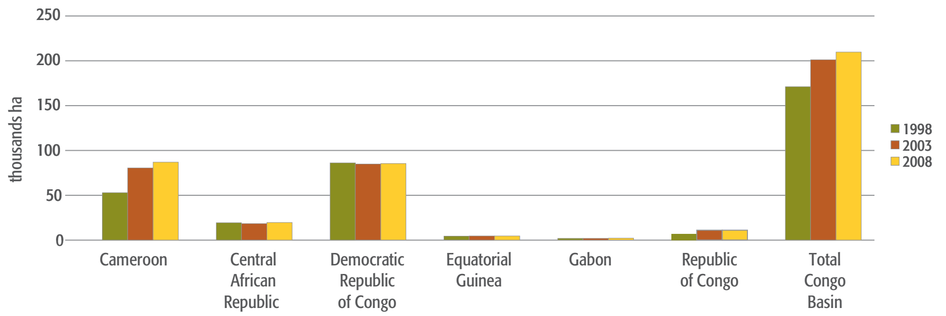


Figure 1.12: Evolution of Banana Harvested Areas, 1998–2008



Source: Calculations from FAOSTAT 2011.

Box 1-2: History of Large-Scale Plantations in the Congo Basin Countries

Gabon: AgroGabon was privatized to the Belgian plantation company SIAT S.A., which also owns plantations in Ghana, Côte d'Ivoire, and Nigeria. It comprises a 100,000 ha cattle ranch with 6,000 animals, situated in a savannah valley surrounded by rainforest and surprisingly free of tse-tse flies. SIAT plans to expand to 25,000 animals. It also runs an 8,500 ha oil palm plantation for the local market, including soap production, as well as 10,000 ha of rubber in a nucleus estate (former OZI), with 2,000 ha under smallholders. The company intends to expand on the existing concession, replanting old plantations using its own generated cash flow. The main constraint is access to labor, which is mostly of Cameroonian or Sahelian origin. No new plantations are planned and no other foreign investments in plantation agriculture or livestock ranching are expected in Gabon; there is plenty of available land, but finding labor is difficult.

Cameroon: All parastatal plantations have been privatized except some belonging to the Cameroon Development Corporation (CDC) that are still in the process of privatization (for more than 10 years now). Existing plantations are doing quite well, replanting and expanding where possible. The main problems are land ownership (land can only be leased for 99 years) and fiscal harassment by the state, including corruption. All palm oil produced is for the domestic market or export to neighboring countries, including Chad and Gabon. New projects for the expansion of oil palm plantations in Cameroon are at various stages of development.

Democratic Republic of Congo: The country never had state-owned oil palm or rubber plantations. Two small cocoa plantations were established in the 1980s. In 1912, Lever Brothers established its first oil palm plantation in the Congo Basin. Rubber plantations followed soon after that and were quite important during World War II, when they were the only source of rubber for the Allied Forces in Europe. Most of the plantations were owned by the conglomerate Société Générale de Belgique, which sold them in the 1980s, when Suez took over, to the Blattner Group. The other main plantation company was Lever Brothers, with Plantations et Huileries du Congo (PHC), which sold Lokutu, Yaligimba, and Yatolema plantations to the Canadian investors group Feronia.

Together, Blattner and PHC have 32,000 ha of oil palm, but 40 percent of the land is abandoned, following the pillages of 1991 and 1993. Current total industrial production is estimated at 25,000 tons of palm oil and 2,000 tons of palm kernel oil. Regarding rubber, production is actually less than 10,000 tons. Recent figures indicate 5,000 tons, of which about 2,000 tons are used locally for tire production (Cobra brand, owned by Blattner group). In the oil palm-rubber sector, some newcomers are coming to the Democratic Republic of Congo, reviving abandoned plantations and replanting old ones. This is the case for SOCFIN-INTERCULTURES, which acquired the large Brabanta plantation near Ilebo, and the planned Chinese investment in oil palm plantations by ZTE.

Republic of Congo: The Ouesso Sangopalm plantation is abandoned. The Italian oil company ENI has a plan to develop 5,000 ha of palm oil in the savannah lands in the Niari and Pool Departments (Republic of Congo 2011–R-PP).

Central African Republic, Equatorial Guinea: No large oil palm or rubber plantations are active in the Central African Republic or Equatorial Guinea.

Source: Tollens 2010.

oil is for local consumption (soap and vegetable oil), while rubber and bananas are exported.

Large-scale plantations are enclaves of the modern sector within the traditional sector, with few or no interrelations (see Box 1.2). Only Gabon has tried to develop a nucleus estate or "outgrower scheme," based on the former OZIs (Opérations Zonales Intégrées). SIAT Gabon operates such a nucleus estate for rubber but encounters many difficulties, including lack of interest among smallholders, poor feeder roads, and poor quality production.

The Congo Basin has not yet experienced the expansion of large-scale plantations that has occurred in other tropical regions. The Basin countries have so far been spared the phenomenon of large-scale land acquisition and conversion for agriculture and biofuel projects that has been observed in other regions of the world (e.g., Southeast Asia, Amazonia). The few current operators in Cameroon, Gabon, and the Democratic Republic of Congo report that they do not plan to invest in new plantations; they intend to extend existing concessions and rehabilitate old or abandoned ones (Tollens 2010).

LITTLE SUPPORT FROM PUBLIC POLICIES

Limited Allocation of Resources

Until the late 1980s, as in almost all Sub-Saharan African countries, the negative impact of public resource scarcity in the Congo Basin was aggravated by fiscal and trade policies that strongly discriminated against agriculture, discouraging investments from both local farmers and foreign operators.[10] With the exception of Cameroon, where some supportive policies were implemented, the Congo Basin countries did not set the basic conditions to unfold their full agricultural potential.

In the 1990s, all countries went through the structural adjustment process, with associated dramatic cuts in public expenditures to reduce the substantial external and internal deficits of their economies. The agricultural sector was one of the most strongly affected by budgetary restrictions: Fertilizer and pesticide subsidies (ranging from 60 to 100 percent in Cameroon) were removed, extension services drastically reduced, rural infrastructure neglected, and R&D almost abandoned. At the same time, major reforms occurred in the export-oriented agricultural sector (such as coffee and cocoa), with the state disengaging and liquidating the national marketing boards for these crops.

Recently, the Congo Basin countries have had a lukewarm response to the continent-wide NEPAD (African Union New Partnership for Africa's Development) initiative in favor of agriculture. The Comprehensive Africa Agriculture Development Programme (CAADP, see box 1.3 and figure 1.13) targets an annual 6 percent

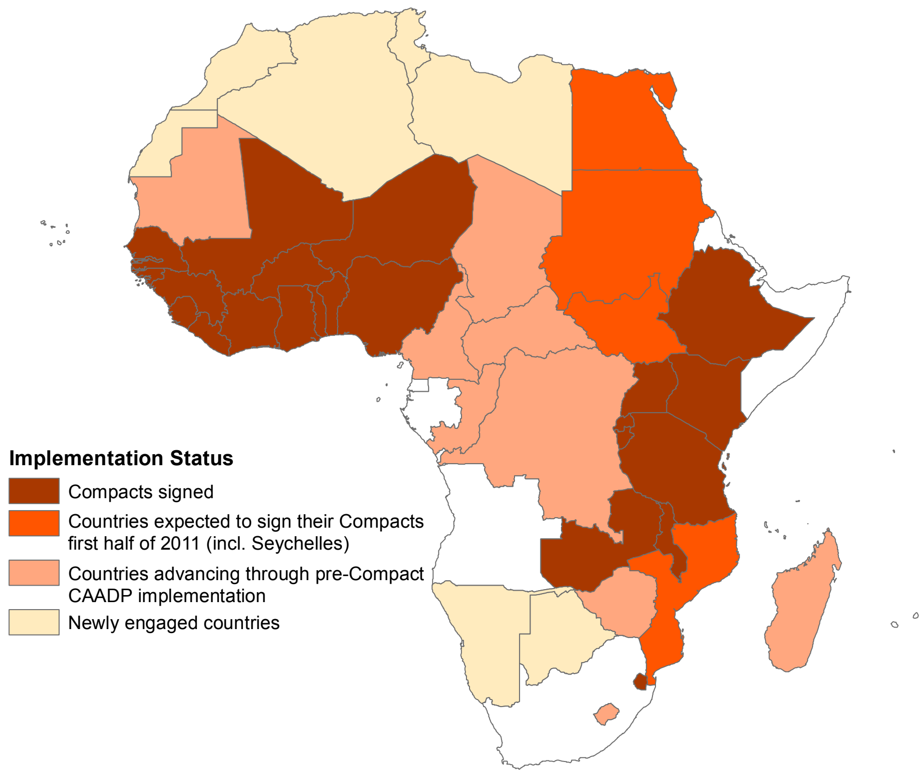
10 It is estimated that in the 1980s, net taxation of the agricultural sector in Sub-Saharan Africa—through overvalued exchange rates, controlled input and output prices, export taxes, and so on—averaged 29 percent and stood at 46 percent for exportables (World Bank 2009).

Box 1-3: Agriculture in Africa and CAADP

CAADP (Comprehensive Africa Agriculture Development Programme) was established as part of the African Union's New Partnership for Africa's Development (NEPAD) Planning and Coordinating Agency (NPCA) and endorsed by the African Union Assembly in July 2003. NEPAD is a radically new intervention, spearheaded by African leaders, to address the main challenges facing the continent. CAADP is considered one of NEPAD's most important subactivities, because Africa is largely agrarian. The goal of CAADP is to help African countries reach and sustain a higher path of economic growth through agricultural-led development that reduces hunger and poverty and enables food and nutrition security and growth in exports through better strategic planning and increased investment in the sector. Through CAADP, African governments are committed to raising agricultural GDP by at least 6 percent per year. This is the minimum required if Africa is to achieve agriculture-led socioeconomic growth. To achieve this, the governments have agreed to increase public investment in agriculture to a minimum of 10 percent of their national budgets—substantially more than the 4–5 percent they commit today. Thus far, nine countries have met this goal: Burkina Faso, Ethiopia, Ghana, Guinea, Mali, Malawi, Niger, Senegal, and Togo. However, a number of governments—including Zambia, Kenya, and Rwanda—have already boosted their agricultural budgets significantly. Recently, 10 countries achieved or exceeded the 6 percent CAADP goal: Angola, Ethiopia, Mali, Mozambique, Namibia, Niger, Rwanda, Senegal, Tanzania, and Uganda. Ghana and Sierra Leone are close. But these improvements are not enough, as they will not put Africa on the path to achieving the UN's Millennium Development Goals (MDGs) of halving poverty and the number of malnourished people by 2015; rather, the goals will be achieved within 10 years. In the Central Africa region, the Economic Community of Central African States (ECCAS) is coordinating the CAADP process with its member states: ECCAS will prepare a regional agriculture investment plan, while member states will prepare national agricultural investment plans.

Sources: www.resakss.org – www.nepad-caadp.net - CAADP Multidonor Trust Fund World Bank Status Report (as of November 15, 2010

Figure 1.13: CAADP Implementation Progress, January 2001



Sources: www.resakss.org–www.nepad-caadp.net–CAADP Multidonor Trust Fund World Bank Status Report (as of November 15, 2010)

agricultural growth through, in particular, greater government support to the sector. The lukewarm response suggests that the governments of the Congo Basin countries do not consider agriculture to be a critical cornerstone to achieve development, food security, and poverty alleviation (see table 1.2). While 22 countries have already signed their CAADP compacts and made substantial progress in achieving their commitments, none of the Congo Basin countries has done so.

The natural resources curse (Collier 2007), also known as the paradox of plenty, is arguably a major reason why the agricultural sector has received so little attention over the past decades. Because they are richly endowed with natural resources—particularly nonrenewable resources, including oil and minerals—the Congo Basin countries tend to neglect their agriculture and import most of their food needs. In addition to policymakers' lack of interest, the boom in

Table 1.2: Share of Agricultural Expenditure in National Budget

	Percent	Year reported
Cameroon	4.5	2006
Central African Republic	2.5	–
Democratic Republic of Congo	1.8	2005
Equatorial Guinea	–	–
Gabon	0.8	2004
Republic of Congo	0.9	2006

Source: ReSAKSS 2011; no data available for Equatorial Guinea.

Note: Public expenditure in agriculture in all six countries is lagging far behind the 10 percent of total national budget targeted by the CAADP initiative, primarily affecting extension services, basic infrastructure (feeder roads), and R&D. Trying to determine total agricultural R&D public sector spending in the Congo Basin countries based on the ASTI IFPRI database is difficult, because most of the Congo Basin countries do not report data, in contrast to Western or Eastern Africa countries. The only data available are for Gabon (2001) and the Republic of Congo (2001) in 2005 USD: respectively 3.8 and 4.7 million, which are among the lowest R&D public budgets in Sub-Saharan Africa. It is also known that the Central African Republic, the Democratic Republic of Congo, and Equatorial Guinea spend very little on agricultural research. Only Cameroon in Central Africa has a performing national agricultural research institute (IRAD, Institut de Recherche Agricole pour le Développement) with about 200 researchers in 10 research stations and minimal operating funds.

extractive industries and associated revenues generates discriminatory conditions against other productive economic sectors, including a decline in competitiveness caused by the appreciation of the real exchange rate as massive amounts of resources enter the economy. Overvalued exchange rates penalize agricultural exports while imports are in fact subsidized, thus discouraging investments in agriculture[11].

However, recent events signal a heightened interest in the agricultural sector in most of the Congo Basin countries; for example, the medium- to long-term strategies for development prepared by these countries, in which agriculture is identified as one of the economic pillars for development and growth.[12] Interestingly, these strategies cover both commercial and subsistence agriculture as complementary segments of the sector.

Weak Land Tenure Security

Current land tenure schemes are not conducive to sustainable grassroots forest management in Congo Basin countries. Outside of commercial logging concessions, forests are considered free access areas under state ownership and are not tagged with property rights. Moreover, tenure laws in most Congo Basin countries directly link forest clearing (mise en valeur) with land property recognition and thus create an incentive to convert forested lands into farmland. Current land tenure laws should be adjusted to separate land property recognition from forest clearing.

The dual land tenure system in the Congo Basin increases uncertainty and inhibits investment. One major problem is that land tenure is characterized by a strong, unresolved duality between the positive law system and the traditional tenure rights system. The positive law system understands land tenure rights as individual and absolute. It is inherited from the French civil code, imported into the region through colonialism in the late 19th and early 20th centuries.[13] The traditional system, on the other hand, perceives tenure rights as collective and relative in time and space. For example, a tree can belong to a clan during harvesting season and belong to another clan in blossom season, and land is defined by its function rather than by geographic delimitation: Agricultural land does not have the same role as a forest area used for prayer (Karsenty and Assemble 2010, p. 6). Traditionally, the land is an object of prayer, because it represents a direct link to the ancestors. Consequently, it is not perceived as a purchasable material good but rather as a collective heritage (Kouassigan 1966). The traditional system still predominates in rural areas, whereas in urban areas the positive law system has imposed itself. The two systems have a difficult time coexisting, and this duality increases uncertainty for investors in agricultural projects and tends to incentivize informal, short-term agricultural exploitation.

PARALYZED BY POOR INFRASTRUCTURE

The transportation system in the Basin is characterized by poor quality. The Road Transport Quality Index was calculated for all Sub-Saharan Africa countries and normalized to 100 for the highest quality road transport, in South Africa.[14] Figure 1.14 shows the low rankings of the Congo Basin countries.

Transport costs are extremely high in the Congo Basin countries, and road infrastructure is very poor. A lot of potentially suitable land in the Basin is not converted into production, as the net profit is likely to be negative once transport costs are taken into account (Deininger

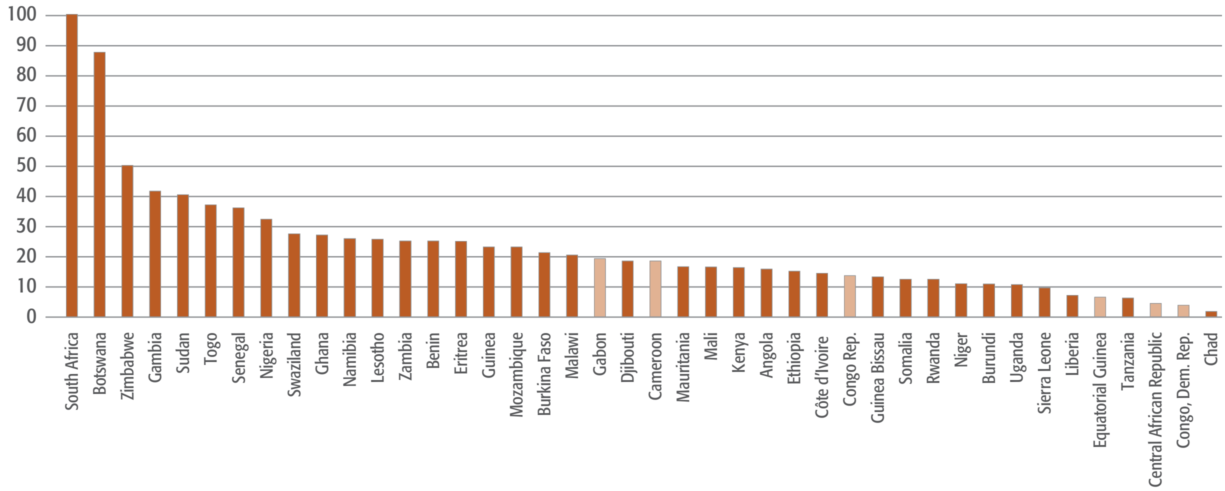
11 This is the case in the CEMAC countries, where the CFA franc has a fixed exchange rate to the euro.In the Democratic Republic of Congo, between 2003 and 2007, the local currency (FC) was pegged to the U.S. dollar at around 500 FC = US$1. The Democratic Republic of Congo let its currency decline against the U.S. dollar, and the exchange rate is now close to 1,000 FC = US$1.

12 The Democratic Republic of Congo's Cinq Chantiers, Republic of Congo's Vision 2025 Pays Emergent, Cameroon's Vision 2025, and Gabon's Emergent, 2025.

13 Given the totally different nature of traditional land tenure rights, colonialists did not recognize the system and declared the land terra nullis. Consequently, they allocated land titles to arriving colonialists and imported their absolute and individual understanding of property.

14 The Road Transport Quality Index is calculated from a formula combining the following parameters: Q = road quality index for a country; P = percentage 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 of transparency, accountability, and corruption in a country (a proxy for delays and costs inflicted on truckers).

Figure 1.14: Road Transport Quality Indices and Road Density for Sub-Saharan and Congo Basin Countries



and Byerlee 2011).[15] As shown in table 1.3, Latin America has a great advantage infrastructure-wise, with more than 75 percent of its non-forested suitable land less than six hours from a market town. Consequently, despite Latin America's having about 40 percent less land available than Sub-Saharan Africa, the regions have roughly the same amount of suitable non-forested land (about 94 million ha) when access to market is taken into account. The situation is even worse in the Congo Basin countries. In the Democratic Republic of Congo, only 33 percent (7.6 out of 22.5 million ha) of the suitable non-forested land is less than six hours from a major market; In the Central African Republic the proportion is 16 percent (1.3 out of 7.9 million ha).

Poor road infrastructure is a major obstacle to agricultural modernization. The extremely poor market access throughout the region, along with limited storage and processing capacities, has made a transition from subsistence agriculture to a more intensive, market-oriented agriculture next to impossible. In addition, while the Congo Basin countries are making plans to rehabilitate their transport infrastructure (see companion report on transport), they are unlikely to improve the feeder roads in the short term; these roads will remain a major obstacle to market access for rural populations living

15 The IIASA model identifies potentially suitable and accessible land, computing production cost estimates to arrive at the net profits rather than the revenues. Possibly suitable land was further classified on the basis of travel time to the next significant market, defined as a city of at least 50,000 inhabitants, with a cut-off of six hours to market (IIASA 2010).

Table 1.3: Potential Supply of Non-cultivated Non-forested Low-Population-Density (< 25 persons/km^2) Land, Applying an Access to Market Criterion

	Total area (million ha)	Area < 6 hours to market (million ha)	% 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 the work of Fischer and Shah (IIASA) 2010.

in remote areas. Feeder roads in the humid forest are difficult to maintain under wet conditions and in many cases are impassable during the rainy season. In the Democratic Republic of Congo, river transport is one of the most efficient means of transport. However, it only works intermittently, depending on water levels. In addition, limited storage and processing capacities prevent farmers from waiting for the dry season to access markets and sell their products. As a consequence, most farmers are completely isolated from potential markets to sell their production and purchase inputs, and thereby cut off from participation in the broader economy that could foster competition and growth. Poor road infrastructure and administrative difficulties (particularly proliferation of roadblocks) have been major obstacles to the development of regional trade.

AN UNDERPERFORMING SECTOR

Low Reliance on Inputs

The reliance on vegetatively propagated crops considerably slows the dissemination of improved varieties. Most important crops at the smallholder level are vegetatively propagated (cassava, plantains, taro, yams, and bananas). Vegetative propagation implies very low multiplication rates; for example, 1 ha of cassava produces planting material (cassava cuttings) for only 10–12 ha, which considerably slows the potential development and diffusion of new varieties and is thus a major constraint for productivity improvement. In the Democratic Republic of Congo, where cassava mosaic disease (Uganda type) is a problem, production and distribution of improved cassava varieties have been supported with more than US$50 million spent since 2002; however, according to the International Institute of Tropical Agriculture (IITA) and FAO-supported project to REAFOR (Reviving Agriculture and Forestry research in the Democratic Republic of Congo) project, only about 15 percent of all cassava grown is now under improved varieties.[16] In the meantime, new diseases—such as the cassava root scale and brown streak disease—have spread, which keeps average cassava yields very low: only 7–10 tons/ha of fresh cassava roots after one to two years of cultivation.

The use of fertilizers and pesticides is among the lowest in Africa. Fertilizer use in the Basin averages less than 2 kg/ha, with the exception of Cameroon and Gabon, where 7–10 kg/ha are reported to be applied (figure 1.15). Subsidies to chemical inputs were generally removed during the structural adjustment process in the 1990s. Subsistence agricultural systems have very limited marketable surpluses and thus limited cash revenues to pay for purchased inputs. Moreover, poor access to markets owing to limited road infrastructure is a further barrier for most farmers to buy chemicals, unless a farmer organization is able to facilitate the process. Mechanization is nearly nonexistent, and most of the work is done with hand tools (e.g., hoe, machete, axes).

Low Productivity

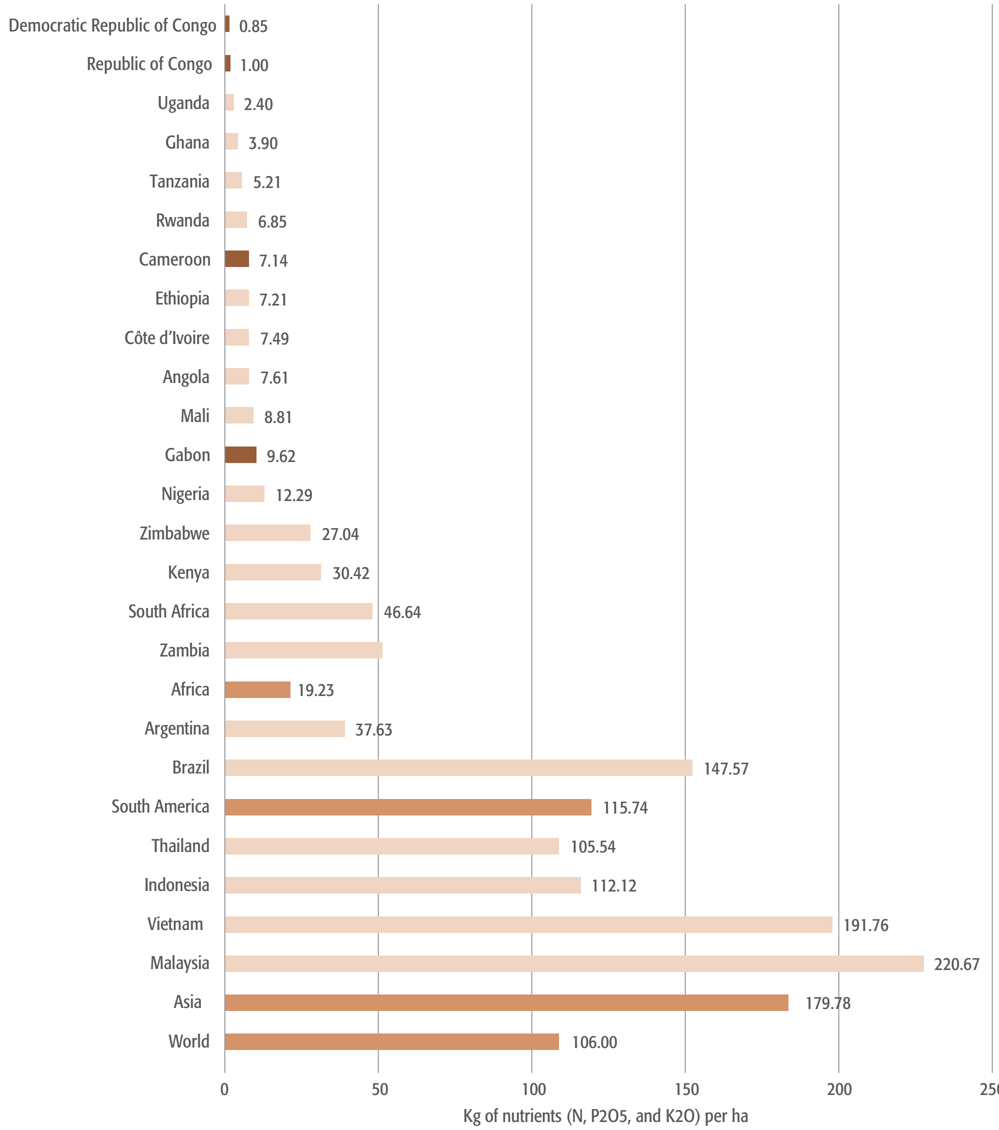
Productivity in the Congo Basin is very low compared with that of countries in other tropical areas for most commodities grown, either staples or cash crops (figure 1.16: a–f). The only exception is palm oil production in Cameroon, with observed yields among the highest in the world and comparable to those of the leader countries for that commodity.

Increased Dependence on Imports

Agricultural trade balances have deteriorated. Except in the Central African Republic, where agricultural import and export values have changed little around the equilibrium over the past 15 years, the agricultural trade balance has severely deteriorated in all other countries of the Congo Basin (figure 1.17). In the Democratic Republic of Congo, agricultural exports declined by about two-thirds over the period, while imports more than doubled. In Equatorial Guinea, exports stagnated while imports increased eightfold. While Cameroon, Gabon, and the Republic of Congo experienced a robust growth of their exports, their imports were multiplied almost fourfold for the first two and twofold for the third, leading to a degradation of the agricultural trade balance for them as well.

16 Program support provided by IITA, FAO, USAID, SECID, and others.

Figure 1.15: Fertilizer Use Intensity in Congo Basin Countries and Selected Countries of Africa, South America anwd Asia, 2008



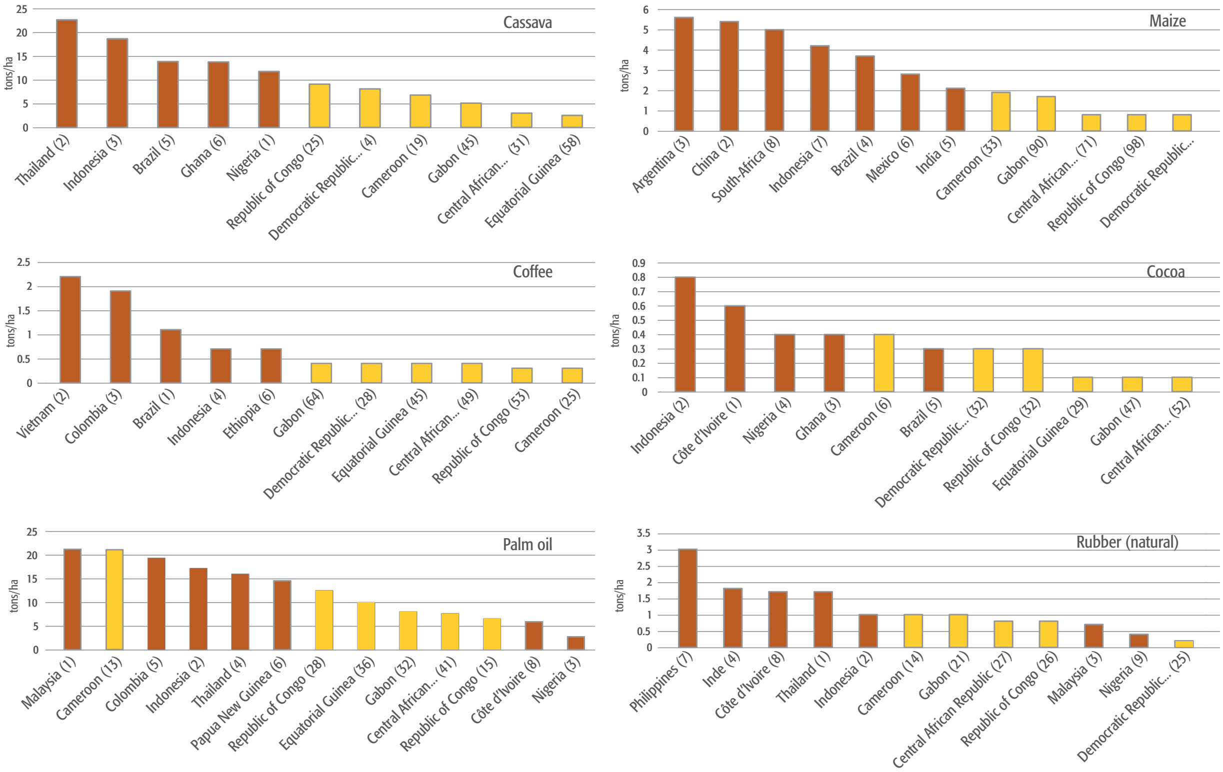
Source: FAOSTAT 2011.
Note: Fertilizer use intensity was obtained by dividing total fertilizer consumption by total area of arable land and permanent crops. No data are available for fertilizer consumption in the Central African Republic and Equatorial Guinea.

Cameroon is the only country in the Congo Basin that has a positive agricultural trade balance, thanks to its strong smallholder production of cocoa and coffee and its sizable plantations of rubber and export bananas. In view of the structural problems of domestic production, the negative agricultural trade balance and the high dependence on imports are likely to worsen in the coming years. A negative balance exposes a country to a very inelastic demand for agricultural products and thus a high vulnerability to price fluctuations on the international food market.

All Congo Basin countries except the Central African Republic are net importers of food, including Cameroon.[17] Statistics from FAO show that food commodity imports are increasing rapidly and that

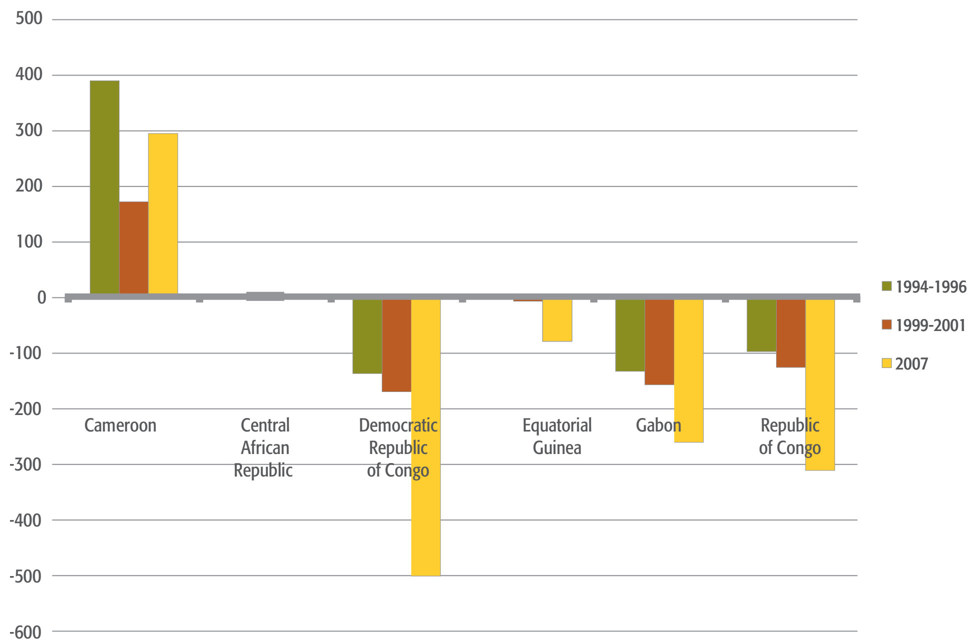
17 "Food" includes all agricultural commodities used for human consumption.

Figure 1.16: Yields of Major Commodities in Congo Basin Countries Compared with Yields Obtained in Major Producer Countries, 2009



FAOSTAT. 2012. http://faostat.fao.org/, FAO, Rome (accessed March 2012).Note: The figure next to each country name is the country world rank for the production of that commodity in 2008.

Figure 1.17: Evolution of the Agricultural Trade Balance, 1994–2007



Source: FAO 2009a.

Note: The Central African Republic's trade balance oscillated around the equilibrium over that period (-4 in 1994–1996, +1 in 1999–2001 and +5 in 2007), Equatorial Guinea's was slightly negative in 1994–1996 (-5) and 1999–2001 (-8).

these countries rely more and more on imports to fill their basic food needs (table 1.4). A large proportion of these rapidly increasing imports reflect urban-based shifts in consumption patterns toward more cereals (wheat and rice) and fewer roots, tubers, and coarse grains; more animal proteins (chicken and eggs); and more readily prepared convenience foods. Rice is the fastest increasing food commodity import, growing at a rate of about 7 percent per year (double the population growth). Wheat and wheat flour imports are large and growing because of the bread-based culture in the cities.

Particularly striking are the large and rapidly increasing imports of poultry, eggs, and fish, despite the potential to produce these commodities locally. The large poultry imports, especially in Equatorial Guinea, Gabon, and the Republic of Congo—despite border tariffs (35 percent in the Democratic Republic of Congo)—reflect the shortage and high cost of maize and soybeans for animal feed in these countries as well as the lesser risks associated with imports. Surprisingly, all countries are also large net importers of vegetable oil, especially refined palm oil from Asia, and sugar.

Table 1.4: Net Food Trade, 2006

Country	% of GDP	Country	% of GDP
Cameroon	-0.7	Equatorial Guinea	–
CAR	-0.5	Gabon	-2.3
DRC	-4.9	Republic of Congo	-2.6

Source: FAO 2009b.

Poor Human Development Indicators

Poor agricultural sector performance has direct effects on human development indicators, for the country as a whole and for the agricultural population in particular. Poor performance directly affects the welfare of the farmers but also that of consumers, as reflected by low health indicators. The vast majority of rural households depend on agriculture to cover their food needs and generate cash revenues. Although most of the Congo Basin countries are richly endowed with natural resources, the food security situation in most of them is a matter of concern (table 1.5). The International Food Policy Research Institute's (IFPRI's) Global Hunger Index (GHI) evaluates the global situation of a country in terms of its vulnerability to hunger. It ranks 84 among developing and transitional countries combining three equally weighted indicators: (1) the proportion of people who are calorie-deficient or undernourished, which is a key indicator of hunger; (2) the prevalence of underweight in children under the age of five, which is a measure of childhood malnutrition, children being the most vulnerable to hunger; and (3) the under-five mortality rate, which measures the proportion of child deaths caused mainly by malnutrition and disease. Countries are ranked on a 100-point scale, with 0 and 100 being the best and worst possible scores, respectively. Only Gabon does relatively better in that respect.

Farming households are among the most vulnerable socioeconomic groups. Poverty prevalence is often highest among farming households and, in some

Table 1.5: IFPRI Global Hunger Index 2009

	Rank	Global Hunger Index	Qualification
Cameroon	44	17.90	Serious
CAR	75	28.10	Alarming
DRC	84	39.10	Extremely alarming
Equatorial Guinea	–	–	–
Gabon	13	6.90	Moderate
Republic of Congo	41	15.40	Serious

Source: IFPRI 2009.
Note: No data are available for Equatorial Guinea. The 2009 GHI is based on data for the 2002–2007 period. Therefore, it only partially reflects the consequences of recent increases in food and energy prices and does not account for the negative effects of the global financial crisis on poor households.

cases, has increased over the past few years. The most recent household survey in Cameroon (ECAM III 2007) classified more than 55 percent of rural households as poor, compared with about 12 percent of urban households. The survey confirmed that the prevalence of poverty was increasing in rural areas (52 percent of rural households were classified as poor in 2001) while it was decreasing in urban centers (17 percent of urban households were classified as poor in 2001). In 2007, 87 percent of the poor were rural (82 percent in 2001).

LIMITED ADVERSE IMPACTS ON FORESTS SO FAR

Overall Low Deforestation Rates

Deforestation rates in the Congo Basin countries are much lower than those in other tropical rainforest areas and are low even by African standards. As shown in table 1.6, the overall annual deforestation rate in the Congo Basin rainforest was estimated at 0.16 percent over the 1990–2000 period. First estimates based on satellite sensing for the 2000–2005 period report a loss of 0.76 percent (0.15 percent per year), which seems to indicate little or no change in the deforestation trend in the region. These rates correspond to a loss of approximately 43,000 km^2 over the 1990–2005 period.

These changes are by far the lowest in the world's tropical rainforest belt—net deforestation rates are more than twice as high in South America and four times higher in Southeast Asia. In comparison, Brazil is estimated to have lost 0.5 percent of its forests per year (i.e., about 28,000 km^2) over the past 20 years, and Indonesia has lost 1.0 percent per year (12,000 km^2) (FAO 2011). In other words, Brazil and Indonesia currently lose more forest in 2 years and 4 years, respectively, than all the Congo Basin countries did over the past 15 years. These figures are confirmed by a global analysis of all forested areas (table 1.7). Overall figures confirm the stability of deforestation rates in Central Africa and 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 (see figure 1.18). Central Africa loses about 40 percent less forest each year than 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.

Deforestation Driven by Demographics and Subsistence Activities

In the Congo Basin, expansion of agricultural land is the most frequently reported proximate cause of tropical deforestation. Zhang et al. (2002) used a GIS-based assessment to determine that small-scale subsistence farming was the principal determinant of deforestation in Central Africa, particularly along the edges between moist forests and non-forest land, where forests are more accessible.

Table 1.6: Total Rainforest Areas and Net Annual Deforestation and Forest Degradation Rates in the Rainforest, 1990–2000

	Total rainforest area (thousand km^2)	Net annual deforestation (%)	Net annual degradation (%)
Cameroon	168.8	0.14	0.01
CAR	46.2	0.06	0.02
DRC	989.1	0.20	0.12
Equatorial Guinea	20.0	0.10	0.00
Gabon	210.9	0.09	0.08
Republic of Congo	184.9	0.02	0.00
Total Congo Basin	1,619.9	0.16	0.09

Source: De Wasseige et al. 2009 (based on the work of Duveiller et al. 2008, and Hansen et al. 2008).
Note: Figures for forest degradation in Cameroon, Equatorial Guinea, and Gabon are to be considered with caution because of insufficient sampling in these countries.

Table 1.7: Changes in Forest Area in Africa and in the Main Negative Contributors to World Total Forest Area, 1990–2010

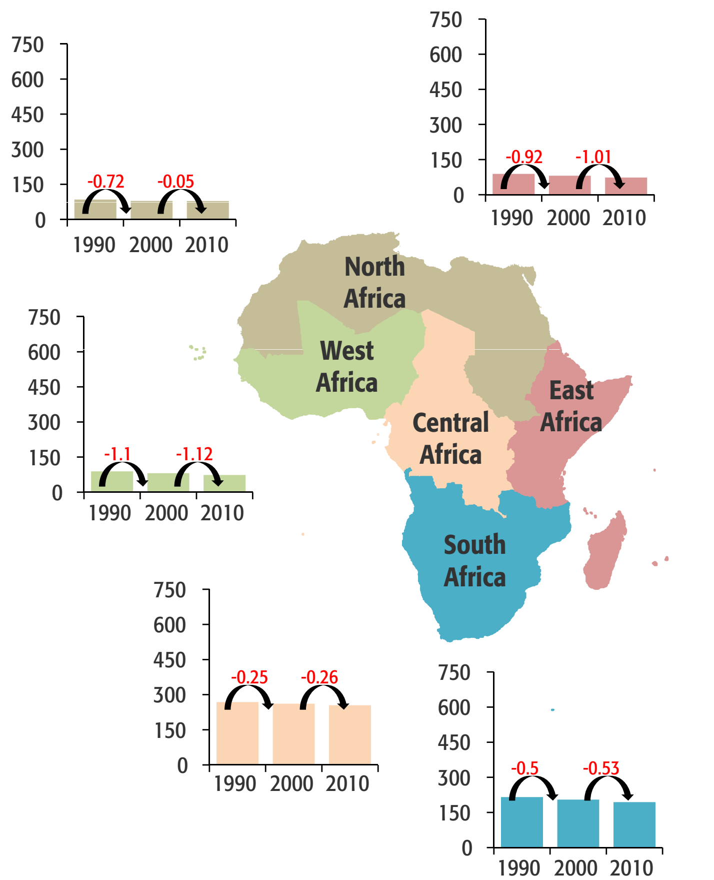
Subregion	Forest Area (thousand ha)			Annual Change (thousand ha)		Annual change rate (%)	
	1990	2000	2010	1990–2000	2000–2010	1990–2000	2000–2010
Central Africa	268,214	261,455	254,854	-676	-660	-0.25	-0.26
East Africa	88,865	81,027	73,197	-784	-783	-0.92	-1.01
North Africa	85,123	79,224	78,814	-590	-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.

Note: The data presented in this table were extracted from the 2011 FAO publication State of the World's Forests. The FAO data differ from Congo Basin-specific data put together by the Observatoire desForêts d'Afrique Centrale (OFAC) and presented in State of Forests in Congo Basin (editions 2008 and 2010 (de Wasseige, 2008 and 2010). The authors of this report relied on FAO statistics for global data on forests; they used OFAC statistics for Congo Basin-specific data.

Main positive contributors include East Asia (especially China), Europe, North America (especially the United States) and South Asia (especially India).

Figure 1.18: Changes in Forest Area in Main Regions in Africa on 1990–2010 period



Source: Authors

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, Sao Tome and Principe;

***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*

***Southeast Asia:** Brunei, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Vietnam;*

***Oceania:** American Samoa, Australia, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Norfolk Island, Northern Marianna Islands, Palau, Papua New Guinea, Pitcairn, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna Islands;*

***Central America:** Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama;*

***South America:** Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Falkland Islands (Malvinas), French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela.*

Source: FAO 2011.

Deforestation trends in the Congo Basin are directly related to population growth and the expansion of associated subsistence activities (agriculture and energy), which usually occur at the expense of the forest. Thus, deforestation and forest degradation have so far been mainly concentrated around urban centers and in the most densely populated areas. This is a completely different picture than in Indonesia, Brazil, and other countries, where large-scale agricultural operations (conversion to pasture and plantations) are by far the main drivers of deforestation.[18]

Population densities in forest areas remain low around the globe, which translates to limited deforestation and forest degradation in rural areas. Although the total population of the six countries was estimated to be about 100 million people in 2010, the Congo Basin itself is sparsely populated, with an estimated 24 million people. More than half of them live in urban areas, including 9 million people in Kinshasa. Average rural population density is therefore very low, estimated at 6.5 inhabitant/km^2, with densities as low as 1–3 people/km^2 in the central cuvette of the Congo River. Some zones in central and northeastern Gabon, northern Congo, and central Democratic Republic of Congo are among the 10 percent wildest zones on earth.[19] Despite high population growth rates, population densities in forested areas have remained low owing to steady rural-urban migration. The transition zones between rainforest and savannah—where population densities can reach up to 150 inhabitants/km^2—usually have significant deforestation or forest degradation rates.

Although Basin countries have low population density rates, urbanization trends are emerging. Urban centers in the Congo Basin are growing rapidly at 3–5 percent per year—even faster (5–8 percent) in the large cities such as Kinshasa and Kisangani, Brazzaville and Pointe Noire, Libreville, Franceville and Port Gentil, Douala and Yaounde, and Bata. These growing urban centers create new dynamics and needs in terms of food and energy (mainly charcoal) supply, both of which are likely to be met by increased pressures on forest areas. Table 1.8 illustrates the population dynamics in the Basin countries; figure 1.19 shows the urbanization trend since 1995.

Deforestation and forest degradation are mainly concentrated around urban centers and in the most densely populated areas (figure 1.20). In a recent phenomenon, rural areas in the rainforest also tend to become more densely populated, as evidenced by the proliferation of urban centers with a population of at least 100,000 inhabitants (cf. territories close to large urban centers). In rural areas, Zhang and colleagues used a GIS-based assessment of the vulnerability and future extent of tropical forests in the Congo Basin to show that the annual clearance of the dense forest is significantly linked to rural population density. Their study also found a positive relationship between the dense forest degraded during the 1980s–1990s and the degraded forest area in the 1980s (Zhang et al. 200). The transition zones between rainforest and savanna, where populations are usually much greater, also usually have high deforestation or forest degradation rates.

The informal nature of deforestation in the Congo Basin makes it hard for governments to address the problem by changing the laws. In most Congo Basin countries (notably the Democratic Republic of Congo and the Central African Republic), the state does not have the necessary power to enact and enforce laws that would regulate informal deforestation (Collier 2007). In other countries—Brazil, for instance—the situation is different: Deforestation is primarily industrial and can be regulated. The uncontrollability factor in the Congo Basin makes the situation very delicate. In the absence of reliable tracking or an effective governing body, deforestation rates will continue to rise with population growth and could rise very quickly in response to a spike in international demand for agriculture products.

18 "Industrial soybean cultivation accounts for 70% of Argentina's deforestation, while Vietnam's export commodities of coffee, cashew, pepper, shrimp (the latter affecting coastal mangroves), rice, and rubber drive forest conversion. Other countries with significant commercial and industrial impacts on forests include Lao PDR (plantation fueled by foreign direct investment, Costa Rica (meat exports to the US promoted by government lending policies), Mexico (82% of deforestation due to agriculture or grazing), and Tanzania (increasing biofuel production)" Kissinger, G., 2011, Policy Brief 3-CGIAR

19 Using the "human footprint" approach described by Sanderson and others in 2002 (De Wasseige et al. 2009).

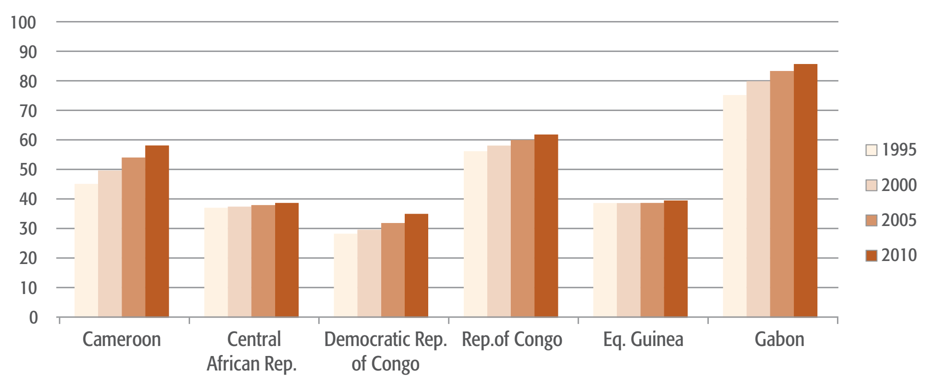
Table 1.8: Rural/Urban Population and Urbanization Trends in the Congo Basin Countries

	1995	2000	2005	2010
CAMEROON				
Total Population	13,940,337	15,678,269	17,553,589	19,598,889
Population growth (%)	2.55	2.29	2.24	2.19
Urban population (% of total)	45.3	49.9	54.3	58.4
Urban population growth (% of total)	4.6	4.15	3.87	3.6
CENTRAL AFRICAN REP (CAR)				
Total Population	3,327,710	3,701,607	4,017,880	4,401,051
Population growth (%)	2.44	1.89	1.65	1.9
Urban population (% of total)	37.2	37.6	38.1	38.9
Urban population growth (% of total)	2.66	2.1	1.91	2.31
CONGO, DEM. REP (DRC)				
Total Population	44,067,369	49,626,200	57,420,522	65,965,795
Population growth (%)	3.27	2.44	2.94	2.71
Urban population (% of total)	28.4	29.8	32.1	35.2
Urban population growth (% of total)	3.69	3.38	4.39	4.48
REP. CONGO				
Total Population	2,732,706	3,135,773	3,533,177	4,042,899
Population growth (%)	2.74	2.6	2.51	2.54
Urban population (% of total)	56.4	58.3	60.2	62.1
Urban population growth (% of total)	3.48	3.25	3.14	3.16
EQU. GUINEA				
Total Population	442,527	520,380	607,739	700,401
Population growth (%)	3.34	3.2	3	2.79
Urban population (% of total)	38.8	38.8	38.9	39.7
Urban population growth (% of total)	5.47	3.2	3.05	3.2
GABON				
Total Population	1,087,327	1,235,274	1,370,729	1,505,463
Population growth (%)	2.95	2.33	1.96	1.87
Urban population (% of total)	75.4	80.1	83.6	86
Urban population growth (% of total)	4.64	3.51	2.8	2.43

Source: Authors, from World Development Indicators database, World Bank (http://databank.worldbank.org/ddp/home.do; accessed March 2012).

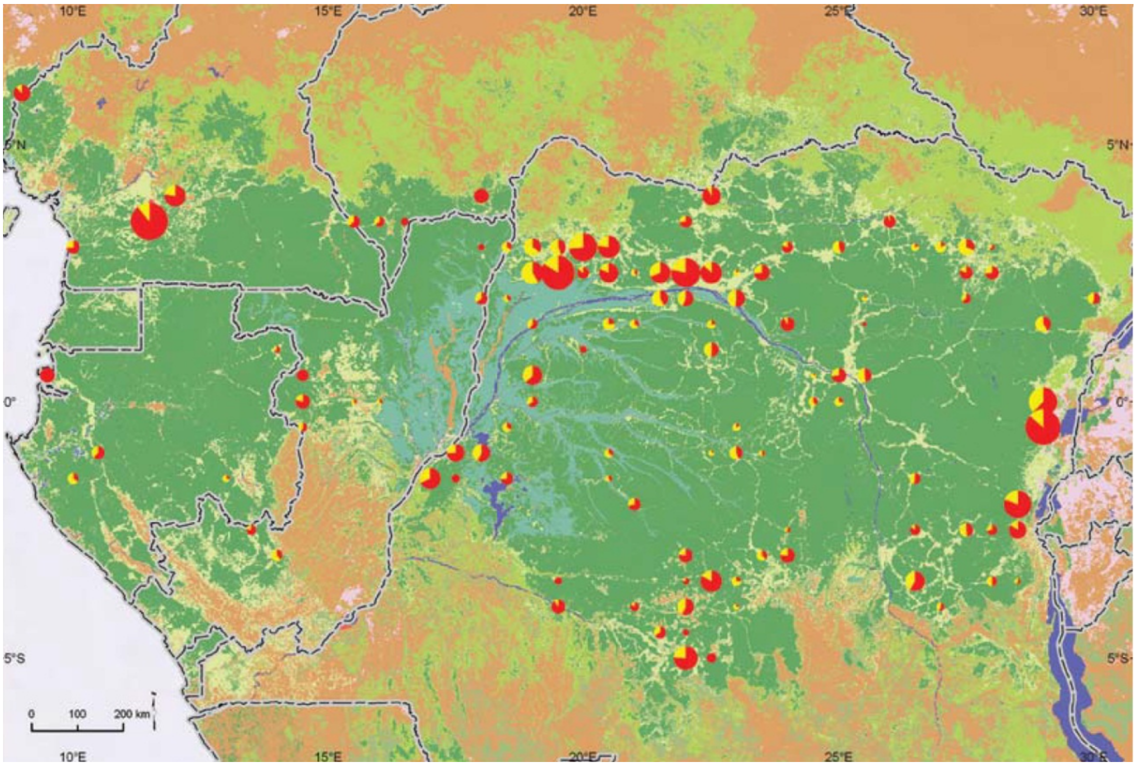
Figure 1.19: Urban Population in the Congo Basin Countries, 1995–2010

(percentage of total population)



Source: Authors, from World Development Indicators database, World Bank (http://databank.worldbank.org/ddp/home.do; accessed March 2012).

Figure 1.20: Spatial Distribution of Deforestation (red) and Forest Degradation (yellow) in the Humid Forests



Source: De Wasseige et al. 2009 (based on the work of Duveiller et al. 2008).
Note: Each circle represents a 10 x 10 km sample. The size is proportional to the total area affected by deforestation and degradation, while the two colors provide information on the relative importance of the two processes.

Low Impact of Large-Scale Plantations

Translating plantation area evolution figures into actual impact on forests is not straightforward. While increases in areas under cocoa, bananas, and oil palm (mainly in Cameroon) have probably been at the expense of forest, the general decrease in most countries' plantation areas does not necessarily mean that the abandoned land has returned to secondary forest. In addition, the sharp decrease in the area under coffee probably corresponds to a decrease in the harvested area, with limited impact on the forest cover, as coffee is generally grown under the primary forest canopy. The authors could not find precise figures on this issue; however, some data suggest that, while expansion of certain plantation crops has had a negative effect on forests, especially in Cameroon, the global effect has been limited so far (Tollens 2010).

The Congo Basin has not experienced the expansion in large-scale plantations seen in other tropical regions. The Basin has significant agro-ecological potential for the development of several major commodities, including soybeans, sugarcane, and palm oil. However, a weak transportation network, low land productivity, and a poor business environment reduce the attractiveness of the region to investors. Because of the availability of suitable land for agricultural expansion in countries with better performance in terms of infrastructure, productivity, and an enabling business environment, the Congo Basin has not attracted sizable investment in large-scale agriculture. However, this situation may change, depending on the external and internal variables discussed in chapter 3.

Because of limited expansion of plantations, the Congo Basin has not experienced the massive deforestation observed in other regions. The phenomenon of large-scale land acquisition for agriculture and biofuel projects in other regions of the world (Southeast Asia, the Amazon) has not yet materialized in the Congo

Basin countries. Most of the planned investments for commercial plantations in the Basin focus on rehabilitating those that were abandoned after the colonization era, which would have no effect on tropical forest area. However, some recent signals (for example, large-scale oil palm plantation projects in Cameroon) clearly indicate that large-scale land conversion could pose a significant threat to tropical forests and could potentially drive significant deforestation (see box 1.4.).

Box 1-4. Palm Oil Potential in Cameroon

Worldwide demand for palm oil—the number one vegetable oil—is projected to rise as the world population looks for affordable sources of food and energy. In 2011, Malaysia and Indonesia dominated the production of palm oil, but strong consumption trends have made it an attractive sector for investors seeking to diversify supply sources across the tropics, including in the Congo Basin. A case in point is Cameroon, where at least six companies are reported to be trying to secure more than a million hectares for the production of palm oil (Hoyle and Levang 2012). In 2010, Cameroon produced 230,000 tons of crude palm oil across an estate of 190,000 ha (independent smallholdings accounted for 100,000 ha; supervised smallholder plantations and agro-industrial plantations accounted for the balance) and was the world's 13th largest producer. Compared with other crops in the Congo Basin, where productivity tends to trail far behind that in other countries, palm oil yields in Cameroon are among the highest in the world, on par with Malaysia's. Because of its potential in terms of growth, employment, and poverty reduction, industrial palm oil production is a national priority, with plans to increase production to 450,000 tons by 2020. Some of the plantation sites identified in emerging land deals could be problematic, because they appear to be in high conservation value forests or near biodiversity hotspots.

2

CHAPTER 2

Will Agricultural Development Be at the Expense of the Forests?

As noted in chapter 1, deforestation and forest degradation have been primarily driven by small-scale subsistence farming concentrated around urban centers and in the most densely populated areas.

This chapter explores possible future developments in the agricultural sector in the six Congo Basin countries and their potential impacts on forest cover. It presents the chief findings of research conducted over the past two years in close consultation with the Basin countries and the regional Forestry Commission for Central Africa (COMIFAC). The study combined robust analysis of the agricultural sector in the six countries and a modeling exercise using the CongoBIOM model developed by IIASA (for more information on the model, see box 2.1 and the annex).

POTENTIAL FOR AGRICULTURAL DEVELOPMENT IN THE CONGO BASIN

The potential for agricultural development in the Congo Basin is significant; however, it remains to be seen whether and to what extent this potential is achieved over the next few decades. The major internal and external factors that might influence agricultural development are discussed below.

Growing International Demand for Agricultural Products

Experts have estimated that global agricultural production should increase by 70 percent by 2050 and by 100 percent in developing countries (Bruinsma

Box 2-1: The CongoBIOM Model

In 2009, the six Congo Basin countries, along with donors and partner organizations, agreed to collaborate to analyze major drivers of deforestation and forest degradation in the region. A modeling approach was chosen because the High Forest Cover, Low Deforestation (HFLD) profile of the Congo Basin countries justified using a prospective analysis to forecast deforestation, and historical trends were considered inadequate to capture the future nature and amplitude of drivers of deforestation. The approach built on an adaptation of the GLOBIOM model set up by the International Institute for Applied Systems Analysis (IIASA) and tailored to the Congo region (CongoBIOM) to investigate drivers of deforestation and resulting greenhouse gas emissions by 2030. It also strongly relied on inputs from regional multistakeholder workshops held in Kinshasa and Douala in 2009 and 2010, as well as in-depth analysis of trends in the agricultural, logging, energy, transport, and mining sectors.

The CongoBIOM was used to assess the effects of a series of policy shocks identified by Congo Basin country representatives. Various scenarios were developed to highlight the drivers of deforestation, both internal (improved transport infrastructure, improved agricultural technologies, decrease in fuelwood consumption) and external (increase in international demand for meat and biofuel).

2009). They foresee an increase of 40 percent in the world's population by 2050, combined with an increase in average food consumption. FAO projections suggest that, although less strong than in the past, yield increases and increased cropping intensity will account for 90 percent of production growth (80 percent in developing countries), with the remainder coming from land expansion. That would translate into 47 million ha of land to be brought into production globally over the 2010–2030 period, with a decrease of 27 million ha in developed and transitional countries and an increase of 74 million ha in developing economies.

Demand for biofuel feedstocks will also be a major factor driving world agriculture evolution, with land conversion for biofuels by 2030 estimated to range between 18 and 44 million ha.[20] In the more industrialized Organization for Economic Co-operation and Development (OECD) countries in particular, increasing the incorporation of biofuels into the domestic energy matrix has become an important policy objective. Most OECD countries have adopted policies and strategies to incentivize the domestic consumption of biofuels; the European Union (EU) in particular is strongly committed to biofuels as part of a climate change mitigation agenda. Some developing countries are embracing the economic opportunities inherent in servicing new export markets.[21]

A total of 6 million ha could be brought to production every year over the next 20 years. While various models have arrived at annual land conversion increases ranging from 4.5 million ha to 12 million ha over the next 20 years, a conservative estimate is that 6 million ha/year of additional land will be brought into production through 2030 (120 million ha in total). Such annual increases represent more than three times the average land expansion rate from 1990 through 2007 (1.9 million ha/year), and the rate is probably higher in developing countries, owing to the ongoing shift in production of bulk commodities to land-abundant regions where land and labor are cheaper and the potential for productivity increases is higher than in traditional producing regions. The strong interest recently expressed by various investors in land acquisition in developing economies is unlikely to slow.

Prospects are positive for most of the commercial crops grown in the sub-region. Globally, palm oil is the most widely used oil, and the evolution of biofuel demand could amplify the demand for oil palm plantations. Rubber, although it was affected by the financial crisis and the subsequent car manufacturing crisis, is showing increasing demand from emerging markets in India and China. Cocoa is the only agricultural commodity that was not affected by the contraction of the markets during the financial crisis; it maintained a strong performance that is likely to continue. Coffee prices are much more volatile but could offer opportunities if fluxes were better controlled. Currently, neighboring countries (mainly eastern African countries, such as Rwanda) have developed processing facilities and become export platforms for agricultural commodities; for example, it seems that a portion of the Democratic Republic of Congo production is informally directed to these countries and then exported under their statistics.

Commodity supply could shift to the Congo Basin. As a response to increasing concerns related to the environment (including climate change), some key-commodity-exporting countries are taking strong measures to limit expansion of commercial agriculture into forest areas. Indonesia, for instance, has made a strong political commitment to a moratorium on awarding concession rights to private companies to convert primary forests into oil palm plantations. This commitment was supported by the government of Norway, which pledged US$1 billion to encourage the Indonesian government to reduce deforestation. In the meantime, some Asian investors have shown increased interest in securing land access for oil palm plantations in Central Africa, particularly Cameroon (see box 2.2). This could be termed "international leakage," in the jargon used in climate change negotiations.

20 Biofuel feedstocks comprise wheat, maize, sugarcane, and oil seeds (not included in the above projections).

21 This chapter draws heavily on data and findings provided by Deininger and Byerlee, 2011.

Box 2-2: Recent Trends in Large-Scale Agricultural Expansion in Cameroon

Industrial production of palm oil is not new to Cameroon. The German colonial administration established the first commercial plantations in 1907 in the coastal plains, around Mt. Cameroon and Edea. The crop was further developed under the Franco-British regime until 1960, when it had reached an estimated production of 42,500 tons. After independence, the government of Cameroon took over the production of palm oil with the creation of public sector companies such as Société des Palmeraies (which later became SOCAPALM), PAMOL, and CDC. According to the Ministry of Agriculture and Rural Development, Cameroon produced 230,000 tons of crude palm oil in 2010 across an estate of approximately 190,000 ha.

As a result of increased global demand for palm oil and suitable conditions for development, Cameroon has witnessed a sharp rise since 2009 in investor enquiries seeking land to plant oil palms. It is believed that at least six companies are currently trying to secure over a million ha for the production of palm oil in the southern forested zone.

- *Sithe Global Sustainable Oils Cameroon (SGSOC)* is a locally registered company in Cameroon, owned by Herakles Farms (affiliate of Herakles Capital), which is based in New York. Since 2009, SGSOC has been trying to secure a large tract of land in the range of 100,000+ ha in the southwestern part of Cameroon to develop a large oil palm plantation. SGSOC is currently in the process of finalizing the acquisition of 73,086 ha (30,600 ha in Ndian Division and 42,600 ha in Kupe-Muanenguba Division). The site of the proposed plantation lies inside a globally recognized biodiversity hotspot, surrounded by the internationally important protected areas of Korup National Park, Rumpi Hills Forest Reserve, Bakossi National Park, and Banyang-Mbo Wildlife Sanctuary.
- *Sime Darby,* a Malaysia-based diversified multinational and the world's biggest listed palm oil producer, is searching for up to 600,000 ha of land in Cameroon to develop oil palm and rubber plantations, across the center, southern, Littoral, and southwest regions. Detailed plans are not clear, but it is believed that Sime Darby is proposing to develop 300,000 ha of oil palm plantation in Yingui, Nkam Division, adjacent to the proposed Ebo National Park and UFA 00-004.
- *SIVA Group/Biopalm Energy* is an Indian-owned, Indonesian-registered set of companies. SIVA has a global plan to secure 1 million hectares under oil palm in several countries. It is seeking at least 200,000 ha in Cameroon (not in one block) and has reportedly already acquired 50,000 ha in the Ocean Division, with authorization to develop 10,000 ha yearly. One of the sites SIVA is trying to secure is UFA 00-003..
- In August 2011, *Good Hope Asia Holdings* from Singapore announced its plan to invest several hundreds of millions of dollars in palm oil plantations in Cameroon. Good Hope is searching for an unknown quantity of land for palm oil development in Ocean Division, South Region.
- In addition, *Palm Co* is requesting at least 100,000 ha in the Nkam area of Littoral, and *Smart Holdings* is trying to acquire 25,000 ha in an unknown location.

Source: Extracts from a WWF-IRD-CIFOR ad hoc working paper, April 2012.

Vibrant Domestic and Regional Markets

The fast-rising urban population will continue to depend on imported foods. In view of the structural problems of domestic production, the demand for food will most likely continue to be largely met by imports, worsening the area's agricultural trade balance and increasing its dependence on imports. Supply volatility and expensive transport owing to poor road infrastructure favor imports, which also benefit from important economies of scale. The energy issue—especially the relatively high cost of fuelwood and charcoal—is also a factor, as rice, for example, cooks much faster than starchy staples. As for animal protein, production in Central Africa is hampered by the prevalence of the tse-tse fly and the absence of a reliable feed industry.

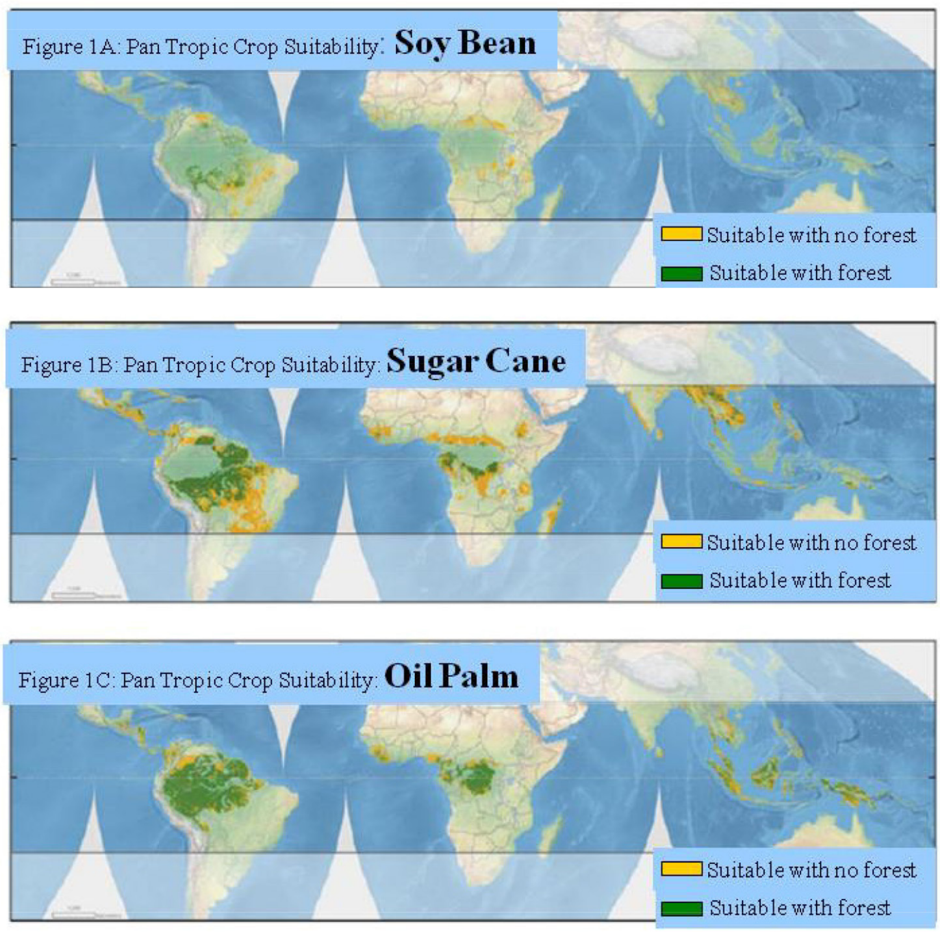
However, the increase in internal demand may create opportunities for local agriculture. Domestic production of vegetable oils (especially palm oil) and sugar could increase—currently, all six countries are net importers. The growing demand could be partially met through the peri-urban expansion of agriculture, especially production of leafy vegetables, tomatoes (market gardening), and small livestock (poultry and small ruminants). Import substitution could also support agricultural growth in these countries: some products could be locally grown and directly substituted for the imported products, while some new products could replace imported ones (for instance, cassava-based flour has the potential to replace imported wheat flour, as happened in western Africa).

A vibrant regional market is still to be unlocked. Agriculture markets in Central Africa are largely segmented. Deteriorated infrastructure and high transaction costs hamper the development of agricultural trade and exchanges not only at the national level but at the regional level as well. Unlocking these markets and the exchanges at the regional level could provide a boost for agriculture in the sub-region. Currently, most of the trans-boundary fluxes, though quite active, are informal; they cover all kinds of products, both staple products and plantation crops. Formalizing these fluxes through regional trade agreements and regional integration could support agricultural growth in Central Africa.

Land Suitability and Availability

Land suitability. The potential to expand agricultural land throughout the Congo Basin is considerable. The maps in figure 2.1 show suitable land for the three

Figure 2-1: Tropical Land Area Suitable for (a) Soybean, Sugar Cane (b), and Oil Palm (c)



Source: Hansen 2001 in: A Preliminary Global Assessment of Tropical Forested Land Suitability for Agriculture.

major export-oriented crops: soybeans, sugar cane, and palm oil. The Congo Basin countries are generously endowed and rank just behind the Latin America.

Land availability. A recent study commissioned by the World Bank (Deininger and Byerlee 2011) modeled the potential worldwide availability of land for rainfed crop production. Altogether, the Congo Basin countries contain about 40 percent of the uncultivated, unprotected low population density land suitable for cultivation in Sub-Saharan Africa and 12 percent of such land available globally (see table 2.1).[22] The ratio between suitable land and cultivated land, particularly high in the Congo Basin countries, illustrates the great potential for investments in land expansion.

22 If forests are excluded, they contain about 20 percent of the land available in Sub-Saharan Africa and 9 percent available globally.

Potential to Increase Productivity

Prospects for yield increase in Africa are promising. While the scope for yield gains over 2010–2050 seems more limited at the international level than in the past, the situation is drastically different in Africa. The potential for agricultural production in the Congo Basin is far from realized for most of the cultivated crops; these countries have important yield gaps that offer significant margins for improvement.

Table 2- 1: Potential Land Availability by Country (million ha)

	Total area	Forest area	Cultivated area	Suitable noncropped, nonprotected area density < 25 people/km²	
				Forest	Nonforest
Sub-Saharan Africa	2,408.2	509.4	210.1	163.4	201.5
DRC	232.8	147.9	14.7	75.8	22.5
Sudan	249.9	9.9	16.3	3.9	46.0
Zambia	75.1	30.7	4.6	13.3	13.0
Mozambique	78.4	24.4	5.7	8.2	16.3
Angola	124.3	57.9	2.9	11.5	9.7
Madagascar	58.7	12.7	3.5	2.4	16.2
Republic of Congo	34.1	23.1	0.5	12.4	3.5
Chad	127.1	2.3	7.7	0.7	14.8
Cameroon	46.5	23.6	6.8	9.0	4.7
Tanzania	93.8	29.4	9.2	4.0	8.7
CAR	62.0	23.5	1.9	4.4	7.9
Gabon	26.3	21.6	0.4	6.5	1.0
Latin America and Caribbean	2,032.4	934.0	162.3	290.6	123.3
Eastern Europe and Central Asia	2,469.5	885.5	251.8	140.0	52.4
East and South Asia	1,932.9	493.8	445.0	46.3	14.3
Middle East and North Africa	1,166.1	18.3	74.2	0.2	3.0
Rest of the World	3,319.0	863.2	358.9	134.7	51.0
World Total	13,333.1	3,706.5	1,503.4	775.2	445.6

Source: Deininger et al. 2011, based on the work of Fischer and Shah (IIASA) 2010.
Note: In Sub-Saharan Africa, only countries that have more non-cropped non-protected suitable land (forest or non-forest) than Gabon are detailed here.

The Congo Basin is among the areas in the world that have the greatest potential for expanding cultivation and increasing yields. The World Bank used the IIASA methodology, with its high-resolution agro-ecological zoning, to predict land suitability, potential yields, and gross value of output for five key crops: wheat (not relevant in the case of Congo Basin countries), maize, oil palm, soybeans, and sugar cane. The model shows that the Congo Basin is one of the areas with the greatest maximum potential value of output in the world for these crops (figure 2.2).

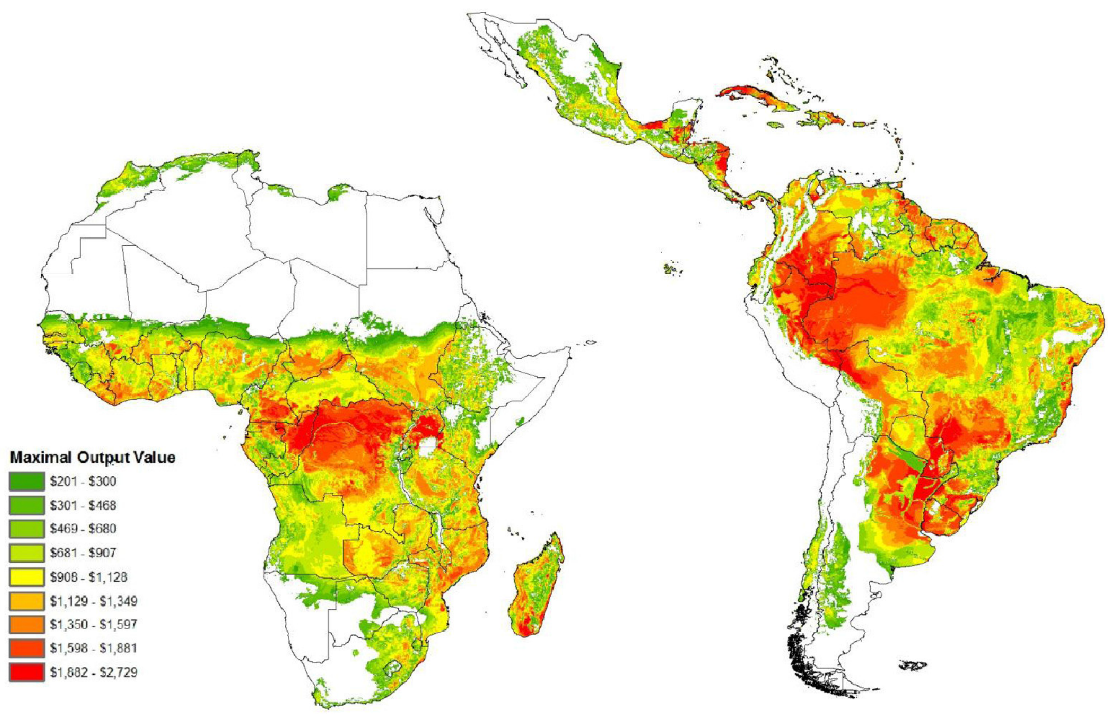
However, constraints to yield increase still need to be removed. The governments of the Congo Basin countries would have to define an ambitious and strategic vision to transform their agriculture and set up mechanisms that systematically address the constraints to agricultural development. This undertaking would encompass removing barriers to private sector investment (improving the business environment), reinvigorating R&D and extension services, building or rehabilitating rural infrastructure, and improving access to markets to facilitate the purchase of inputs, including fertilizers, and the sale of products.

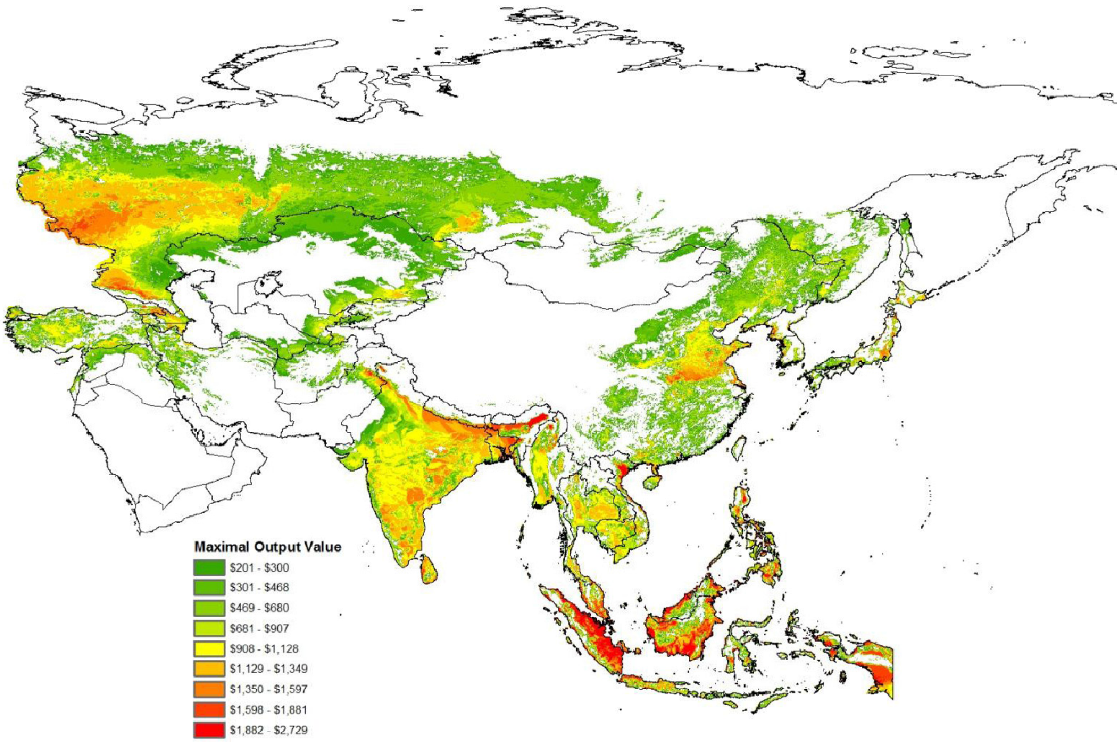
Unconstrained Water Resources

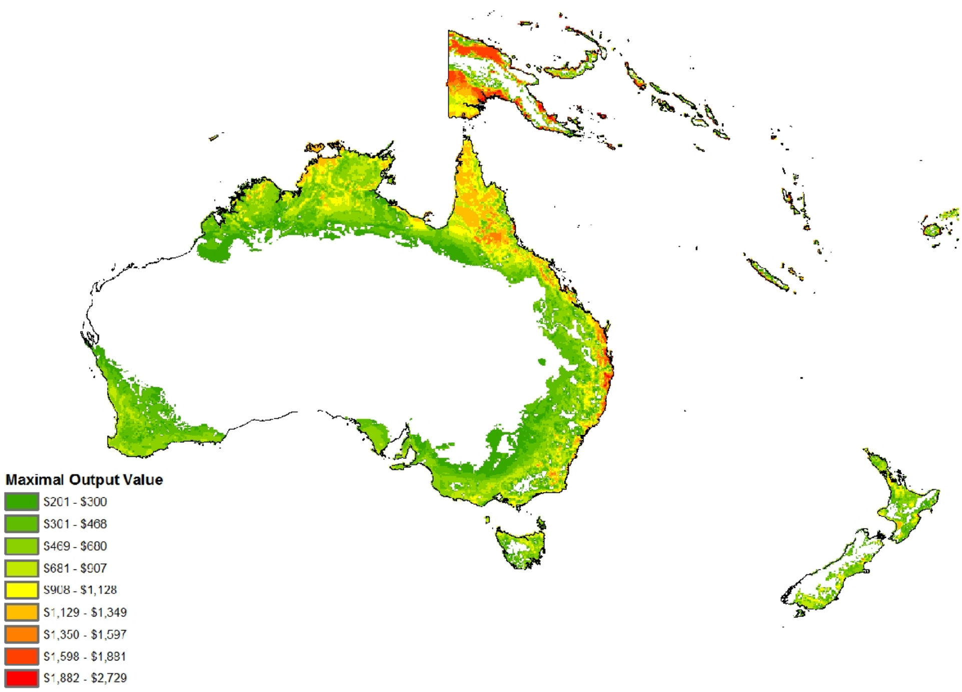
Many parts of the world, especially in developing countries, are expected to experience water scarcity and stresses in the future. Water scarcity and competition with other uses in many regions (such as China, South Asia, the Middle East and North Africa) will have profound effects on agricultural production, possibly including changes in cropping patterns, reduced yields, increased frequency of extreme weather events resulting in higher variability of output, and the necessity in certain areas to invest in water storage infrastructure to capture more concentrated rainfall and minimize associated soil erosion.

In the context of climate change, the profile of the Congo Basin countries does not show constraints on water resources. Hydro-meteorological models predict that this profile is likely to persist in the coming decades, giving Congo Basin countries a comparative advantage

Figure 2- 2: Maximum Potential Value of Output (US$/ha) in Tropical Areas







Source: Deininger et al. 2011, based on the work of Fischer and Shah (IIASA 2010).

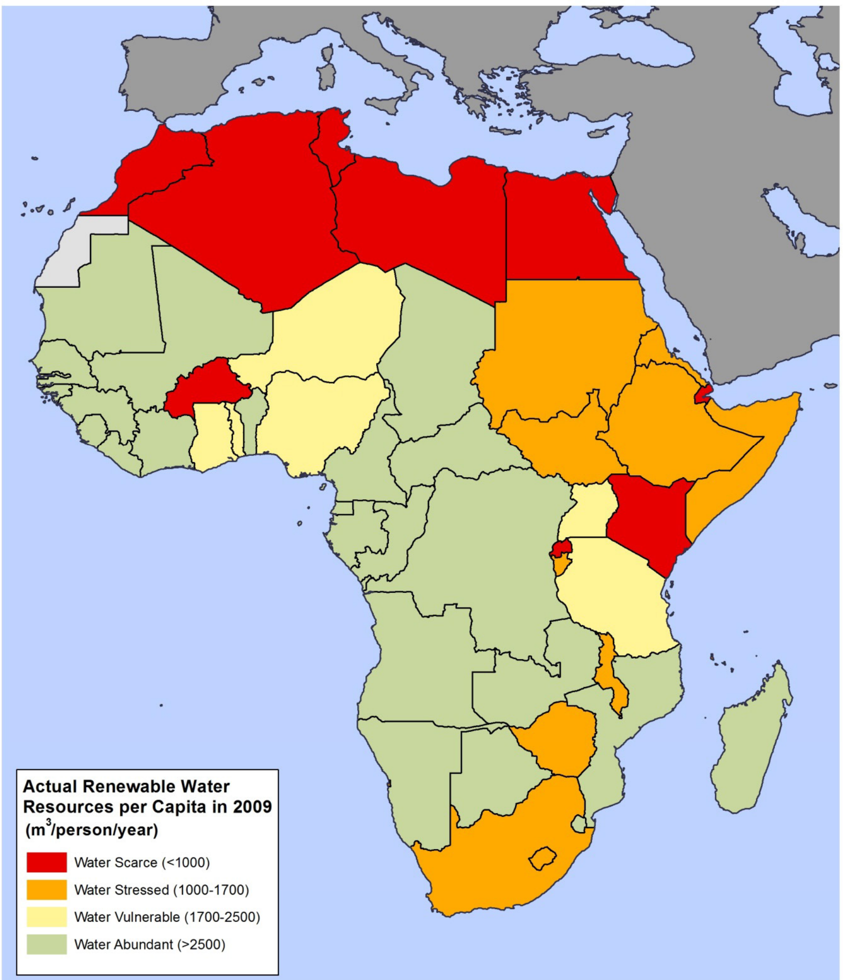
over most neighboring countries, which are predicted to face increased scarcity of water. So far, Congo Basin countries have been spared the natural disasters related to weather extremes that have occurred in some neighboring countries. This resilience to climate change will provide the Congo Basin countries with a comparative advantage at the global level (figure 2.3).

FUTURE IMPACTS ON FORESTS

The factors described in the previous section suggest that the agricultural sector has potential to take off during the next few decades, but unlocking this potential might lead to increased pressures on forests. The following section explores how developments in the sector could affect the forest cover in the Congo Basin.

The CongoBIOM was used to assess the effects of a series of policy shocks identified by Congo Basin country representatives. Five different scenarios were tested, in addition to the baseline and three of them were directly related to the agriculture sector (S1 and S2 tested external policy shocks, while S5 was an internal policy shock): S1 assumed an increase in international demand for meat; S2, an increase in international demand for biofuels; and S5, improved agricultural productivity through enhanced technologies. The main findings from the modeling exercise on these three

Figure 2- 3: Water Availability in the Congo Basin Countries (m³/person/year)



Source: Authors.

scenarios are presented below. (For more information on the modeling exercise, see the annex.)

In addition to these three scenarios, population growth is likely to remain a major driver of deforestation through expansion of subsistence agriculture. This growth is expected to cause high demand for agricultural products and thus foster deforestation in a largely incontrollable way. The trend was observed in a study of drivers of deforestation in the Democratic Republic of Congo conducted by the Catholic University of Louvain (Belgium) (Delhage and Defourny 2011). In this study, 35 variables were tested on 1,365 sample sites for correlations with variable deforestation. The strongest correlation (0.83) was observed for population growth. Because the Democratic Republic of Congo covers a large part of the Congo Basin, this observation has an important, almost representative, value for the region; it allows us to conclude that uncontrollable small-scale deforestation will probably be a key driver of deforestation in the Basin.

Will an Increase in Land Productivity Reduce or Exacerbate the Pressure on Forests?

Until now, agricultural performance in the Congo Basin has remained very weak, with substantial yield gaps, under-mechanized agriculture, and limited or no use of fertilizers (see chapter 1). Land productivity could be increased through a coordinated approach, including R&D, extension services, improvements in varieties and use of fertilizers, and development and rehabilitation of rural infrastructure. Such an approach would likely yield transformational effects in the agricultural sectors of the Congo Basin.

Increase in land productivity is often seen as the most promising means to achieve both food production and forest preservation. It is assumed that producing more on the same land would enable countries to avoid the conversion of new lands into agricultural production and that the spared land would then sequester more carbon or emit fewer greenhouse gases than farmland. While this logic is attractive, models show that it is unlikely to materialize unless some accompanying measures are put in place.

In the Congo Basin, an increase in productivity could be accompanied by an expansion of cultivated lands at the expense of the forests. The CongoBIOM model indicates that the intensification of land production in response to a growing demand for food—as well as an unlimited labor market, which is the case in the Congo Basin—leads to an expansion of agricultural lands. Production costs fall, which stimulates local consumption of agricultural products; demand then rises above the level that can be met simply by the increase in productivity. The reduction in unit production cost narrows the difference in opportunity costs between agricultural and forest uses, and generally more than compensates for the cost of converting forests into cropland. The productivity gains, by making the agricultural activities more profitable, can increase pressure on forested lands, which are generally the easiest new lands for farmers to access. Without pairing with accompanying policies and measures on land planning and monitoring, stimulating agricultural productivity will likely lead to more deforestation in the Congo Basin (see recommendations in chapter 3).

The CongoBIOM model also suggests that changes in global commodity prices can lead to substitution of imports by local production. In fact, the model indicates that when the international price for an agricultural product rises above a critical threshold, the imported product becomes less affordable for local populations and drives local production. Thus, the combination of growing demand for food and unlimited labor availability in the Congo Basin is likely to ultimately foster domestic production.

Effect of International Demand for Agricultural Commodities

The Congo Basin is not yet really integrated in the global agricultural markets (with the exception of coffee and cocoa). However, the CongoBIOM model shows that despite its marginal contribution to global markets, the Basin could still be affected by global trends in agricultural commodity trade. The two examples presented below describe how external shocks could indirectly affect the Congo Basin forests.

First-Generation Biofuels

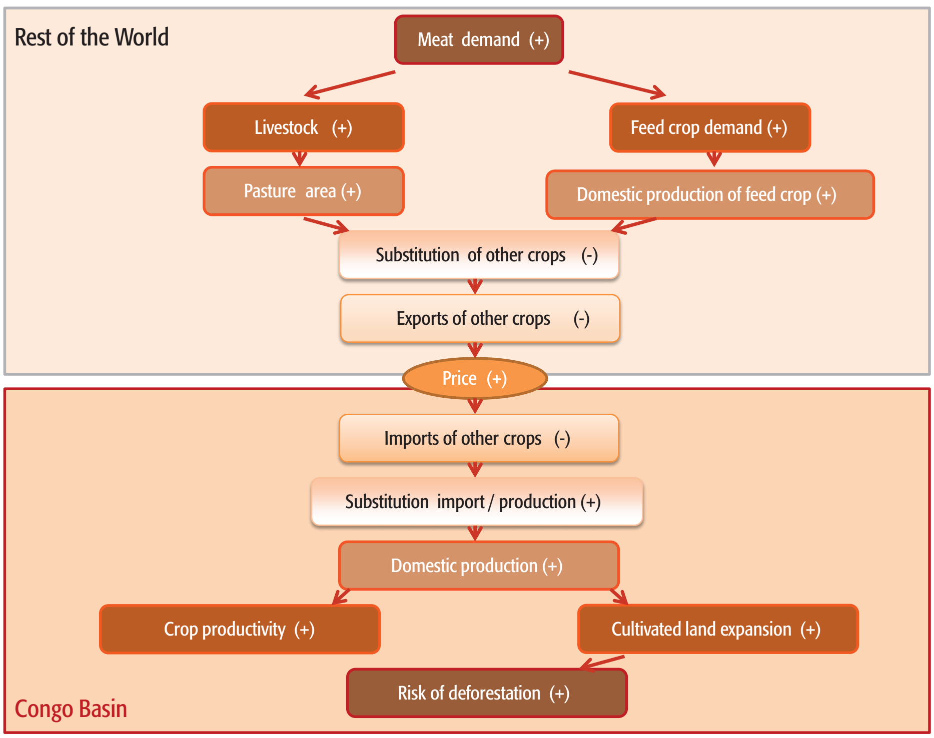
Sugar cane and palm oil can be used directly to produce first-generation biofuels and are currently the major options in terms of biofuels.[23] There has been a spectacular increase in biofuel demand since 2000, primarily because of public sector support. This trend responds to the decline in known and affordable reserves of fossil fuels, and the need to diversity energy supply. While at some point it was considered that the substitution of fossil fuel by biofuels could reduce global CO^2 emissions in the atmosphere, this is now being seriously questioned because of the potential contribution of biofuel development to increased deforestation in the tropics.

23 Second-generation biofuels should also reduce the pressure on land—ameliorating the conversion of biomass energy and extending usable biomass resources—but the technologies are not yet commercially available. Production of biodiesel from used cooking oil or low-grade tallow (for example, Jatropha, which can grow on some low-productivity land in Asia and Africa) is occurring; however, the use of these substances is marginal in total biodiesel production, and their potential large-scale future use is questionable. (See FAO 2010b for a discussion of Jatropha's potential.)

The climatic conditions for growing sugar cane and oil palms are particularly suitable in tropical countries (see the maps in figure 2.2 above), and planting them does not directly compete with forest resources. However, despite the general trend of "land grabbing" elsewhere, the Congo Basin countries do not yet show significant signs of expansion of biofuel plantations, mainly because of their lack of comparative advantage against countries that can access large areas of suitable land and have better infrastructure, productivity, and business environments. The current trend in the Congo Basin is to rehabilitate abandoned plantations.

However, the fact that the Congo Basin does not produce significant amounts of biofuels now does not mean that it will not eventually do so. The modeling exercise showed that the indirect effects of biofuel expansion in other regions of the world will reduce agricultural exports from primary exporting regions, which could then increase deforestation in the Congo Basin. The path of these indirect effects is shown in figure 2.4.

Figure 2- 4: Channels of Transmission of International Crop Demand Increase to Deforestation in Congo Basin



Source: Authors from IIASA 2011.

Meat Consumption

As living standards rise, diet patterns shift toward an increase in consumption of animal calories, particularly in emerging economies such as China, Russia, and India. The average annual meat consumption in developed countries is 80 kg per capita; in the developing world, it is about 30 kg per capita and growing fast. Livestock production could increase sharply during the next decades, which would create a double pressure on climate change: the enteric fermentation of ruminants that creates methane emissions and the conversion of forested lands into pasture and feed croplands. During the past decade, Brazil has become a meat exporter; mechanized agriculture for soybean cultivation and intensive cattle grazing have been the dominant drivers of land clearing in the Amazon Forest.[24]

The Congo Basin has no comparative advantage for producing meat; it lacks the appropriate biophysical and climatic conditions for large-scale cattle farming. However, the increase in international demand for meat could affect its forest cover, as demonstrated by the CongoBIOM model: the Congo Basin countries could suffer an indirect effect through the substitution of crops and changing price signals. The model indicates that the development of cattle farming and feedstock production in Latin America and Asia might reduce crop production in these countries, and that this reduction in supply could lead to an increase in crop prices. The Congo Basin countries could react to this development by increasing the area under production for traditionally imported crops, especially corn.

Land Availability: Forested Versus Nonforested Lands

The previous sections highlighted the risk for increased deforestation linked to local and international pressures, but the Congo Basin could benefit from significant reserves of nonforested lands suitable for agriculture that could be turned into production lands if it had a structural political framework that could redirect pressure on forests to nonforested land.

24 Between 2000 and 2007, poultry exports increased by a factor of 23, and beef exports rose by a factor of 7. In China, soybean imports increased by a factor of 2.6 between 2000 and 2007 to support livestock production.

The Congo Basin could almost double its cultivated area without converting any forested areas. While the vast majority of suitable land (uncropped, unprotected areas) lies under forests, there is also considerable nonforested land in the Basin. In fact, in most of the countries it represents more than the area currently under production: the mean ratio of cultivated area to nonforested area in the Congo Basin countries is 0.61, ranging from 1.45 in Cameroon to 0.14 in the Republic of Congo, far below the global ratio of 3.37 (see table 2.1).

- *The Democratic Republic of Congo* has the greatest reserve of uncultivated, unprotected, and low population density land suitable for cultivation in Sub-Saharan Africa (table 2.1).[25] The reserve is estimated at 98.3 million ha, of which three-fourths is currently under forest; it represents nearly 7 times the area presently cultivated in this country (more than 16 times if the FAO figure for the Democratic Republic of Congo's cultivated land is used).[26] If only nonforested suitable land is considered, the Democratic Republic of Congo still ranks among the six countries with the largest amount of suitable but uncultivated land: Sudan, Brazil, Russia, Argentina, Australia, and the Democratic Republic of Congo, in that order. The Democratic Republic of Congo's suitable nonforested land is estimated at more than 1.5 times its currently cultivated land (almost 4 times its currently cultivated land if the FAO figure is used).
- *Cameroon* is estimated to have a reserve of 13.6 million ha, of which about two-thirds is presently under forest. This is about twice its area presently under is considered.
- *The Republic of Congo* is estimated to have 15.8 million ha of suitable uncultivated land, of which about three-fourths is under forest. This reserve

25 A threshold of 25 persons/km2 (i.e., more than 20 ha per household) was used, under which the authors of the IIASA study consider that voluntary land transfers that benefit all stakeholders can easily yield agreement.

26 FAO figures for Congo Basin countries' cultivated area (2008) significantly differ from the figures used by Deininger and Byerlee (2011), especially for the Democratic Republic of Congo. FAO figures, in millions ha: Cameroon: 4.7; the Central African Republic: 1.0; the Democratic Republic of Congo: 5.9; Gabon: 0.2; Equatorial Guinea: 0.1; Republic of Congo: 0.3 (FAOSTAT 2011).

represents more than 30 times the area presently cultivated (7 times if only nonforested suitable land is considered).

- *The Central African Republic* is estimated to have a reserve of 12.3 million ha, approximately a third under forest, which represents more than 6 times its area currently cultivated (more than 4 times if only nonforested suitable land is considered).
- *Gabon* is estimated to have 7.4 million ha available, almost 90 percent of which is currently under forest, representing about 19 times its area presently under cultivation. If only nonforested suitable land is considered, the land potentially available in that country amounts to 2.5 times its currently cultivated land.

3 CHAPTER 3

Reconciling Agricultural Development and Forest Protection

So far, deforestation in the Congo Basin countries has been limited because of “passive protection” resulting from low population densities, historical political instability, poor infrastructure, and a business environment that is not conducive to private sector investment. Shifting slash-and-burn smallholder agriculture has been the main driver of deforestation in the Congo Basin countries, but agricultural impacts on the rainforest have been limited partly because of underdevelopment of the agricultural sector. Deforestation rates are more than twice as high in South America and four times as high in Southeast Asia: Brazil and Indonesia currently lose more forest in 2 years and 4 years, respectively, than the six Congo Basin countries together did over the past 15 years.

However, the situation may change in response to exogenous and endogenous variables. These countries have a strong potential to expand their cultivation areas and increase productivity, resulting in associated income, jobs, and revenues. The increasing global demand for food and biofuels, as well as potential changes in some key-commodities-producing countries, would increase pressure for plantation establishment in the Congo Basin.[27] Political stability, improvement in the business environment, and infrastructure development would also contribute to attracting private investment in agricultural expansion.

Overall agricultural production expansion can be achieved without converting primary forests. The high proportion of suitable uncultivated, nonforested land seems to indicate that there is a path to transform the agricultural sector in the Congo Basin while limiting the negative effects on forests. Sufficient land resources and agricultural development paths exist that could lead to substantial agricultural production increases without drawing on currently forested areas. This would mean enhancing food security, poverty reduction, and economic growth while preserving the rainforest for the benefit of the world community.

It will not be an easy path. For that goal to be achieved, each country must establish strong agricultural policies, with priority given to a clear and participatory zoning exercise to define the areas suitable for agricultural expansion (nonforest zones) and to smallholder farming intensification (through climate-smart agriculture, for instance). Strong land management policies—especially land tenure clarification and security—are a prerequisite to provide smallholders with an incentive for investing in their land and to reduce the risk of negative social and environmental externalities in the case of land expansion. Transport infrastructure development choices need to be made on the basis of their potential impacts (direct, indirect, and induced) on forests.

The Congo Basin countries need to identify policies that favor a development path that can reconcile increasing agricultural production and preservation of primary forests. The international community

27 As is the case in Indonesia, where the government recently declared a moratorium on any new oil palm plantations because of REDD+ policies.

recognizes that forests (especially tropical forests) are a key element in the fight against global warming. Development of the agricultural sector in the Congo Basin should be defined in a way that will respond to the urgent need to increase production, support job creation, and limit adverse effects on natural forests. The Congo Basin countries are at a crossroads where they can define a forest-friendly path for agricultural development. They are not yet locked into a development path that takes a high toll on forests. The REDD+ mechanism, under discussion among the parties of the United Nations Framework Convention on Climate Change (UNFCCC), has the potential to generate significant financial flows to help developing countries sustain economic development while reducing pressures on their natural forests.[28]

The following section offers some recommendations and guidance on how the REDD+ mechanism could be used to support new development paths that would reconcile economic growth and poverty alleviation with forest preservation. It includes policy recommendations that could help the Congo Basin countries design a strategy to unlock the potential of the agricultural sector while limiting adverse effects on forests.

Prioritize Agricultural Expansion in Non-forested Areas

The Congo Basin contains large amounts of high-potential non-forested land in low population density areas, which implies that there is no need, in principle, to draw on forested areas to satisfy the future demand for agricultural commodities. However, past trends show that forested areas may be more vulnerable to agriculture expansion; if forests are to be protected, governments need to establish proactive measures.

A comprehensive, participatory land use planning exercise can determine the various land uses to be pursued on the national territories. Participatory land use planning can maximize economic and environmental objectives and reduce problems resulting from overlapping titles and potentially conflicting land uses. While planning for economic development, particular attention should be given to protect high-value forests in terms of biodiversity, watershed, and cultural values. Optimally, mining, agriculture, and other activities should be directed away from forests of great ecological value. In particular, agricultural development should primarily target degraded lands.[29]

Such an exercise requires strong multi-sectoral coordination. Trade-offs among different sectors and within sectors need to be clearly understood by the stakeholders so they can define development strategies at the national level. Such a planning exercise will have to rely on robust socioeconomic analysis as well as coordination among ministries and, in many cases, some form of high-level arbitrage to reconcile potential conflicting land uses. Once completed, the land plan would identify the forest areas that need to be preserved, the areas that can coexist with other land uses, and those that could potentially be converted to other uses.

One output of land use planning could be the identification of growth poles and major development corridors that could be established in a coordinated manner, with the involvement of all government entities as well as the private sector and civil society. In the Congo Basin, this approach would likely be driven by natural resources and would provide upstream and downstream links around extractive industries. While a land use planning exercise definitely needs to be conducted at the country level (and even at the provincial level), the Economic Community of Central African States (ECCAS) has adopted the corridor approach at the regional level to foster synergies and economies of scale among member states.

28 REDD+ refers to reducing greenhouse emissions from deforestation and forest degradation and considering the role of conservation, sustainable forest management, and enhancement of forest carbon stocks in developing countries.

29 The Global Partnership on Forest Landscape Restoration estimates that more than 400 million ha of degraded land in Sub-Saharan Africa offers opportunities for restoring or enhancing the functionality of mosaic landscapes that combine forest, agricultural, and other land uses.

Enforce Forest Protection and Manage the Agricultural Frontier

Once the status of the forested areas is officially defined, the boundaries need to be enforced. The agricultural frontier can only be contained 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 restrain 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 farmers to maintain or increase their production without converting new lands.

Enforcement measures will have to go hand in hand with the promotion of more intensive agricultural practices because intensification, while increasing productivity, is likely to lead to more conversion of forested lands in response to unemployment and a growing demand (both internal and potentially external) for agricultural products.

Community-based systems for forest management can contribute to managing the agricultural frontier. Experiences in the Democratic Republic of Congo show that a combination of agricultural and forestry activities conducted by the communities according to a land use plan defined at the local level can have positive effects in terms of poverty alleviation and forest preservation. Supporting an adequate framework for community forestry in the Congo Basin is key; while most of the legal frameworks in the Basin countries mention "community-based forest management," work remains to be done to operationalize this concept.

Clarify Land Tenure Governance

Forests are often considered to be "free access" areas and are not tagged with property rights; it is considered that all forested lands fall under state ownership. Moreover, tenure laws in most Congo Basin countries directly link forest clearing (mise en valeur) with land property recognition and thus create an incentive to target forested lands to expand agriculture. The land tenure laws need to be adjusted to delink property recognition and forest clearing.

Congo Basin countries must strengthen their rural land governance and tenure recognition frameworks. Effective systems of land use and access rights—and property rights in general—are essential to improve management of natural resources and stimulate sustainable agriculture. Improving these systems is a priority to provide farmers, especially women, with incentives to make long-term investments in agricultural transformation.

In addition to encouraging farmers to invest in their land, clarification of land rights over the whole territory would allow the Congo Basin countries to become more proactive and to engage in more successful negotiations with potential large investors. Field evidence (Deininger and Byerlee 2011) indicates that policy, regulatory, and institutional deficiencies increase environmental and social risks related to large private land development investments. Land governance is weak; in particular, there is a risk that investors will acquire land essentially for free and without consideration for local rights or environmental issues, with potentially far-reaching negative consequences.[30] A strong correlation has been shown between applications for large tracts of land and the weakness of rural land tenure recognition in the target countries; this suggests that the Congo Basin countries are at risk.

Promote Climate-Smart Agriculture

Agriculture in the Congo Basin is underperforming, and the prospects for productivity increases are huge. However, more intensive practices may not necessarily be environmentally sustainable in the long term. Without the concurrent adoption of sustainable natural resource management practices, more intense production could lead to increased soil erosion and greater

30 For example, on-the-ground verification of recent land acquisitions in the Democratic Republic of Congo has uncovered irregularities in land allocation processes: Although all concessions of at least 1,000 ha must be approved by the minister of land affairs, data collection in Katanga and Kinshasa Provinces suggests that governors have in some cases awarded multiple concessions of up to 1,000 ha each to individual investors to get around the required approval procedure (Deininger and Byerlee 2011).

vulnerability to external shocks, climate variability, and climate change. This two-pronged approach is generally referred to as climate-smart agriculture (see box 3.1). In the Congo Basin countries, climate-smart agriculture would mainly take the form of conservation agriculture (minimal soil disturbance, meaning no tillage and direct seeding; maintenance of a mulch of carbon-rich organic matter that protects and feeds the soil; rotations and associations of crops—including trees—that would include nitrogen-fixing legumes) and agroforestry (intensive use of trees and shrubs in agricultural production).

The trend of productivity gains in smallholder agriculture in the Congo Basin over the past few years could be accelerated. It has been minimal and has even declined in terms of land productivity, mainly because of reduced fallow periods, absence of fertilizers and improved varieties, and pest and disease problems. The main food staple crops in the forest zone are roots, tubers, bananas, and plantains, and prospects for a yield increase are limited because of the slow vegetative propagation. However, labor productivity has the potential to increase greatly through mechanization, including the labor-intensive postharvest operations of women. Signs of mechanization can be seen but remain limited. The use of fertilizers, which is practically nonexistent on small farms, could increase the yields. However, this potential could only be optimized if progress were simultaneously made on improved varieties—it would not be economically profitable to invest in fertilizers without also promoting improved varieties.

Box 3-1. Climate-Smart Agriculture: Enhanced Food Security, Reduced Vulnerability, and Climate Change Mitigation

Climate change is expected to exacerbate the challenges faced by agriculture. In many areas of the world, where agricultural productivity is still low and the means of coping with adverse events are limited, it is expected to reduce productivity to even lower levels and make production more erratic. Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and lower variability in the face of climate risk, as well as risks of an agro-ecological and socioeconomic nature. A more productive and resilient agriculture requires transformations in the management of natural resources (e.g., land, water, soil nutrients, and genetic resources) and higher efficiency in the use of these resources and inputs for production. Transitioning to such systems could also generate significant mitigation benefits by increasing carbon sinks and reducing emissions per unit of agricultural product.

Source: FAO 2010a.

Regarding plantation agriculture, productivity gains are typically realized through mechanization and the use of improved planting materials and fertilizers. New techniques in Southeast Asia for oil palm and rubber are rapidly transferred to Africa, as the same multinational plantation companies operate on both continents.[31] Margins of increase can be found at any level of the chain in large-scale plantations: in production (with improved varieties, better use of fertilizer, and better agricultural techniques) and in processing (where the extraction rates are very low because of obsolete equipment).

Very little attention has been paid to peri-urban agriculture; so far, its development has been spontaneous in the Congo Basin countries. Deforestation and forest degradation occur primarily around the urban centers in these countries, owing to anarchical agricultural expansion in response to rising demand for food and energy. Peri-urban agriculture deserves special attention: if it were well organized, it could not only secure food provision for growing urban populations in most Congo Basin countries but could also provide sustainable solutions to unemployment and waste management.

One aspect often neglected in Africa is the postharvest management of food production. Major losses

31 An example of an improved production technology is rubber production stimulation with the RRIM Flow method imported from Malaysia. This stimulation with a growth hormone occurs with a special gas instead of a liquid and is more efficient.

occur each year because of poor storage capacities and inefficient marketing strategies. There is no option for adjusting to market prices. Governments should prioritize postharvest management of crops and food production, as they are clearly part of a global strategy for climate-smart agriculture.

Reinvigorate Research and Development

R&D capacities in the Congo Basin, with the exception of Cameroon, have been dismantled over the past decades. National research centers are dysfunctional and unable to take on the challenge of transforming the agricultural sector. Partnerships need to be established with international research centers (members of CGIAR) to stimulate agricultural research in the Congo Basin and progressively strengthen the national capacities.

Many climate-smart techniques have been successfully tested and implemented all over the world, but the Congo Basin has not been a focus for such research; very few experiments exist in the Basin, and they are limited in scale. Applied research is needed to adjust these techniques and practices to the agro-ecological zones of the Congo Basin and to make the best use of the agricultural inputs (water, fertilizers, etc.).

Research on genetics has largely neglected the most common staple food crops in the Congo Basin, such as yams, plantains, and cassava. So far, the potential to increase their productivity and improve their resistance to disease and tolerance to climatic events remains untapped. International research centers, along with African organizations (for example, the African Union and NEPAD) and national research centers should focus on "neglected crops" as one priority to increase crop production in Africa.

In addition to R&D activities, extension services need to be revitalized to mainstream new agricultural practices in rural areas. Experimental farms could be set up to facilitate the penetration of new practices. Though it has not yet played this role in the Congo Basin, large-scale commercial agriculture could pave the way for improvements in agricultural productivity and support R&D activities as it has in other regions; it could promote new techniques and technologies, new varieties and inputs. Large-scale private operators could also help fill the gaps in extension services and reach out to a large number of smallholders.

Empower Smallholder Farmers

With about half the population active in agriculture in most countries of the Congo Basin, there is a need to foster sustained agricultural growth based on smallholder involvement. Experience in other tropical regions shows that this is possible. Thailand, for example, considerably expanded its rice production area and became a major exporter of other commodities by engaging its smallholders through a massive land titling program and government support for research, extension, credit, producer organizations, and rail and road infrastructure development.

Promote a Sustainable Large-Scale Agribusiness Industry

The superior ability of large companies to overcome the market imperfections prevailing in the Congo Basin countries—especially access to finance, technology, inputs, processing, and markets—makes these companies potentially important and desirable actors in a sustainable agricultural development strategy. Large operations can generate considerable employment, especially for rubber, palm oil, and sugar production, and this employment tends to benefit the landless and the very poor. They can also play a positive role in reducing deforestation and forest degradation by employing relatively large populations that would then forgo their traditional slash-and-burn practices. In addition to providing employment, the estates have a legal obligation in most Congo Basin countries to provide social infrastructure (schools, hospitals, etc.).

Although largely exempted from significant land grabbing attempts so far, the Congo Basin forests may be at risk in the future. Moreover, countries with a high proportion of suitable land currently under forest—such as the Democratic Republic of Congo, the Republic of Congo, Cameroon, Gabon, and Equatorial Guinea—will feel pressure to allocate forested land for cultivation, especially because logging can generate large rents on top of subsequent land cultivation returns. A moratorium has been applied to logging concessions in the Democratic Republic of Congo; however, some fear that logging interests will submit applications for forested land concessions for agricultural development as a way of getting around the regulations and will then not make significant agricultural investments. This phenomenon has occurred in countries in Southeast Asia. Current institutional deficiencies and associated gaps in the provision of public goods in the Congo Basin countries may result in large operations enjoying a competitive edge, while insufficient attention is paid to social and environmental externalities and no attempt is made to maximize the potential effect of private investment on poverty reduction.

To overcome these limitations, governments should establish stronger policies vis-à-vis large agricultural investments. Large land applications should be oriented toward abandoned plantations and suitable nonforested land, which is sufficiently availabile, and all possible environmental externalities should be assessed. All formal or customary land (and possibly water) rights in the potentially suitable areas should be identified and respected, and transparent and voluntary transfers promoted. Large firms should be encouraged to fill gaps in public services, transport infrastructure, and applied R&D, for example, and possibly to enter into arrangements with smallholders that would maximize technological spillovers and the sharing of benefits with local populations (contract farming, nucleus/outgrower schemes, etc.).

Foster Win-Win Partnerships between Large-Scale Operators and Smallholders

The current dualistic profile of agriculture in the Congo Basin (smallholder and large-scale) could become an engine for transforming agriculture through win-win partnerships. While this scenario has not yet materialized in the Basin, in many places in the world meaningful partnerships between smallholders and large-scale operators have yielded successful results and promoted a well-balanced development of agriculture (box 3.2)

Develop Transport Infrastructure

Transport infrastructure development should be the cornerstone of agricultural development strategies. In many developing countries, transport infrastructure construction has had a major impact on agricultural trade, farm intensification and diversification, and ultimately rural poverty. In some countries, returns to road investments in terms of rural household welfare have been estimated to be higher than returns to any other

Box 3-2. Partnerships Between Large-Scale Operators and Smallholders

In Indonesia (which is the world's largest palm oil producer), smallholders account for about a third of the country's production. Because of processing requirements, the rapid deterioration of fresh fruit, and poor access to capital and planting material, most small palm oil producers are in formal partnerships with palm oil companies through nucleus/outgrower schemes. Still, the average income from oil palm cultivation is much higher than from subsistence farming or competing cash crops, and it is estimated that oil palm expansion in Indonesia significantly helped reduce rural poverty. Rubber was originally grown on large plantations in humid forest areas of Southeast Asia but, because of rising labor and land costs, it increasingly became a smallholder production. Farms of 2–3 ha now make up 80 percent of world production. This situation was made possible by the development of improved hevea clones and techniques suited to production and processing at the smallholder level. Smallholders in Indonesia produce rubber in improved agro-forestry systems that maintain carbon stocks and species richness. While returns from such systems are lower than those of monocultures, reduced risk and lower initial capital costs more than compensate, and efforts are under way to certify rubber from these systems to obtain a price premium.

kind of public spending.[32] In the Congo Basin countries, transport infrastructure construction will be critical to set in motion a virtuous cycle of development for cropping expansion on suitable nonforested land (the bulk of which is located far from infrastructure) and for intensification of smallholder agriculture.

Create Positive Incentives and Remove Potential Negative Incentives

New incentive schemes will have to be set up, especially if the adoption of new practices means a loss of income in the first years. These incentives could include payments for environmental services (PES). At the country level, access to credit or provisions in kind (including access to land, markets, or production inputs) could be established to stimulate the adoption of sustainable agricultural practices. On a broader level, market-based incentives could be set up through certification schemes to support large and small producers in large agro-industries (e.g., palm oil and rubber) that adhere to sustainable practices.

On the other hand, measures that might adversely affect forests must be removed. Such negative incentives include regulatory provisions that link property rights with forest clearing and credit schemes offered by commercial banks to support activities that require deforestation. Removing such perverse incentives has proved to be particularly efficient in terms of curbing deforestation: in Brazil, vetoes from the Banco do Brazil on agricultural credit for farmers who wanted to clear areas of the Amazon Forest immediately reduced pressures on the forest.

32 This is the case in Ethiopia, for example (Mogues, Ayele, and Paulos 2008).

CONCLUSION AND OUTLOOK

New dynamics in deforestation trends are likely to emerge in the Congo Basin. While subsistence activities such as small-scale agriculture and fuelwood collection are currently the main causes of deforestation and degradation in the Congo Basin, new threats are expected to emerge and aggravate the pressures on natural forests. Local and regional development, population increases, and global demand for commodities are expected to jointly drive accelerated deforestation and forest degradation, if business-as-usual models are applied.

Congo Basin countries are at a crossroads. They are not locked into a development path that will come at a high cost to forests. They can define a new path toward forest-friendly growth. The question is how to link economic change with smart measures and policy choices so that the Congo Basin countries sustain and benefit from their extraordinary natural assets over the long term. In other words, they need to determine how to leapfrog the dip in forest cover usually observed in the forest transition curve.

New environmental finance mechanisms can help the Congo Basin countries transition toward a forest-friendly development path. Environmental finance includes climate funding for adaptation and mitigation efforts in general (and REDD+ in particular) as well as financing for biodiversity, wetlands, or soil restoration. In accessing these new resources, countries may consider a number of issues to prioritize activities and effectively allocate the funds. It is up to national governments to define how these various mechanisms fit into their own development, how to best use the resources, and whether and how to meet the relevant criteria of funds or mechanisms. They are also responsible for assessing the risks and benefits associated with particular funds, including the costs of establishing relevant information and institutional conditions.

REDD+ provides an important opportunity for the Congo Basin countries to develop strategies that will move them toward sustainable development while protecting the natural and cultural heritage of the region. This new focus on forest protection in international climate agreements, in combination with the availability of significant new financial resources, moves sustainable forest management up in the political agenda and has facilitated dialogues in many countries among forest agencies and the ministries and entities that regulate broader industrial and agricultural development.

However, the conditions and scale of eventual REDD+ financing remain uncertain. In particular, it is not clear how results-based financing will be measured, what the criteria for payments will be, and how much funding will be made available. So far, these issues have not been clarified by international negotiations, nor have the rules that will guide the establishment of national reference levels or reference emissions levels that would allow fully measured results-based financing. In the near to medium term, there will likely be a multiplicity of donors, and fragmentation of REDD+ financing, including a fragmented REDD+ market. In this complex landscape, it is important for governments to prioritize activities, partnerships, and processes. Engagement with each donor and its specific requirements and with each process related to multilateral funding or emerging carbon markets requires significant resources.

"No-regrets" measures should yield benefits regardless of the shape and volume of a future REDD+ mechanism under the UNFCCC. Such measures, while differing from country to country, should seek to create the enabling conditions for the implementation of inclusive and forest-friendly growth. This report has outlined a number of no-regrets actions. It is up to the Congo Basin countries to use them as general guidelines for more detailed discussion as they engage in the preparation of their national REDD+ strategies.

REFERENCES

Andersen, L. E., Granger, CWJ, Reis, EJ, Weinhold, D. & Wunder, S., 2002. The Dynamics of Deforestation and Economic Growth in the Brazilian Amazon. Cambridge, UK: Cambridge University Press.

Bruinsma, J., 2003. "World Agriculture towards 2015/2030," ed. FAO, Rome.

Bruinsma, J. 2009. "The Resource Outlook for 2050: By How Much Do Land, Water and Crop Yields Need to Increase by 2050?" Expert Meeting on How to Feed the World in 2050, FAO, Rome, 24-26 June 2009

Buys, P., U. Deichmann, and D. Wheeler. 2006. "Road Network Upgrading and Overland Trade Expansion in Sub-Saharan Africa." Policy Research Working Paper 4097, December 2006, World Bank, Washington DC.

CAADP (Comprehensive Africa Agriculture Development Programme). 2010. "Multi-donor Trust Fund World Bank." Status Report, November, 2010.

Collier, P. 2007. The Bottom Billion: Why the Poorest Countries Are Failing and What Can Be Done About It. Oxford: Oxford University Press.

De Wasseige, C., D. Devers, P. De Marcken, R. Eba'a Atyi, R. Nasi, and P. Mayaux. 2009. The Forests of the Congo Basin—State of the Forest 2008. Luxembourg: Publications Office of the European Union.

De Wasseige, C., P. de Marcken, F. Hiol-Hiol, P. Mayaux, B. Desclee, R. Nasi, A. Billand, P. Defourny, and R. Eba'a Atyi, eds. 2012. The Forests of the Congo Basin—State of the Forest 2010. Luxembourg: Publications Office of the European Union.

Deininger, K., and D. Byerlee. 2011. "Rising Global Interest in Farmland—Can It Yield Sustainable and Equitable Benefits?" World Bank, Washington DC.

Delhague, C., and P. Defourny. 2011. "Analyse quantitative des causes de la déforestation et de la dégradation des forêts en République démocratique du Congo." Rapport Final, Université Catholique de Louvain. Requested by FAO-RDC and Coordination Nationale REDD-RDC.

ECAM III. 2007. " Troisième Enquête Camerounaise auprès des Ménages." Institut National de la Statistique, Yaoundé, Cameroon.

Food and Agriculture Organization of the United Nations (FAO)., 2003. "Land in Agricultural, Pastoral and Forestry Context." In Multilingual Thesaurus on Land Tenure and Forestry Context, chapter 7. Rome: FAO.

———. 2009a. Statistical Yearbook 2009. Rome: FAO.

———. 2009b. The State of Food Insecurity in the World." FAO, Rome.

———. 2010a. "Climate-Smart Agriculture—Policies, Practices and Financing for Food Security, Adaptation and Mitigation." Paper prepared for The Hague Conference on Agriculture, Food Security and Climate Change. FAO, Rome.

———. 2010b. "Jatropha: A Smallholder Bioenergy Crop—The Potential for Pro-Poor Development." FAO, IFAD, Rome.

———. 2011. State of the World's Forests 2011. FAO, Rome.

FAOSTAT. 2011. http://faostat.fao.org (accessed January-February 2011).

Hansen, M., S. Stehman, P. Potapov, T. Loveland, J. Townshend, R. Defries, K. Pittman, B. Arunarwati, F. Stolle, M. Steininger, M. Carroll, and C. DiMiceli. 2008. "Humid Tropical Forest Clearing from 2000 to 2005 Quantified by Using Multitemporal and Multiresolution Remotely Sensed Data." Proceedings of the National Academy of Sciences (PNAS) 105 (27): 9439–44.

Holyle, D., and P. Levang. 2012. "Oil Palm Development in Cameroon." WWF (World Wildlife Fund) report, April 2012, in partnership with Institut de Recherche pour le developpement and CIFOR (Center for International Forestry Research), Yaoundé, Cameroon.

Howitt, R.E. 1995. "Positive Mathematical Programming." American Journal of Agricultural Economics 77 (2): 23–31.

IFPRI (International Food Policy Research Institute). 2009. 2009 Global Hunger Index. IFPRI, Washington DC. http://www.ifpri.org. (last accessed in March 2012)

IIASA (International Institute for Applied Systems Analysis). 2010. "Modelling Impacts of Development Trajectories on Forest Cover and GHG Emissions in the Congo Basin." Report prepared under World Bank contract. (The data presented in figure 1.6 of this report were communicated by IIASA as an addendum to the report.)

IIASA (International Institute for Applied Systems Analysis). 2011. Modeling Impacts of Development Trajectories on Forest Cover and GHG Emissions in the Congo Basin. Washington, DC: World Bank.

Kissinger, G. 2011. "Linking Forests and Food Production in the REDD+ Context." CCAFS (Climate Change, Agriculture and Food Security) Policy Brief 3, CGIAR Research Program on Climate Change, Agriculture and Food Security, Copenhagen, Denmark.

Karsenty, A., and Samuel Assemble. 2010. "Diagnostics des Systèmes de Gestion foncière—Renforcement des capacités institutionnelles liées à la réduction des émissions dues à la dégradation et à la déforestation (REDD) en vue d'une gestion durable des forêts du Bassin du Congo." Rapport COMIFAC (Central Africa Forests Commission).

Kouassigan, A. 1966. L'homme et la terre, droits fonciers coutumiers et droits de propriété en Afrique occidentale. Paris Office de la recherche scientifique et technique outre-mer (ORSTOM): Berger-Levrault.

López, R., and Gregmar I. Galinato. 2004. "Trade Policies, Economic Growth and the Direct Causes of Deforestation." University of Maryland, College Park, Maryland.

Loi N° 66/343 du 07 juin 1966. Gouvernement de la République Démocratique du Congo (Zaïre), Kinshasa.

Loi N° 72-021 du 20 juillet 1973 portant régime général des biens, régime foncier et immobilier et régime des suretés telle que modifiée et complétée par la loi N° 80-008 du 18 juillet 1980. Cabinet du président de la République, Journal Officiel de la RDC, Kinshasa, 1973.

McCarl, B., and T. Spreen. 1980. "Price Endogenous Mathematical Programming as a Tool for Sector Analysis." American Journal of Agricultural Economics 62(1): 87–102.

Megevand, C., A. Mosnier, J. Hourticq, K. Sanders, N. Doetinchem, and C. Streck. 2012. Deforestation Trends in the Congo Basin, Reconciling Economic Growth and Forest Protection (chapter 1). Sustainable Development Department, Africa Region, World Bank, Washington DC.

Mogues, T., G. Ayele, and Z. Paulos. 2008. "The Bang for the Birr—Public Expenditures and Rural Welfare in Ethiopia." IFPRI Research Report 160, IFPRI, Washington DC.

Mosnier, A., P. Havlik, M. Obersteiner, and K. Aoki. 2012. Modeling Impacts of Development Trajectories on Forest Cover in the Congo Basin. Laxenburg, Austria: International Institute for Applied Systems Analysis Environment Research and Education (ERE).

ReSAKSS. 2011. http://www.resakss.org (accessed January-February 2011).

Tollens, E. 2010. "Potential Impacts of Agriculture Development on the Forest Cover in the Congo Basin." Report prepared under World Bank contract, World Bank, Washington DC.

Transparency International. 2010. http://www.transparency.org. (last accessed in March 2012)

UNFPA (United Nations Population Fund). 2009. State of World Population, 2009 and 2009 World Population Data Sheet. UNFPA, New York.

Walker, R. T. 1993. "Deforestation and Economic Development," Canadian Journal of Regional Science 16(3): 481–497.

World Bank. 2007. World Development Indicators. World Bank, Washington DC.

———. 2009. "Awakening Africa's Sleeping Giant: Prospects for Commercial Agriculture in the Guinea Savannah Zone and Beyond." World Bank, Washington DC.

———. 2010a. Doing Business 2010. Washington DC: World Bank. http://www.doingbusiness.org (last accessed in March 2012)

———. 2010b. "Rising Global Interest in Farmland: Can It Yield Sustainable and Equitable Benefits?" World Bank, Washington, DC.

———. 2010c. "World Development Indicators and Global Development Finance." World Bank, Washington DC. http://databank.worldbank.org (accessed 30 July 2010).

Zhang, Q., C. Justice, P. Desanker, and J. Townshend. 2002. "Impacts of Simulated Shifting Cultivation on Deforestation and the Carbon Stocks of the Forests of Central Africa." Agriculture, Ecosystems & Environment 90 (2): 203–09.

Zhang, Q., C. Justice, M. Jiang, J. Brunner, and D. Wilkie. 2006. "A GIS-Based Assessment on the Vulnerability and Future Extent of the Tropical Forests of Congo Basin." Environmental Monitoring and Assessment 114 (1–3): 107–21.

ANNEX: THE CONGOBIOM MODEL

UNDERSTANDING THE IMPACT OF GLOBAL TRENDS ON THE CONGO BASIN

The nature and amplitude of deforestation are likely to significantly change in the Congo Basin in the next two decades. Compared with other tropical forest blocks, deforestation and forest degradation have been globally low. They have been traditionally and dominantly caused by shifting cultivation and fuelwood collection in Central Africa; however, there are signs that the Basin forest is under increasing pressure and that deforestation is likely to soon increase through the combined effect of the amplification of the existing drivers and the emergence of new ones.

- **Current internal drivers of deforestation are expected to amplify.** Demographic factors (population growth as well as rural/urban profile) are determinant causes of deforestation and forest degradation in the Congo Basin (Zhang et al. 2006). If existing rates of demographic growth remain constant, then the population of the Basin will double by 2035–2040. In most Basin countries, the population is still largely involved in subsistence farming and predominantly relies on fuelwood for domestic energy.
- **New external drivers are emerging in the context of a more and more globalized economy.** Congo Basin countries are poorly connected to the globalized economy; thus, the drivers of deforestation have so far mainly been endogenous (essentially population-driven). However, signs suggest that the Basin may no longer be immune to global demands for commodities—directly or indirectly—with increasing pressure from a variety of forces, including oil and mineral extraction, road development, agribusiness, and biofuels.

A modeling approach has been elaborated to investigate the effect of the predicted main future drivers of deforestation in the Congo Basin on land-use change and resulting greenhouse gas (GHG) emissions by 2030. The High Forest Cover, 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 drivers of deforestation. To include global parameters, we took a macroeconomic approach based on the GLOBIOM model (Global Biosphere Management Model).

GLOBIOM is a partial equilibrium 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 (see box A.1). GLOBIOM includes the main sectors involved in land use: agriculture, forestry, and bioenergy. It is an optimization model that searches for the highest possible levels of production and consumption, given the resource, technology, and political constraints in the economy (McCarl and Spreen 1980). The demand in the GLOBIOM model 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. The optimization procedure ensures that the spatial production allocation minimizes the resource, technology, processing, and trade costs. Final equilibrium quantities result from an iterative procedure between supply and demand in which prices finally converge to a unique market price. The box provides a detailed description of the GLOBIOM model.

Box A.1. Underlying Assumptions

GLOBIOM relies mainly on neoclassical assumptions. Agents are rational: consumers want to maximize their utility and producers want to maximize their profits. The markets are perfectly competitive, with no entry and no exit costs and homogeneous goods, which implies that agents have no market power and that the profits are equal to zero at the equilibrium. The equilibrium prices ensure that demand equals supply. Agents have perfect knowledge; that is, no uncertainty is taken into account. We assume that buyers are distinct from sellers so that consumption and production decisions are made separately. Markets are defined at the regional level, meaning that consumers are assumed to pay the same price across the whole region; however, selling prices could vary across the region because production costs and internal transportation costs are defined at the pixel level.

GLOBIOM is designed for the analysis of land use changes around the world.[33] The biophysical processes modeled (agricultural and forest production) rely on a spatially explicit dataset that includes soil, climate/weather, topography, land-cover/use, and crop management factors.[34] Harvesting potentials in cropland are computed with the EPIC model (Williams 1995), which determines crop yields and input requirements based on relationships among soil types, climate, hydrology, and so on. Timber-sustainable harvesting potential in managed forests is computed from the G4M model's forest-growth equations. The GLOBIOM model 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 model is calibrated by employing positive mathematical programming (Howitt 1995), which involves 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 unobservable constraints to production. It is used to calibrate crop, sawn-wood, wood-pulp, and animal calories production.

GLOBIOM is a global simulation model that divides the world into 28 regions. One of these regions is the Congo Basin (the six highly forested countries covered in this 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 cost and the trading costs (tariff and transportation costs).

The CongoBIOM is an elaboration of the GLOBIOM.[35] The Congo Basin region was specifically created within the GLOBIOM, and additional details 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 102 km and 502 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 CongoBIOM model was calibrated on the data collected in the 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. We first investigated 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 (see table A.1). The selection of the policy shocks was based on a literature review and was

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

34 The land-cover data for 2000 are taken from the Global Land Cover GLC2000.

35 Mosnier et al. (2012), prepared by the IIASA team, is an output of this study.

validated during two regional workshops with local experts. Policy shocks were chosen to describe impacts from both internal and external drivers. The former were (S1) increase in international demand for meat and (S2) increase in international demand for biofuel factors of deforestation. The latter were (S3) improved transport infrastructure, (S4) decrease in fuelwood consumption, and (S5) improved agricultural technologies. Table A.1 describes the scenarios and the main results. The objectives 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 areas and GHG emissions from deforestation with respect to different drivers.

Data availability and quality were major challenges for the modeling approach. Spatially explicit input parameters are mainly related to resource availability, production costs, and production potentials. Crop-harvested areas and forest carbon stocks have been allocated at the pixel level by downscaling methodologies that are subject to error. Uncertainty about land cover is especially prevalent in the Congo Basin owing to the permanence of clouds and the limited number of images in the past. Despite a significant effort to enhance both availability and quality of the data used in the model (through a data collection campaign in all six countries), limitations persisted. Consequently, we decided that the modeling exercise would be primarily used to strengthen the understanding of deforestation dynamics and causal chains (internal/external drivers) in the Basin. The quantitative outputs of the model presented in table A.1 should be used only as a comparison of the different scenarios. Validation of these data would require additional statistics at a finer resolution level and would ideally be available for several years.

Table A.1. Policy Shocks Tested with CongoBIOM

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% 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% 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% 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: Infrastructure	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% 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%) 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 1m^3 to 0.8 m^3 per year.	Within the 0.4 Mha deforested per year on the baseline, fuelwood counts for 30%. A 20% decrease in fuelwood consumption induces therefore a 6% 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% for cash crops.	Calories intake per capita increases by 30% and imports are reduced. Increase in emissions from deforestation by 51% over the 2020–2030 period because consumption increases faster than that of crop productivity.

Source: IIASA 2011

GLOBIOM MODEL—DETAILED FORMAL DESCRIPTION

Objective function

$$\begin{aligned}\text{Max } WELF_t = & \sum_{r,y}\left[\int \phi^{demd}_{r,t,y}\left(D_{r,t,y}\right)d(\cdot)\right] - \sum_{r}\left[\int \phi^{splw}_{r,t}\left(W_{r,t}\right)d(\cdot)\right] \\ & - \sum_{r,l,\tilde{l}}\left[\int \phi^{lucc}_{r,l,\tilde{l},t}\left(\sum_{c,o,p,q} Q_{r,t,c,o,l,\tilde{l}}\right)d(\cdot)\right] \\ & - \sum_{r,c,o,p,q,l,s,m}\left(\tau^{land}_{c,o,p,q,l,s,m}\cdot A_{r,t,c,o,l,s,m}\right) \\ & - \sum_{r}\left(\tau^{live}_{r}\cdot B_{r,t}\right) - \sum_{r,m}\left(\tau^{proc}_{r,m}\cdot P_{r,t,m}\right) \\ & - \sum_{r,\tilde{r},y}\left[\int \phi^{trad}_{r,\tilde{r},t,y}\left(T_{r,\tilde{r},t,y}\right)d(\cdot)\right].\end{aligned} \tag{1}$$

Exogenous demand constraints:

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

Product balance

$$\begin{aligned}D_{r,t,y} \leq & \sum_{c,o,p,q,l,s,m}\left(\alpha^{land}_{t,c,o,l,s,m,y}\cdot A_{r,t,c,o,l,s,m}\right) + \alpha^{live}_{r,t,y}\cdot B_{r,t} \\ & + \sum_{m}\left(\alpha^{proc}_{r,m,y}\cdot P_{r,t,m}\right) + \sum_{\tilde{r}} T_{\tilde{r},r,t,y} - \sum_{\tilde{r}} T_{r,\tilde{r},t,y}.\end{aligned} \tag{3}$$

Land use balance

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

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

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

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

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

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

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

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

Variables

D	demand quantity (tons, m3, kcal)
W	irrigation water consumption (m3)
Q	land use/cover change (ha)
A	land in different activities (ha)
B	livestock production (kcal)
P	processed quantity of primary input (tons, m3)
T	interregionally traded quantity (tons, m3, 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, m3, kcal)
α^{land}	crop and tree yields (tons/ha, or m3/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/m3)
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 (m3/ha)
ε	emission coefficients (tCO2eq/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)	

(Table A.1 continued)

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)	FORAF	
Maximum share of sawlogs in the mean annual increment (m^3/ha/ year)	Kindermann et al. (2006)	
Harvestable wood for pulp production (m^3/ha/year)	Kindermann et al. (2006)	
Mean annual increment (m^3/ha/year)	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.

REFERENCES

Agritrade. 2009. "The Cocoa Sector in ACP-EU Trade." Executive brief, October 2009.

Andersen, P., and S. Shimorawa. 2007. "Rural Infrastructure and Agricultural Development." In *Rethinking Infrastructure for Development.* Annual World Bank Conference on Development Economics.

Angelsen, A., M. Brockhaus, M. Kanninen, E. Sills, W. D. Sunderlin, and S. Wertz-Kanounnikoff, eds. 2009. *Realising REDD+, National Strategy and Policy Options*. Bogor, Indonesia: CIFOR.

Atyi, R. E., D. Devers, C. de Wasseige, and F. Maisels. 2009. "Chapitre 1: Etat des forêts d'Afrique centrale: Synthèse sousrégionale." In *Etat de la Forêts 2008*, OFAC-COMIFAC.

Biomass Technology Group. 2005. *Handbook on Biomass Gasification*. H.A.M. Knoef. ISBN: 90-810068-1-9.

Bouet A., Y. Decreux, L. Fontagne, S. Jean, and D. Laborde. 2005. "A Consistent Ad-Valorem Equivalent Measure of Applied Protection Across the World: The MacMap HS6 Database. Document de travail CEPII N. 2004, December 22 (updated September 2005).

Carpentieri, A. E., E. D. Larson, and J. Woods. 1993. "Future Biomass-Based Electricity Supply in Northeast Brazil." *Biomass and Bioenergy* 4 (3): 149–73.

Chiba, S., and Y. Nagata, 1987. "Growth and Yield Estimates at Mountainous Forest Plantings of Improved Populus Maximowiczii." In *Research Report of Biomass Conversion Program. No.3 "High Yielding Technology for Mountainous Poplars by Short- or Mini-Rotation System I."* Japan; Agriculture, Forestry, and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries.

CIESIN (Center for International Earth Science Information Network), Columbia University; and Centro Internacional de Agricultura Tropical (CIAT). 2005. Gridded Population of the World Version 3 (GPWv3): Population Density Grids. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. http://sedac.ciesin.columbia.edu/gpw.

CONCAWE/JRC/EUCAR. 2007. "Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European context." *Well-to-Tank Report* Version 2c: 140.

EPA (Environmental Protection Agency). 2006. *Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990–2020*. Washington, DC: United States Environmental Protection Agency.

FAO (Food and Agriculture Organization of the United Nations). 2006a. *Global Forest Resources Assessment 2005. Progress towards Sustainable Forest Management*. Rome, Italy: Food and Agriculture Organization of the United Nations.

———. 2006b. "Global Planted Forests Thematic Study: Results and Analysis." Planted Forests and Trees Working Paper 38, FAO, Rome.

Gaulier, G., and S. Zignago. 2009. "BACI: International Trade Database at the Product-level, the 1994–2007 Version." CEPII Working Paper.

Grübler, A., B. O'Neill, K. Riahi, V. Chirkov, A. Goujon, P. Kolp, I. Prommer, S. Scherbov, and E. Slentoe. 2007. "Regional, National, and Spatially Explicit Scenarios of Demographic and Economic Change Based on SRES." Technological Forecasting and Social Change 74: 980–1027.

Hamelinck, C. N., and A. P. C. Faaij. 2001. "Future Prospects for Production of Methanol and Hydrogen from Biomass." Utrecht University, Copernicus Institute, Science, Technology and Society, Utrecht, Netherlands.

Hass, M. J., A. J. McAloon, W. C. Yee, and T. A. Foglia. 2006. "A Process Model to Estimate Biodiesel Production Costs." Bioresource Technology 97:671–78.

Havlík, P., U. A. Schneider, E. Schmid, H. Boettcher, S. Fritz, R. Skalský, K. Aoki, S. de Cara, G. Kindermann, F. Kraxner, S. Leduc, I. McCallum, A. Mosnier, T. Sauer, and M. Obersteiner. 2011. "Global Land-Use Implications of First and Second Generation Biofuel Targets." *Energy Policy* 39(10): 5690–702.

Herzogbaum GmbH. 2008. Forstpflanzen-Preisliste 2008. HERZOG.BAUM Samen & Pflanzen GmbH. Koaserbauerstr. 10, A-4810 Gmunden, Austria. Available at http://www.energiehoelzer.at.

Hummels D., J. Ishii, and K. M. Yi. 2001. "The Nature and Growth of Vertical Specialization in World Trade." *Journal of International Economics, Trade, and Wages* 54 (1): 75–96.

IFA (International Fertilizer Industry Association). 1992. *World Fertilizer Use Manual*. Germany: IFA.

IPCC (Intergovernmental Panel on Climate Change). 1996. "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories." Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organisation for Economic Co-Operation and Development, International Energy Agency, Paris.

Izaurralde, R. C., J. R. Williams, W. B. McGill, N. J. Rosenberg, and M. C. Q. Jakas. 2006. "Simulating Soil C Dynamics with EPIC: Model Description and Testing Against Long-Term Data." *Ecological Modelling* 192: 362–84.

Jurvélius, M. 1997. "Labor-Intensive Harvesting of Tree Plantations in the Southern Philippines." Forest Harvesting Case Study 9, RAP Publication: 1997/41, Food and Agriculture Organization of the United Nations, Bangkok, Thailand. http://www.fao.org/docrep/x5596e/x5596e00.HTM.

Kindermann, G. E., M. Obersteiner, E. Rametsteiner, and I. McCallum 2006. "Predicting the Deforestation-Trend under Different Carbon-Prices." *Carbon Balance and Management* 1: 15.

Kindermann, G., M. Obersteiner, E. Rametsteiner, and I. McCallum. 2008. "A Global Forest Growing Stock, Biomass and Carbon Map Based on FAO Statistics." *Silva Fennica* 42 (3): 387–96.

Leduc, S., D. Schwab, E. Dotzauer, E. Schmid, and M. Obersteiner. 2008. "Optimal Location of Wood Gasification Plants for Methanol Production with Heat Recovery." *International Journal of Energy Research* 32: 1080–91.

Rametsteiner, E., S. Nilsson, H. Böttcher, P. Havlik, F. Kraxner, S. Leduc, M. Obersteiner, F. Rydzak, U. Schneider, D. Schwab, and L. Willmore. 2007. "Study of the Effects of Globalization on the Economic Viability of EU Forestry." Final Report of the AGRI Tender Project: AGRI-G4-2006-06, EC Contract Number 30-CE-0097579/00-89.

Renewable Fuels Agency. 2009. "Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation, Technical Guidance Part Two, Carbon Reporting—Default Values and Fuel Chains." Version 2.0, 207. Hastings, U.K.

Ruesch, A., and H. K. Gibbs. 2008. *New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000*. Oak Ridge, TN: Oak Ridge National Laboratory. http://cdiac.ornl.gov.

Russ, P., T. Wiesenthal, D. van Regenmorter, and J. C. Císcar. 2007. *Global Climate Policy Scenarios for 2030 and Beyond—Analysis of Greenhouse Gas Emission Reduction Pathway Scenarios with the POLES and GEM-E3 models*. JRC Reference Reports. Seville, Spain: Joint Research Centre—Institute for Prospective Technological Studies.

Sauer, T., P. Havlík, G. Kindermann, and U. A. Schneider. 2008. "Agriculture, Population, Land and Water Scarcity in a Changing World—The Role of Irrigation." Congress of the European Association of Agricultural Economists, Gent, Belgium.

Seale, J., A. Regmi, and J. Bernstein. 2003. "International Evidence on Food Consumption

Patterns." ERS/USDA Technical Bulletin No. 1904, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

Skalsky, R., Z. Tarasovicova, J. Balkovic, E. Schmid, M. Fuchs, E. Moltchanova, G. Kindermann, P. Scholtz, et al. 2008. *GEO-BENE Global Database for Bio-Physical Modeling v.1.0—Concepts, Methodologies and Data*. The GEOBENE database report. Laxenburg, Austria: International Institute for Applied Analysis (IIASA).

Teravaninthorn, S., and G. Raballand. 2009. *Transport Prices and Costs in Africa: A Review of the Main International Corridors.* Washington, DC: World Bank.

Williams J. R. 1995. "The EPIC model." In *Computer Models of Watershed Hydrology,* ed. V. P. Singh, 909–1000. Highlands Ranch, CO: Water Resources Publications.

You, L., and S. Wood. 2006. "An Entropy Approach to Spatial Disaggregation of Agricultural Production." *Agricultural Systems* 90: 329–47.

You, L., S. Wood, U. Wood-Sichra, and J. Chamberlain. 2007. "Generating Plausible Crop Distribution Maps for Sub-Saharan Africa Using a Spatial Allocation Model." *Information Development* 23 (2–3): 151–59. International Food Policy Research Institute, Washington, DC.

Zomer, R. J., A. Trabucco, D. A. Bossio, and L. V. Verchot. 2008. "Climate Change Mitigation: A Spatial Analysis of Global Land Suitability for Clean Development Mechanism Afforestation and Reforestation." *Agriculture, Ecosystems and Environment* 126: 67–80.

Deforestation Trends in the Congo Basin: Reconciling Economic Growth and Forest Protection

WORKING PAPER 1 | AGRICULTURE

THE WORLD BANK