An Analysis of Access to Central Africa's Rainforests

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An Analysis of Access into Central Africa's Rainforests

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Key Findings

- Over two-thirds of central Africa's forests still qualify as large tracts of low-access forest i.e., contiguous forest areas of at least 1,000 square kilometers (km^2), unbroken by public roads. Only South America's Amazon basin has larger areas of undisturbed tropical forest.
- About a third of forests remain within very large (over 10,000 km^2) tracts of low-access forest, primarily in the interior Congo Basin. Much of this is inhospitable swamp forest and/or is located in very sparsely populated areas.
- However, our regional analysis did not factor in logging roads, for lack of data. Pilot work for Cameroon using satellite images suggests that much of the forest mapped as low-access and falling within concessions has, in fact, been opened up by logging roads. New data show that logging roads provide logging access to 16% of large low-access forest tracts in Cameroon and hunting access to almost two-thirds of these forests.
- At most, 35% of central Africa's forests remain within large tracts of low-access forest that have yet to be allocated for logging.
- Most large, low-access forest tracts in central African countries (except the Democratic Republic of Congo) are within active or allocated logging concessions.
- Only 8% of central Africa's large tracts of low-access forest are in parks ands reserves, but even these protected areas are poorly managed.

Introduction

In the absence of detailed information about central Africa's rainforests, Global Forest Watch has undertaken to provide a coarse-scale picture of the region's *large tracts of low-access forest*—i.e., forests at least 2 kilometers (km) from public roads and in contiguous blocks of at least 1,000 km^2. To identify blocks of forest relatively undisturbed by commercial-scale activities, we assessed the degree to which these forest tracts were located in protected areas or in areas allocated for logging. This coarse-scale approach offers an indication of which forests are more or less impacted by development, but overall it underestimates human access into forests. Detailed data for Cameroon, unavailable for the rest of central Africa, allowed us to examine the extent to which logging roads and other newly constructed transport routes are opening access into previously remote forest tracts (i.e., those identified in the coarser-scale regional analysis). This two-tiered approach offers insight into the potential condition of forests in logging concessions region-wide and reveals the need for improved roads data.

Why Identify Low-Access Forests in Central Africa?

Forests are accessed by transportation routes including roads, railroads, and rivers that bring human populations into contact with forest ecosystems. In central Africa (Figure 1), new sources of forest access result primarily from road construction to support the logging industry. Access impacts forest ecosystems in two principal ways. First, transport routes have direct ecological effects, such as biomass loss, impeding the movement of animal species, microclimate changes, and other so-called edge effects that take place along the sides of roads. Second, access routes open the forest to human activity, including timber harvesting, bushmeat hunting, gathering of woodfuel, and agricultural conversion of forest land. The impact of access into forests depends largely on the scale of these activities.

In sparsely populated areas used only for subsistence-level human activities, these activities may prove more sustainable in the long run if population density remains low. In areas of high (or growing) population density and/or where access routes are constructed to serve commercial-scale extractive activities, the indirect impacts of access can be much more damaging. In these cases, the opening of access routes can, over time, lead to the hunting out of large forest areas, forest fragmentation (i.e., the breaking up of forest into remnants surrounded by land converted to other uses), and deforestation. In more densely populated areas such as southwest Cameroon, the eastern Democratic Republic of the Congo, and areas surrounding large cities fragmentation and deforestation are taking place on a large scale. In central Africa's low-access forest tracts, population density is very low and, to date, deforestation has been limited. The primary adverse impact of forest access in these regions is widespread defaunation (i.e, removal of animals from the forest faster than their populations can recover) caused by commercial-scale bushmeat hunting.

Improved road networks benefit people, but may harm ecosystems. Improved road networks are essential to economic development and growth. They often indirectly harm the environment, however, as roads provide access to previously undisturbed forest. Road improvement increases opportunities for trade by reducing the time and costs required to transport goods to market. Roads can enable previously isolated communities to gain access to education and medical services as well as

markets (FAO and ATIBT 1999). While road networks are expanding rapidly in many areas of central Africa especially eastern Cameroon, the northern Republic of the Congo, and the southern tip of the Central African Republic in much of the Democratic Republic of the Congo, road infrastructure has declined as a result of years of civil war. Future expansion of road networks in central Africa is unavoidable and road improvements are a necessity for economic development, but, without appropriate interventions, environmental degradation will accompany roads wherever they are constructed.

A broad range of political, economic and cultural factors drive the damaging effects of increasing forest access. These include political and economic instability, foreign debt, corruption, poverty, poor law enforcement, and cultural traditions that place low priority on environmental protection. Such factors lead in turn to poor forest management, unsustainable logging practices, semi-open access to forests, and uncontrolled commercial-scale bushmeat hunting—all of which contribute to the indirect environmental damage observed in central Africa in association with the opening of new transport routes through the forest (Geist and Lambin 2001). The adverse impact of roads likely cannot be reduced without also addressing the broad underlying factors that contribute to environmental harm.

Access adversely impacts wildlife populations. Forest animals vary greatly in their ability to tolerate roads, clearings, and agricultural areas that may separate forest areas. A landscape that serves as continuous habitat for one species may offer only a limited usable habitat area for more sensitive species. Species living in the tropical rainforest tend to be intolerant of conditions outside intact forest, making them sensitive to the barriers that roads create. Roads, especially heavily traveled ones with a corridor of cleared vegetation on either side, may be a permanent barrier to the movement of some animals, such as understory birds or small mammals (Bierregaard et al.1992, Forman and Alexander 1998, Turner 1996). Infrequently used roads may, however, attract predator species that travel or hunt along roads as well as foraging herbivores that graze on roadside vegetation (Forman and Alexander 1998).

For other species, the presence of human populations may be a more significant factor than the impact of roads per se. Forest elephants, for example, are attracted to areas of secondary growth, such as abandoned logging concessions, fields or villages, but hunted populations avoid coming within several kilometers of areas of current human activity (Barnes et al. 1991, Barnes et al. 1995, Wilkie and Morelli 1998). As road density increases, forests may become fragmented and forest species confined to smaller, isolated patches. In areas of increasingly dense human populations, forests begin to be converted to agricultural and other uses.

Forest access facilitates commercial bushmeat hunting. Perhaps the most severe impact of road construction on wildlife populations in central Africa is the expanded movement of bushmeat hunters into remote forest. In this region, wild game contributes nearly all of the animal protein consumed by forest-dwelling people. It is also a favored food of city dwellers, who are willing to pay premium prices for bushmeat relative to meat from domesticated animals. Bushmeat has become a substantial market commodity in cities throughout central Africa and trade in this commodity is becoming increasingly commercialized (Wilkie and Carpenter 1999, Wilkie et al. 2000). Increased access to forests by hunters may lead to the local extirpation or extinction of animals through direct defaunation (Redford 1992, Rudel and Roper 1997). Because of the significant threat to wildlife from over-hunting, many areas likely suffer from the "empty forest" syndrome (Redford 1992); i.e., though forest cover remains, much of the native fauna and flora may be locally extinct or in danger of extinction (Terborgh 1992, Rudel and Roper 1997, Saunders et al. 1991).

Logging facilitates bushmeat hunting by increasing access to formerly remote forest areas on newly built road networks. Improved access to such remote areas means that bushmeat can be transported to market by motor vehicle in a fraction of the time required to take out game on foot. Logging vehicles often provide transportation for bushmeat and hunters, and in many cases the concession employees themselves earn a significant portion of their income by hunting (Wilkie and Carpenter 1999). The present level of bushmeat hunting is unsustainable; unless the removal of animals in and around many logging concessions is scaled back, many species face local extirpation and potential extinction.

Forest access is linked to degradation and deforestation. Road construction, coupled with selective logging, is often the first step in a process leading to forest degradation, fragmentation, and eventual deforestation. Commercial logging causes direct

environmental damage; it also creates the first opening in the forest, facilitating further access via logging roads and exacerbating the initial damage. These roads draw in hunters and poachers as well as landless immigrants, who convert forest outside the concessions and along the sides of main roads to agricultural uses. Commercial logging operations employ many workers and pay relatively high wages, attracting large numbers of people into sparsely populated areas (Wilkie and Carpenter 1999, Wilkie et al. 2000). Logging thus often leads indirectly to further degradation and deforestation.

Poor management of forests, including those managed for timber supply as well as protected areas, threatens remaining low-access tracts. While central Africa retains a substantial share of the world's largest tracts of intact rainforest, these forests are becoming increasingly open to human access. Currently, unsustainable forestry practices threaten the ecological integrity of these forests and are incompatible with the conservation of biological diversity. (See Box 1.) Most logging operations lack basic safeguards, such as management plans and controls on wildlife hunting, to minimize forest degradation. In addition, illegal logging and forestry code violations are widespread in many parts of the region (Greenpeace 2000). Poor management plagues the region's protected areas system: many protected areas are no more than "paper parks," established in legislation, but with few or no resources or staff to protect forests from commercial bushmeat hunting, poaching of endangered species, illegal logging, and other damaging exploitation.

How This Analysis Was Conducted

This study was carried out using ArcView 3.2 and ArcGIS 8 geographic information systems (GIS) software and ERDAS Imagine 8.4 remote sensing software. Steps in the analysis are outlined below.

Regional analysis of forest access in central Africa

1. *Roads datasets were prepared and, where possible, updated.* Public roads data for the region-wide analysis depicted public access routes and did not include logging roads or other private roads, as these data are generally not available region-wide. Datasets were collected from various sources, including digital datasets, scanned topographic maps, and paper maps. (See Appendix: Technical Notes for more details.)

2. *Forest cover data were prepared to identify rainforest areas and to exclude from the analysis areas of secondary or degraded forest.* The TREES 2001 (EU Joint Research Centre, Ispra, Italy) forest cover dataset was used to identify areas of forest and nonforest. The 1-km-resolution TREES map was derived from 2000 NOAA AVHRR and SPOT VEGETATION satellite imagery, as well as ERS and JERS radar imagery.

   Three classes of TREES data lowland rainforest, mangrove, and swamp forest were designated "forest" for the purposes of this analysis. To ensure that "forest" included only relatively intact areas, the "secondary forest and rural complex" class was removed. This class represents primarily degraded forest around cities, along roadsides, and within small fragments of forest remaining in agricultural or savanna regions.

3. *A forest buffer was established.* Public roads datasets were buffered by 2 km and overlaid with the TREES map to exclude from the analysis forest within this buffering distance. The buffer size was selected based on the results of a study in eastern Cameroon, which found that 80% of all deforestation takes place within 2 km of a road (Mertens and Lambin 1997).

   While a buffer of this size will segregate from the analysis most degraded and deforested areas, in some cases it will also remove forest classified by the TREES map as closed-canopy forest. Forests such as these, located on the boundaries of deforested areas, suffer from so-called edge effects, which may include microclimate changes, biomass loss, decline in species richness, increased susceptibility to fire, and invasion by exotic species, among other damaging impacts (Rudel and Roper 1997, Terborgh 1992, Lambin and Ehrlich 1997, Barnes et al. 1995). Excluding these edge forests from the analysis helps ensure that the large, low-access forest tracts described by this study better represent truly intact rainforest habitats.

   This regional analysis does not consider the potential impacts of hunting, because the lack of region-wide data on logging roads provides an insufficient basis for a reasonable estimate. We have produced a national-level estimate of the

Box 1 The Importance of Central Africa's Rainforest Ecosystems

Central Africa is home to one of the world's largest contiguous blocks of tropical rainforest, second only to the rainforest of the Amazon Basin in South America. These regional rainforests perform valuable ecosystem services, support globally important biodiversity, are essential to regional economies, and contain the most intact forest ecosystems left anywhere in Africa.

Ecosystem services provided by tropical forests include watershed protection, maintenance of water quality and supply, regulation of local climate patterns (such as rainfall), carbon sequestration, and timber and wood fuel production, among others. Central Africa's dense rainforests sequester two-thirds of the carbon stored in live vegetation in tropical Africa. Forest loss and degradation in central Africa already are responsible for the release of more carbon to the atmosphere than any other source of land use change on the continent (73% of total carbon released from land use changes) (Gaston et al. 1998). Forests have considerable economic importance across the region: wood fuel accounts for the majority of national energy consumption (e.g., over 80% of energy use in the Democratic Republic of Congo (IEA 1996)) and timber production and export are major contributors to the region's economies.

In terms of globally important biological diversity, the rainforests of central Africa are significant both for the total number of species found there and for endemic species (i.e., species found nowhere else on earth). Intact forest communities of large mammals—including gorillas, bonobos, bongos, mandrills, and forest elephants—are unique to this region. Regional centers of biodiversity and endemism include the Cameroon highlands, the western equatorial forests of Cameroon and Gabon, coastal mangroves, the Albertine Rift highlands, and the eastern lowland forests of the Democratic Republic of Congo (Sayer et al. 1992). These forests are also notable for plant biodiversity; some areas in Cameroon contain levels of plant diversity that are among the highest recorded worldwide (Sayer et al. 1992). However, outside a few well-studied areas (e.g., Mount Cameroon, Gabon's Lopé Reserve), central Africa's rainforests remain largely unknown and their species undocumented.

Central African rainforests take on added importance because so much rainforest has been lost in neighboring West Africa, the only other rainforest region on the continent. Once extending from Guinea-Bissau to Ghana, West African rainforests share many common species with the forests of central Africa. Logging, fragmentation, and clearing for agriculture have largely degraded West African forests in this century: by some estimates, these are the most fragmented tropical forests in the world (Sayer et el. 1992, Myers et al. 2000, Rudel and Roper 1997). In contrast, the rainforests of central Africa encompass many areas that remain largely undisturbed, due in large part to low population density and the remoteness of interior rainforests. The rapid expansion of commercial logging, however, is opening access routes into previously remote areas, threatening these relatively pristine ecosystems.

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area potentially accessible to hunters in Cameroon (Map 3), the only country for which logging roads data are available. The Cameroon analysis offers insight into potential patterns of access in logging concessions across central Africa.

4. *Tracts of low-access forest were identified and grouped.* Only forests at least 2 km from a roadside and in blocks of at least 1,000 km^2 were designated as large tracts of low-access forest. These thresholds were chosen in an attempt to identify those tracts of forest large enough to sustain native flora and fauna (see Box 2). The two size classes for large tracts of low-access forest (1,000-10,000 km^2 and larger than 10,000 km^2) were established to permit comparison with relevant studies, including other Global Forest Watch mapping projects and the World Resources Institute's Pilot Analysis of Global Ecosystems (Matthews et al. 2000). They were also selected for compatibility with proposed indicator criteria under the Convention on Biological Diversity (UNEP 1997).

Finer-Scale Analysis of Cameroon's Low-Access Forest Tracts

1. *Logging roads and other previously unmapped roads were digitized from satellite imagery.* We used 1999-2001 high-resolution Landsat 7 satellite imagery to digitize logging roads and other roads within Cameroon's forests not included in the dataset used for the regional-level analysis described above. Images were obtained from the University of Maryland through NASA's Land Use Land Cover Change (LULCC) program.

   Recently constructed logging roads are clearly visible on Landsat images, as are some of the openings in the forest created by selective logging. For some areas known to have been previously logged (e.g., expired concession areas), no logging roads were visible, indicating that over time the forest canopy closes over roads and obscures them from view. Also, some minor logging roads may not be visible if only small breaks in the forest canopy were created during construction. While most of the roads that we digitized are within concessions and appear to be logging roads, other roads through the forest, including new major transportation routes, were digitized if they did not appear in the Cameroon national roads dataset.

   The logging roads dataset was created as a pilot dataset for the study, "État des Lieux du Secteur Forestier au Cameroun," in collaboration with Nature+, Programme Tropenbos International, Global Witness, and the World Resources Institute. Planned ground-truthing of this dataset using global positioning system (GPS) points has not yet been carried out, so the accuracy and completeness of this dataset are unknown.

2. *Logging roads were buffered to estimate access for logging and hunting*. Logging roads were buffered by two distances: first by 1 km, to estimate the maximum reach of logging equipment into the forest, and second by 10 km, to estimate the minimum area accessed for bushmeat hunting. The 1-km buffer represents the penetration into remote forest of large vehicles, which are commonly used to transport bushmeat from the forest to markets. The 10-km buffer is a conservative estimate of the distance that hunters are willing to travel on foot from roads. This distance is likely to vary greatly depending on location, terrain, size of animals hunted, and abundance of wildlife in a particular area (Peres and Terborgh 1995). Estimating the area accessed by hunters is further complicated by the fact that hunters use footpaths and forest tracks that are for the most part unmapped and not visible in satellite imagery. Therefore, it is likely that our estimate of the area accessed by hunters is considerably less than the actual figure.

3. *Buffered areas were overlaid with low-access forest tracts to determine the proportion of these areas accessed for logging or hunting*. Road buffers were overlaid with low-access forest tracts identified during the coarse-scale regional analysis to estimate how much of these tracts is actually accessed for logging (1-km buffer) or for hunting (10-km buffer). The results of this national-level analysis for Cameroon are indicative of potential levels of access across central Africa where active logging concessions are present.

Box 2 How Much Low-Access Forest is Required to Sustain Forest Species?

Considerable uncertainty surrounds the issue of minimum habitat area required to ensure the long-term survival of forest species. Much evidence supports the notion that small forest fragments will tend to lose species over time, especially large mammals and top predators. On average, larger areas are more likely to sustain a full range of forest species (Turner 1996). There is less experimental evidence to indicate specifically the minimum habitat area required to maintain viable populations for resident species—a figure that will vary greatly by ecosystem type (Bierregaard et al. 1992, Saunders et al. 1991). Large mammals native to central Africa—including forest elephants, gorillas, mandrills, and leopards—may require very extensive areas of undisturbed forest, either because they have inherently large habitat requirements or because they are sought after by hunters and poachers (Armbruster and Lande 1993, Wilkie et al. 2000).

Area required to support large mammals. A forest tract sufficiently extensive to sustain species needing large habitat areas is likely to meet habitat requirements for most other species. In central Africa, elephants are generally thought to have the largest habitat requirements. Estimates of the area required for African elephant populations or family groups range from 2,500 to 5,800 km^2 and up (Armbruster and Lande 1993, Lindeque and Lindeque 1991). Studies in other tropical forest regions indicate that, while tracts of at least 1,000 km^2 are capable of sustaining most forest species, some animals may require areas in excess of 10,000 km^2 to sustain their populations (Chiarello 2000, Thiollay 1989, Redford and Robinson 1991, Soulé et al. 1979).

Area required to support hunted animals. Hunted species will require a greater area to sustain viable populations. Estimates of the minimum viable habitat size for large hunted mammals of the Amazon rainforest were four times as large as those needed to sustain non-hunted populations (Peres 2001, Redford and Robinson 1991). Moreover, levels of hunting in central Africa far exceed those of the Amazon. A comparative study of extraction rates of hunted animals in the Amazon and Congo river basins found that in the latter, species exploitation rates were 30 times higher. It concluded that 60% of mammal taxa in central Africa were hunted unsustainably (Fa et al. 2002).

This study uses a conservative threshold of 1,000 km^2 for designating large, low-access forest tracts. This is the minimum area needed to sustain many, if not all, tropical forest species. Our analysis identifies very large, low-access forest tracts (in excess of 10,000 km^2) in an effort to depict areas likely to be the most able to support the full range of native central African species, including large mammals and species under hunting pressure.

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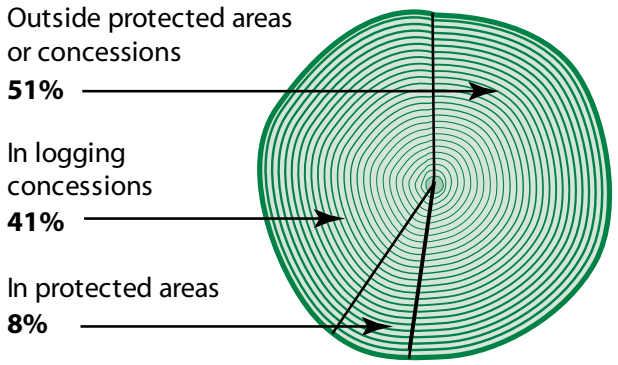
How Much of Central Africa's Forests Have Been Accessed?

Results show that much rainforest in central Africa remains in *large tracts of low-access forest*—defined for the purposes of this study as contiguous forest blocks, unbroken by public roads, of at least 1,000 km^2 (Map 1, Table 1). Over two-thirds (68%) of central Africa's rainforests is in such tracts. Aside from the Amazon Basin, these tracts constitute the largest expanse of intact tropical rainforest on earth. However, such forests are increasingly coming under development and new roads are providing access to previously remote regions. Of central Africa's remaining large tracts of low-access forest, 41% are within commercial logging concessions (see Box 3), only 8% are in protected areas, and 51% are outside concessions or protected areas (Figure 2, Map 2). Large, low-access forest tracts not included in concessions or protected areas account for about 52% (651,000 km^2) of central Africa's low-access forest and 35% of forests as a whole. They represent "opportunity areas" for sustainable management and conservation.

Approximately one-third (37%) of all central African rainforest is found in very large tracts of low-access forest, i.e., tracts larger than 10,000 km^2. The largest single tract of low-access rainforest, located in the Democratic Republic of Congo, exceeds 140,000 km^2, an area one-fourth the size of France or about as large as the U.S. state of North Carolina. Very large tracts of low-access forest are also found in the interior of the Congo River basin, where extensive areas of swamp forest make these tracts less desirable for human habitation or commercial logging.

Figure 2. Status of Large Low-Access Forest Tracts (>1,000 km^2)



National and local patterns of access. New instances of deforestation tend to take place near areas of recent forest fragmentation or deforestation, as roads and clearings in the forest attract further development, human settlement, and additional clearing (Mertens and Lambin 1997, 2000; Mertens et al. 2001; Skole and Tucker 1993). This pattern holds true in central Africa: very densely populated areas, such as western Cameroon and eastern Democratic Republic of the Congo, contain few large tracts of low-access forest (Table 1). In contrast, the largest tracts of low-access forest—in excess of 100,000 km^2—are found in the remote, very sparsely populated interior of the Congo River basin. Among central African countries, Gabon, the Republic of Congo, and the Democratic Republic of Congo have the greatest share of their forests in large, low-access tracts, with each exceeding 70%. Cameroon and the Central African Republic have approximately 40% of their forests in such tracts, while for Equatorial Guinea, the figure is less than 10%.

Cameroon ranks first in terms of share of large, low-access forest tracts included in protected areas (12%). Second highest is the Republic of Congo (10%), due in part to the recent quadrupling in size of Odzala National Park. The Central African Republic and the Democratic Republic of Congo lag in forest protection, with 5% and 6%, respectively, of large, low-access forest tracts held in protected areas. The largest share of forest in "opportunity areas"—i.e., large, low-access forest tracts outside concessions or protected areas is found in the Democratic Republic of Congo (44%), while Equatorial Guinea, at just 4%, has the lowest proportion.

Closer examination of ostensibly low-access forest tracts in Cameroon shows that many such areas have actually been accessed by logging roads. The regional analysis reported on here provides only a rough picture of forest access; due to data gaps, it did not account for the extensive network of logging roads being constructed in concessions throughout central Africa. A finer-scale analysis of Cameroon the only central African country for which new logging roads data, mapped from 1999-2001 satellite imagery, are available reveals that significant areas mapped as low-access forests in the regional analysis have actually been accessed by commercial logging operations. Almost 16% of the

Table 1 Results of Access Analysis and Status of Low-Access Forest Tracts

	Area in Low-Access Forest Tracts			Status of Low-Access Forest Tracts					
	Forest cover[1] (000 km^2)	Forest area in low-access tracts >1,000 km^2 (000 km^2)	% Forest in Low-Access Tracts	Within low-access tracts, concession area (000 km^2)	% of low-access tracts in concessions	Within low-access tracts area in parks (000 km^2)	% of low-access tracts in parks	Opportunity areas[2] not in concessions or parks (000 km^2)	% of low-access tracts in opportunity areas
Cameroon	194	86	45%	47	54%	17	20%	22	26%
Central African Republic	49	21	43%	13	60%	1	5%	7	33%
Dem. Republic of Congo[3]	1,125	807	72%	267	33%	49	6%	491	61%
Equatorial Guinea	21	2	9%	1	68%	< 1	8%	1	40%
Gabon	219	159	73%	92	58%	11	7%	56	35%
Republic of Congo	216	168	78%	92	55%	17	10%	59	35%
Central Africa	**1,863**	**1,258**	**68%**	**512**	**41%**	**95**	**8%**	**657**	**52%**

Notes:

[1] Forest cover consisted of the lowland rainforest, swamp forest and mangrove TREES land cover classes.

[2] Low-access forest tracts not included in logging concessions or protected areas are designated "opportunity areas," but other land uses may in fact already be assigned to these areas.

[3] Data used for the Democratic Republic of the Congo was the best available but may not represent the current extent and location of logging concessions.

Percentages may not add to 100 due to rounding.

low-access forests within Cameroon (Map 3) are accessed for logging (i.e., are 1 km or less from a logging road). 59% is within 10 km of a logging road, and thus is potentially impacted by bushmeat hunting.

Indeed, Map 3 likely underestimates the area of Cameroon accessed for logging, because some roads, including relatively old logging roads obscured by canopy regrowth, may not be visible on satellite imagery. If other central African countries are experiencing similar levels of access by logging roads, up to 41% of the region's low-access forest tracts may be at risk for local extirpation of wildlife resulting from unsustainable hunting. In the Democratic Republic of Congo, where years of conflict have largely destroyed road networks (Wilkie and Morelli 1998) and prevented extensive commercial logging, levels of access in concessions is probably significantly lower. However, in some places, conflict has led to extensive forest degradation (Geist and Lambin 2001) where displaced populations have become dependent on local forests for wood fuel and hunting.

Data gaps for Central Africa. Poor data quality and data gaps currently preclude accurate mapping of the status of central Africa rainforests. Most available geographic data for Africa are coarse and inaccurate, and often based on outdated maps. Limited data are available on the extent of logging roads in central Africa outside of Cameroon, except for localized studies. Most publicly available datasets omit roads constructed in the last 20 years, provide no indication of seasonal accessibility, and often fail to record the condition of roads in areas, such as the Democratic Republic of Congo, where road infrastructure is decaying. In addition to roads data, other data relevant to estimating forest condition are lacking or difficult to obtain. These include census information, accurate settlements datasets, accurate and up-to-date protected area boundaries, and information on the location and attribution of logging concessions, among others. Information on forest cover or condition (e.g., whether degraded or intact, biomass estimates, age, etc.) is also limited. Datasets such as TREES, while the best currently available, due to coarse resolution have limited applicability for monitoring forest change over time or at scales finer than national or regional levels.

Given the lack of quality datasets, this coarse-scale analysis likely contains some systematic errors with respect to estimates of forest fragmentation in central Africa. Where datasets omit many new or existing logging roads, the analysis will tend to underestimate fragmentation. However, in some areas, we likely overestimate fragmentation, because declining road infrastructure, particularly in the Democratic Republic of Congo, has rendered many routes impassable to motor vehicles. The increasing availability of low-cost satellite imagery provides an opportunity to update roads datasets, as Global Forest Watch has begun to do for Cameroon. In the meantime, estimates of the status of central Africa's remain limited by the lack of accurate data.

Table 2 Area in logging concessions

	Forest Area[1] (000 km^2)	Concession Area[2] (000 km^2)	% of Total Forest Area in Concession
Cameroon	194	72	37%
Central African Republic	49	35	71%
Dem. Republic of Congo[3]	1125	409	36%
Equatorial Guinea	21	15	71%
Gabon	219	120	55%
Republic of Congo	216	171	79%
Central Africa	**1824**	**822**	**45%**

Notes: Concession area does not include expired or abandoned concessions, so is not an estimate of the total area ever logged.

[1] Forest area consist of TREES lowland rainforest, swamp forest, and mangrove classes.

[2] Calculated from GFW concession data from various sources (See Map 2 Technical notes). Calculations are based on total concession area; Table 1 shows low access forest in concessions.

[3] Data used for the Democratic Republic of the Congo was the best available but may not represent the current extent and location of logging concessions.

Conclusions and Next Steps

This coarse-scale analysis of access into central Africa's tropical rainforest provides evidence that the region retains some of the world's largest tracts of low-access forests. However, commercial logging is rapidly opening access routes into these forests, exposing them to harm from unsustainable bushmeat hunting and other damaging human activities. Improved management of forest resources and protected areas, accompanied by effective enforcement of forestry and wildlife codes, is urgently needed to ensure both the viability of productive forest uses and to reduce the harmful effects associated with forest access. National and regional land-use planning is an important component of improved forest management, as central African governments decide which forest areas will be slated for economic development and which will be preserved intact to maintain biological diversity as well as ecological integrity.

While this study provides a rough overview of forest access trends in central Africa, it is important to note that data gaps and uneven data quality preclude accurate and comprehensive documentation of forest conditions at the regional scale. In a pilot study of Cameroon, recent, finer-scale data indicate significantly greater forest access than the coarser-scale regional analysis, suggesting that actual levels of logging-associated forest access across the region may be considerably higher than those estimated here.

Governments, donors, and international institutions should cooperate in efforts to improve the quality of geographical data, which in turn would enable development of a more accurate picture of forest conditions and pressures on natural resources. As human activities accelerate in previously isolated forests, such data are crucial for supporting improved forest management and conservation. The future of the central African rainforests depends not only on segregating conservation and production areas, but also on proper management of these areas. Sustainable forest planning and management cannot be implemented without information on human activities and their location within forests. Global Forest Watch is committed to working with other interested parties to promote such data collection, update this analysis accordingly, and make datasets publicly available to support decision-making by regional and institutional policymakers.

Complicating this analysis are information gaps, including the lack of comprehensive roads data as well as incomplete understanding of ecological issues, such as minimum habitat requirements for central African species. Nevertheless, the potential impacts of the loss of central Africa's rainforests are so great that even a rough estimate of forest access and fragmentation provides important information on the critical factors affecting this ecosystem.

Box 3 Logging in Central Africa

Logging undoubtedly affects large swaths of forest in central Africa. Over the past 40 years, commercial logging has spread from the accessible coastal forests to remote interior forests. Typically, to meet market demand and to recover high operational costs, companies selectively log only the most commercially valuable species. The challenge of sustainable forest management is to ensure that forestry contributes to national economic development without excessively damaging forests' capacity to provide locally and globally important ecosystem services, including those related to global climate and biodiversity.

In both Cameroon and Gabon, forest products are the second largest export, generating around 20% of Cameroon's export revenue and 13% of Gabon's foreign exchange earnings (Economist Intelligence Unit 2001). Timber exports (logs, sawnwood, veneer, and plywood) from central Africa steadily increased throughout the 1990s, except for a brief, sharp downturn due to the Asian financial crisis (Table B). For the period 1993 to 1999, Europe imported 40% of central African logs (Figure A), making it the largest importing region. In 1996-97, however, Asia began to surpass Europe as an importing region, a trend that will likely continue due to increased population and economic growth, particularly in China (Table A). Rising Asian log imports are driven in part by the exhaustion of commercial timber supplies within much of that continent's natural forests, as well as a partial logging ban established in China in 1998.

Governments are the principal landowners in central Africa and lease logging rights to companies and individuals through allocation procedures that vary from country to country. Well over a thousand companies and individuals hold logging concessions in central Africa. Many concessionaires are unable to carry out logging operations and subcontract out their concessions, often to large foreign companies. Of the many existing logging companies, few have the financial capital, logistical resources, and experience needed to conduct long-term, large-scale operations. Those that do are often foreign multinational groups with a complex web of subsidiaries, involving local and foreign companies (Collomb and Bikié 2001).

Sustainable management of natural resources began to appear on political and economic agendas in central Africa following the Rio UNCED conference (United Nations 1992), often at the urging of donors and international non-governmental organizations (NGOs). Compared with international forestry standards, however, logging practices in the region lag considerably in terms of efficiency and sustainability. Only in the past five to seven years have governments and the private sector begun to consider sustainable forest management in central Africa; steps towards implementation remain limited to a few companies. Progress is limited by conditions that provide disincentives for sustainable management, including political and economic instability and widespread illegal logging. These conditions make it more difficult for companies to make long-term investments and commit to the long rotation cycles required for sustainable forest management.

Recently, a number of European companies announced their willingness to lead efforts to improve forest management in the region. Members of the European Foundation for the Preservation of African Forest Resources (Fondation Européenne Pour la Preservation des Ressources de la Forêt Africaine), these companies lease substantial concession areas in Cameroon, Gabon, and the Republic of Congo (Figure B). They have made significant environmental commitments, including creation of a standard practical forest-management plan, improvement of reduced-impact logging techniques, a professional code of conduct, and establishment of a Pan-African Certification System. Such commitments could play an influential role in spurring improved forest management among the central African logging industry as a whole. Because logging concessions cover approximately 41% of low-access forest tracts, much of the future of central Africa's forests depends on how well companies manage their concessions. Monitoring the performance of these companies is essential; even companies that have pledged publicly to improving forest management have committed documented forestry code violations (Ministère de l'Environnement et des Forêts, Cameroon 1999). This indicates that not all companies will successfully implement their environmental commitments and points to the need for strengthened enforcement of forestry legislation by governments in the region.

continued next page

Box 3 continued

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Figure A. Destination of central African Timber Exports, 1993–1990 (ITTO)

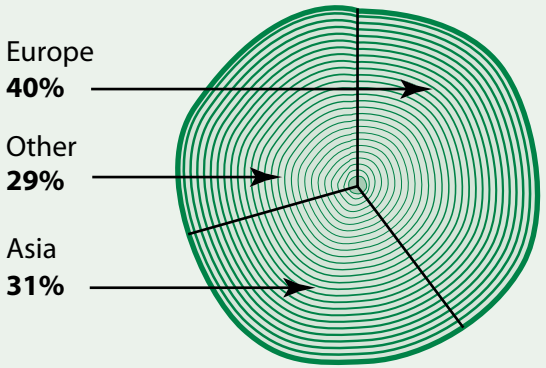
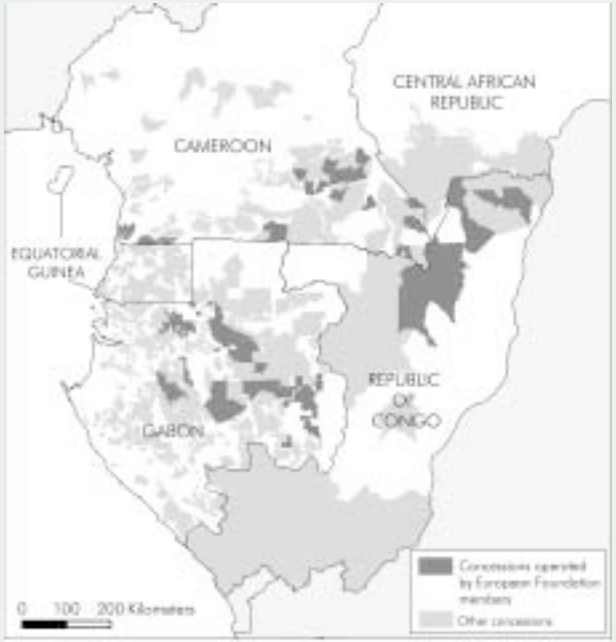


Figure B. Logging Concessions Operated by Companies Belonging to the European Foundation



Notes

This map shows concessions operated by companies belonging to the European Foundation for the Preservation of African Forest Resources (Fondation Européenne Pour la Preservation des Ressources de la Forêt Africaine). Data were unavailable for the Democratic Republic of the Congo.

1. This map represents our best estimate of the location of concessions held by foundation members, but is not an official European Foundation map.

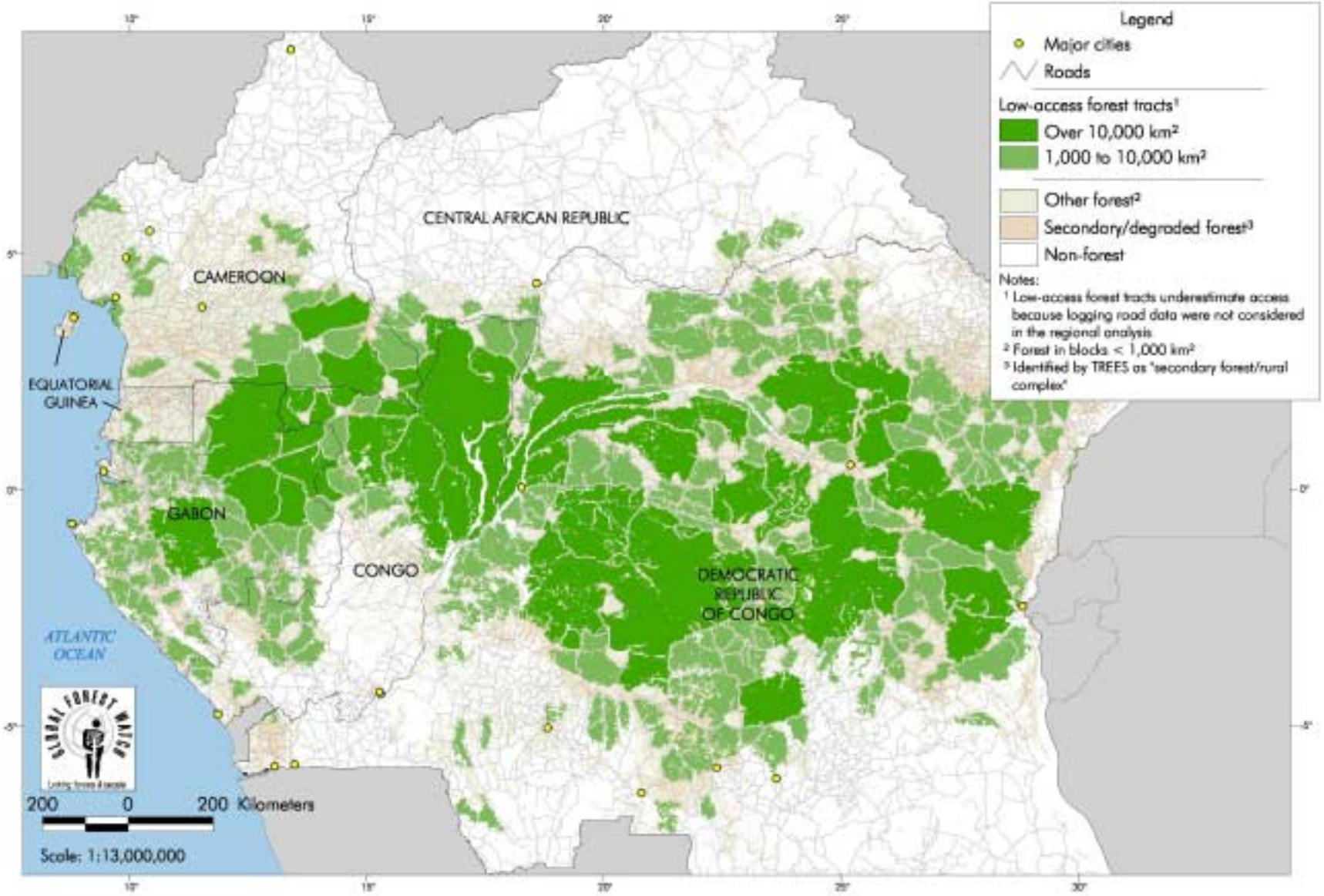
2. The area of the southern portion of the Republic of Congo shown as "other concessions" encompasses land uses including logging concessions, plantations, and protected areas. Boundaries were unavailable for several smaller concessions (Unités Forestières d'Exploitation) in this region that are operated by European Foundation members.

3. In some cases we could not confirm subcontracting agreements between concession holders and parent companies to determine if concessions were operated by European Foundation members.

Source

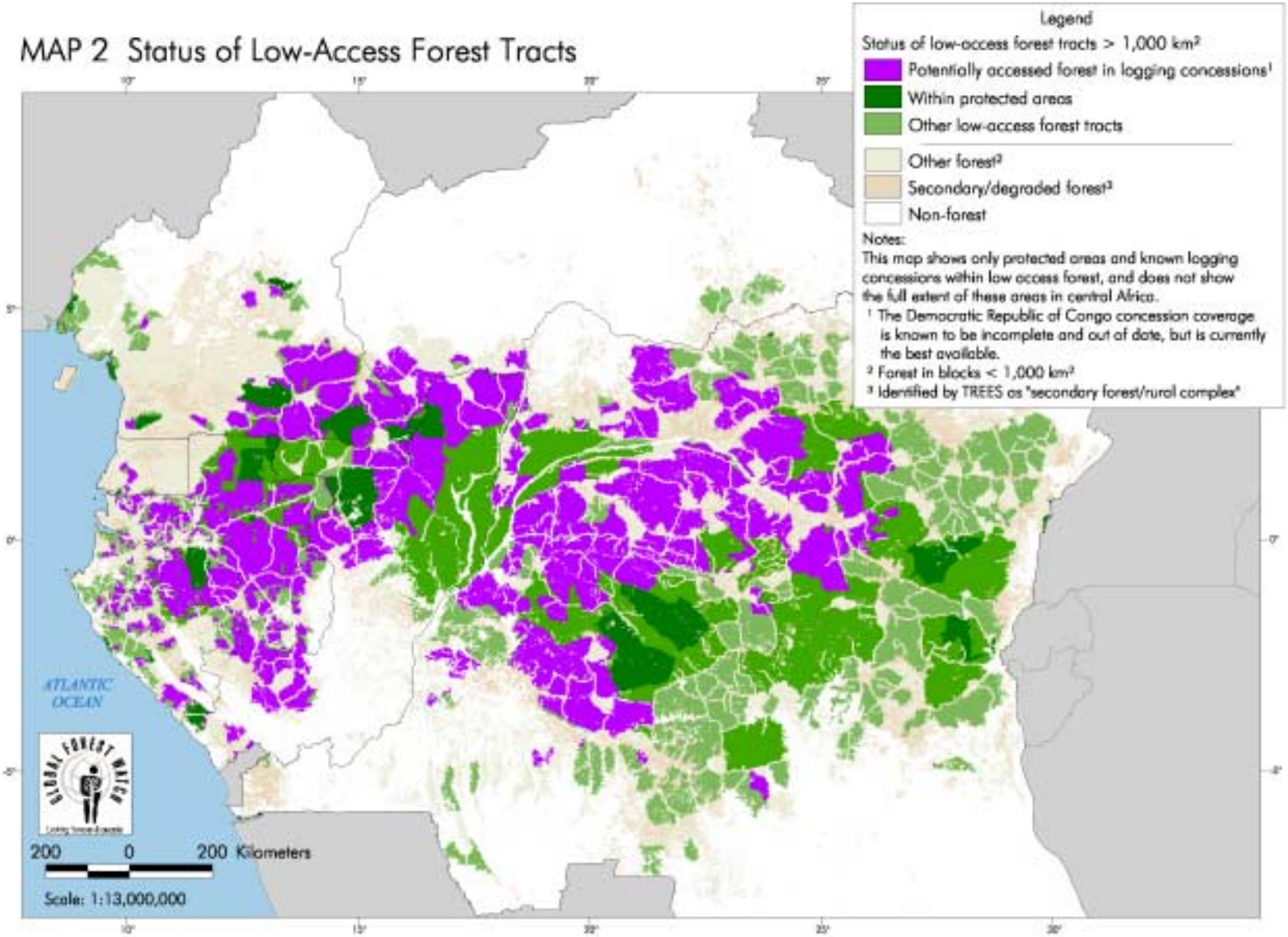
European Foundation for the Preservation of African Forest Resources; personal communication with Jean-Jacques Landrot (European Foundation/IFIA), February 2002.

MAP 1 Coarse-Scale Estimation of Central Africa's Low-Access Forest Tracts



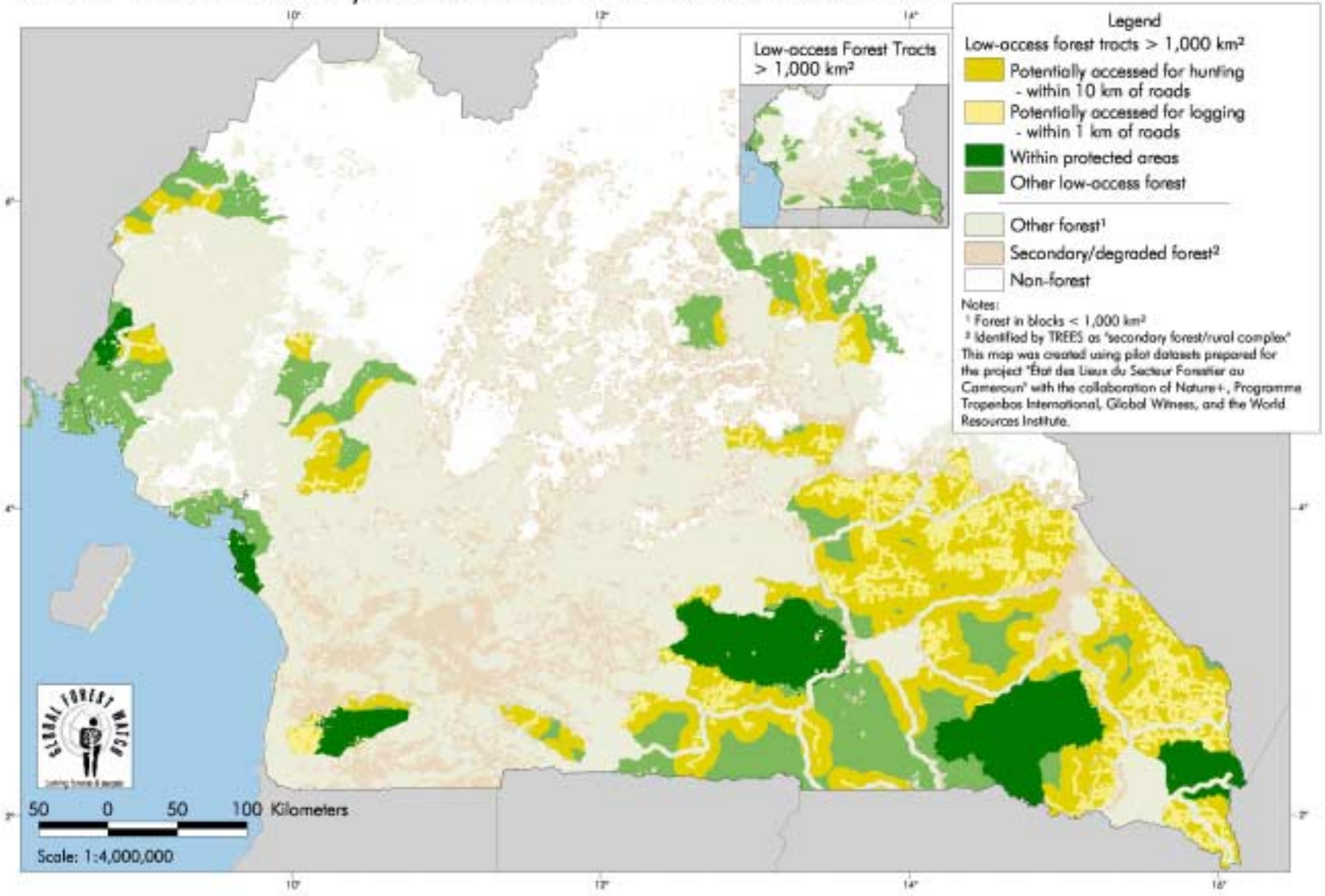
Sources: Forest cover from TREES (EC Joint Research Centre), 2000. Roads data from CARPE/WRI, National Imagery and Mapping Agency (NIMA) VMAP Level 0, WWF, and GFW. Cities data from ESRI. Country boundaries from National Imagery and Mapping Agency (NIMA) VMAP Level 0.

MAP 2 Status of Low-Access Forest Tracts



Sources: Forest cover from TREES (EC Joint Research Centre), 2000. Logging concessions -- Cameroon: MINEF; Central African Republic: Projet d'Amenagement Ressources Naturelles; Democratic Republic of Congo: SPIAF, WRI; Equatorial Guinea: GFW and local partners; Gabon: Ministère des Eaux et Forêts, Jnl. Officiel du Gabon, WCMC, WWF; Republic of Congo: WRI, WWF. Protected areas from CARPE, GFW, WCMC, WCS, WWF, ECOFAC. Country boundaries from National Imagery and Mapping Agency (NIMA) VMAP Level 0.

MAP 3 Finer-Scale Analysis of Cameroon's Low-Access Forest Tracts



Sources: Forest cover from TREES (EC Joint Research Centre, Ispra, Italy), 2000. Logging roads were digitized by GFW from 2000-2001 Landsat 7 images obtained from the University of Maryland through NASA's Land Use Land Cover Change (LULCC) program. Country boundaries from National Imagery and Mapping Agency (NIMA) VMAP Level 0.

APPENDIX: Technical Notes

Map 1: Coarse-Scale Estimation of Central Africa's Low-Access Forest Tracts and Map 2: Status of Low-Access Forest Tracts

The base vegetation layer used was the latest TREES 2000 land cover map for central Africa (Mayaux and Malingreau 2000), updated from the original, approximately 1-km^2 resolution dataset (Mayaux et al.1997).

- A forest/ non-forest map was created to separate natural closed-canopy forest from other vegetation. The "forest" category included lowland rainforest, mangroves, and swamp forest (classes 1, 6, and 9). "Non-forest" included secondary forest and rural complex, forest-savanna mosaic, nonforest, water bodies, swamp grasslands, and plantations (classes 2-5, 7-8, and 10).
- Updated roads datasets were prepared:
  - National-level roads data were updated.
  - The CARPE roads dataset (Central African Regional Program for the Environment/World Resources Institute) was used as the base layer.
  - Roads data missing from the CARPE dataset were supplemented with available data from the National Imagery and Mapping Agency (NIMA) Vector Map Level 0 dataset. VMAP (1997) is an update of the Digital Chart of the World, which was used as the base layer for the CARPE roads datasets.
  - Additional roads were digitized at WRI using recent (1993 to 2000) national maps at various scales (1:1,000,000 to 1:3,300,000). These coarse-scale maps were used to digitize newer roads not depicted by other sources. No finer-scale (e.g., 1:200,000) maps created within the last decade were available for any countries in the region.
  - The Gabon roads dataset was updated with roads data provided by WWF-Gabon that were digitized from local topographic maps (1:200,000) and Landsat satellite imagery.
  - Foot paths, ferry crossings, and other non-pertinent transport routes were removed prior to the forest fragmentation analysis.
  - No information was available on degraded or impassable roads (especially prevalent in the Democratic Republic of Congo).
  - These roads datasets were not verified in the field.
- Roads were buffered to a distance of 2 km, and converted to a 100-meter (m) grid. The TREES landcover map was also resampled to 100 m, to prevent the buffers from removing excess forest due to the coarseness of the forest cover map.
- Rivers are important access routes throughout central Africa. They were not, however, considered access routes for the purposes of this study, due to the difficulty in determining with consistent accuracy across the region which rivers are used as access routes. The region's largest rivers are considered indirectly in the analysis; they appear on the TREES land cover dataset as "non-forest" and therefore divide large forest areas into smaller blocks.
- Railroads were not considered access routes for the purposes of this analysis, even though they are important means of transporting timber and bushmeat in many forest areas.
- The buffered roads grid was used to segregate forest within 2 km of roads from the TREES forest cover map.
- Remaining forest areas were grouped into contiguous blocks, and sorted by size:
  - Over 10,000 km^2
  - 1,000 to 10,000 km^2
  - Under 1,000 km^2
- Contiguous forest areas of at least 1,000 km^2 were defined as "large tracts of low-access forest."
- Logging concessions and protected areas GIS datasets were overlaid on the low-access forest tracts and the portion of these tracts in concessions or protected areas was calculated. All calculations were made using datasets in an Albers equal-area projection.
  - Protected areas information was obtained from CARPE, based on datasets from the World Conservation Monitoring Centre (WCMC). Protected areas datasets for Cameroon and Gabon have been reviewed and updated by Global Forest Watch, with input from WWF and Wildlife Conservation Society (WCS); GFW also updated the boundaries for Odzala National Park in the Republic of Congo (ECOFAC). Protected areas datasets

Table A Log Exports out of Central Africa[1] (million cubic meters)

	1993	1994	1995	1996	1997	1998	1999	
Total	2,429	3,212	3,472	3,030	5,019	4,083	3,913	
Europe[2]	1,019	1,478	1,674	756	1,253	2,041	1,610	
Asia[3]	667	945	732	1,101	2,216	1,116	1,320	
Other[4]	743	789	1,066	1,173	1,550	927	983	
								Average
% Europe	41.9	46	48.2	25	25	50	41.1	*39.6*
% Asia	27.5	29.4	21.1	36.3	44.2	27.3	33.7	*31.4*
% Other	30.6	24.6	30.7	38.7	30.9	22.7	25.1	*29*

Source: International Tropical Timber Organization Annual Review from http://www.itto.or.jp/sitemap/sitemap.html.

Notes:

[1]Central Africa includes Cameroon, Republic of Congo, Democratic Republic of Congo, and Gabon, (DR Congo did not report 1999 figures).

[2]Europe includes Belgium, France, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, and Spain.

[3]Asia includes China, India, Japan, Korea, Malaysia, Philippines, Taiwan, and Thailand.

[4] "Other" category was calculated by subtracting the regional figures from Total Exports figures reported by either the exporting country or estimated by the ITTO.

outside Cameroon and Gabon have not been extensively reviewed.

- Logging concessions data were provided by: MINEF (Cameroon); Projet d'Amenagement Ressources Naturelles (Central African Republic); SPIAF and WRI (Democratic Republic of Congo); GFW and local partners (Equatorial Guinea); Ministère des Eaux et Forêts, Journal Officiel du Gabon, WCMC, and WWF (Gabon); and WRI and WWF (Republic of Congo).
- Concessions data for Cameroon and Gabon have been reviewed by in-country partners and local experts. Datasets for the Republic of Congo, Equatorial Guinea, Central African Republic, and the Democratic Republic of Congo have not been reviewed for accuracy or completeness. In the Democratic Republic of Congo, the current status of concessions is unknown, including whether mapped concessions remain valid and whether there are additional unmapped concessions.

- Country boundaries used for this analysis are from National Imagery and Mapping Agency (NIMA) VMAP Level 0.

Table B Central African[1] timber[2], production and exports (million cubic meters)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Production	5,265	5,395	6,552	7,631	7,514	7,780	8,743	8,560	9,166	9,664
Exports	2,874	2,572	2,941	3,805	4,285	4,407	5,682	4,953	5,117	5,627
% Exported	55%	48%	45%	50%	57%	57%	65%	58%	56%	58%

Source: ITTO Annual Reviews from http://www.itto.or.jp/sitemap/sitemap.html

Notes

[1]Central Africa includes Cameroon, Gabon, Republic of Congo, Democratic Republic of Congo and the Central African Republic, except in 1991 and 1992 for which Central African Republic data were not available. Note that data for Equatorial Guinea data were not available through ITTO, and thus not included here.

[2]Timber includes the following categories from the International Tropical Timber Organization: Logs, Sawnwood, Veneer and Plywood.

Map 3: Finer-Scale Analysis of Cameroon's Low-Access Forest Tracts

- Logging roads within Cameroon were digitized from 1999-2001 Landsat 7 ETM+ satellite imagery. The Landsat scenes provided full coverage of Cameroon's forested areas, though in some cases clouds prevented road mapping. The logging roads data layer includes main logging roads, secondary logging roads, and some new primary transportation routes through forest used to reach logging concessions.
- Logging roads were buffered twice: first by 1 km, to estimate the area accessed for logging and deepest penetration of vehicles into the forest; and second by 10 km, to estimate the area accessed for bushmeat hunting. The areas accessed for logging and hunting were calculated as a percentage of the total area of Cameroon's large (at least 1,000 km^2), low-access forest tracts.
- Buffered road areas for the Cameroon map were not removed from the low-access forest tracts because these are not permanent roads. Also, a calculation of the portion accessed allows an indication of the extent of forest accessed in concessions across the region.

Table 1. Results of Access Analysis and Status of Low-Access Forest Tracts

Calculations of forest areas were based on the TREES 2000 central African vegetation map (Mayaux and Malingreau 2000). The 1-km-resolution TREES map was derived from 2000 NOAA AVHRR and SPOT VEGETATION satellite imagery, as well as ERS and JERS radar imagery. Landcover types included are: lowland rainforest, secondary forest and rural complex, forest-savannah mosaic, nonforest, mangrove, water bodies, swamp grasslands, swamp forest, and plantations. The coarse-scale TREES vegetation map is suitable for regional analyses where the dataset can be compared to data from other sources. TREES data are much less accurate locally, as the coarseness of the sensor creates spatial aggregation errors (Mayaux et al. 1998).

The area of forest cover in central Africa has been reported in several global forest-resource assessments, including from TREES 1997 (E.C. Joint Research Centre), FAO (United Nations Food and Agriculture Organization, and IUCN (The World Conservation Union). Another estimate is available from the Central African Regional Program for the Environment (CARPE) (LaPorte et al. 1998). The extent of forest cover varies according to forest definition, date of the analysis, and methods used to develop land cover classifications, among other factors. Our estimate of 1,863,000 km^2, derived from the TREES 2000 data, compares with

1,839,670 km^2 estimated by TREES 1997 ("evergreen and semi-deciduous forest"); 1,583,000 km^2 by FAO-FORIS ("closed broadleaf forest"); 1,858,020 km^2 by IUCN ("closed forest"); and 1,815,753 km^2 by CARPE (LaPorte et al. 1998). For a discussion and detailed comparison of the TREES 1997, FAO, and IUCN datasets, see Mayaux et al. 1998.

Box 3, Figure A: Destination of Central African Timber Exports, 1993-1999

Regional totals are based on figures reported by International Tropical Timber Organization (ITTO) members, generally those reported by major importing countries.

- Estimates of log export underestimate the volume of timber felled, since logs are a subset of forest products produced and exported by central African countries. In addition, this estimate does not account for illegal logging. Cameroon and Gabon are rapidly developing a wood processing industry to complement log production and exports with value-added products, such as sawnwood, plywood, and veneer sheets.
- Accurate data on the volume and direction of trade of processed products are difficult to obtain due to overlapping definitions used by international reporting agencies (Food and Agriculture Organization, International Tropical Timber Organization), and conflicting authority within the exporting countries' forestry and customs services. Therefore, the direction of trade for all timber products (logs and processed products) may differ from the direction of log trade. Overall, export figures presented here are to be interpreted with caution due to discrepancies both within a single data source (e.g., ITTO) and between data sources (e.g., ITTO and FAO). However, these numbers give an indication of trends in trade and the associated order of magnitude.

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