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# Mapping the changing forests of Africa [1]

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A new biomass map of Africa will help answer a complex question: what are the global and local effects of land-use change in African forests?

- About the data used
- About Land Processes DAAC [2]

In the Central African Bwindi forest in Uganda, a gorilla sits on the forest floor nursing her young. A few miles away, a subsistence farmer burns a patch of forest in preparation for a crop that will feed his family. And as the smoke from the burning forest floats into the sky, carbon dioxide ($CO_2$) drifts into the Earth's atmosphere.

The gorilla, the farmer, and the burning forest's emissions are interconnected by a single phenomenon: a change in the way people use land. More than 900 million people live in Africa, and many of them rely on traditional slash-and-burn agriculture to survive lives of profound poverty. Slash-and-burn fires in developing countries contribute a significant amount of $CO_2$ to the atmosphere; up to a third of all global $CO_2$ emissions comes from land-use changes, including agricultural fires. Carbon dioxide is one of the greenhouse gases that is causing our planet's average surface temperatures to rise.

But land-use change does more than just add to our world's growing burden of $CO_2$. Land-use change also affects and threatens entire ecosystems and the plants and animals within them. In the case of the Central African forests, land-use change has contributed to pushing three species of Great Ape to the edge of extinction. Sadly, the very people who burn the forests to survive can deepen their own plight if they run out of the vital fuel and resources the forests provide. Land-use change and its global and local effects are interrelated from the point of view of Nadine Laporte, a scientist at the Woods Hole Research Center in Woods Hole, Massachusetts. Laporte is the director of the Africa Program, which studies African land-use planning and forest management. For Laporte, finding a way to address rising $CO_2$ and dwindling Great Apes populations, as well as helping to improve forest management, are central to her day-to-day work. Land-use change and its global and local effects are interrelated from the point of view of Nadine Laporte, a scientist at the Woods Hole Research Center in Woods Hole, Massachusetts. Laporte is the director of the Africa Program, which studies African land-use planning and forest management. For Laporte, finding a way to address rising $CO_2$ and dwindling Great Apes populations, as well as helping to improve forest management, are central to her day-to-day work.

## A biomass map of Africa

Scientist Nadine Laporte sits with Mbaka Pygmy women in Northern Congo. Pygmies, who survive primarily through traditional hunting and gathering, often serve as guides for forest research and conservation expeditions. (Courtesy Nadine Laporte, Tiffany Lin/WHRC)

In the spring of 2005, Laporte accepted an invitation to visit Uganda's National Forest Authority. While there, she learned that the Ugandans were trying to use maps of the forest's biomass—trees, plants, and other living matter—to help them manage the land use of their forests. "By law, the government of Uganda must come up with an estimate of the forest biomass every five years," Laporte said. On-the-ground field surveys are expensive and time-consuming, so the Ugandans had turned to satellite imagery, also called remote sensing data, as a logical solution for creating a map. "But the last time they produced a map," Laporte said, "they used high-resolution satellite imagery and it took them almost ten years to produce." Laporte thought she knew why.

The satellite imagery the Ugandans used is called Satellite Pour l'Observation de la Terra (SPOT) data. The SPOT sensor collects data at a resolution of two-and-a-half to twenty meters, and its image footprint covers areas measuring sixty kilometers by eighty kilometers (thirty-seven miles by fifty miles). "It's like covering the whole country with hundreds of little tiles that you have to put together," Laporte said. "It's very time consuming to do that, especially with limited resources."

Laporte knew of another option: data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, flying aboard NASA's Terra satellite. MODIS data are distributed by the NASA Land Processes Distributed Active Archive Center (LP DAAC) at the United States Geological Survey's Earth Resources Observation and Science (EROS) Data Center in Sioux Falls, South Dakota. The data have a lower resolution than SPOT data; the specific data set that Laporte used has a resolution of one kilometer (six tenths of a mile). However, MODIS data are organized in large tiles that cover entire regions, so MODIS data were a more manageable choice for the project. The Ugandans welcomed Laporte's help and expertise. Laporte said, "For all of Uganda, we only had to process two giant tiles from MODIS instead of hundreds of tiny tiles from SPOT."



Laporte realized that the biomass map that the Ugandan government needed for forest management was actually one piece of a much larger puzzle. "The same remote sensing data sets can have different applications according to the question you want to answer," she said. She decided to propose an expanded version of the Ugandan biomass-mapping project to NASA through its Land-Cover Land-Use Change and Biodiversity and Ecological Forecasting programs. Laporte knew that the biomass project would be more useful if it extended to all of Africa rather than just focusing on Uganda. She also recognized that the biomass map of Africa could be used to seamlessly address multiple needs at the same time: quantifying $CO_2$ emissions, helping conserve the Great Apes, and improving forest management.

## Quantifying carbon dioxide emissions

When a farmer burns a patch of forest, carbon stored in the trees and forest biomass returns to the atmosphere as $CO_2$; this exchange of carbon between the Earth and the atmosphere is called the carbon cycle. By changing its land use, the forest patch goes from being a "carbon sink," which stores carbon, to being a "carbon source," which gives off $CO_2$.

Different countries produce different amounts of $CO_2$, depending on various factors, including the amount of forest that is burned within their borders. However, the amount of carbon released into the atmosphere also varies depending on the type of forest burned. Evaluating the forest types of Central Africa is one of the main goals of the Africa biomass map project.

Alessandro Baccini, a remote-sensing scientist at Boston University who is collaborating with Laporte on the biomass map, explained the reason that different forests store differing amounts of carbon. "If you log a young forest, the amount of carbon released may not be very big," he said. "But if you log a mature forest, the amount of carbon released is probably much higher because the trees are taller and have a larger diameter." So, if scientists assume one average biomass amount for an entire country or region, their carbon estimates probably will not be accurate.

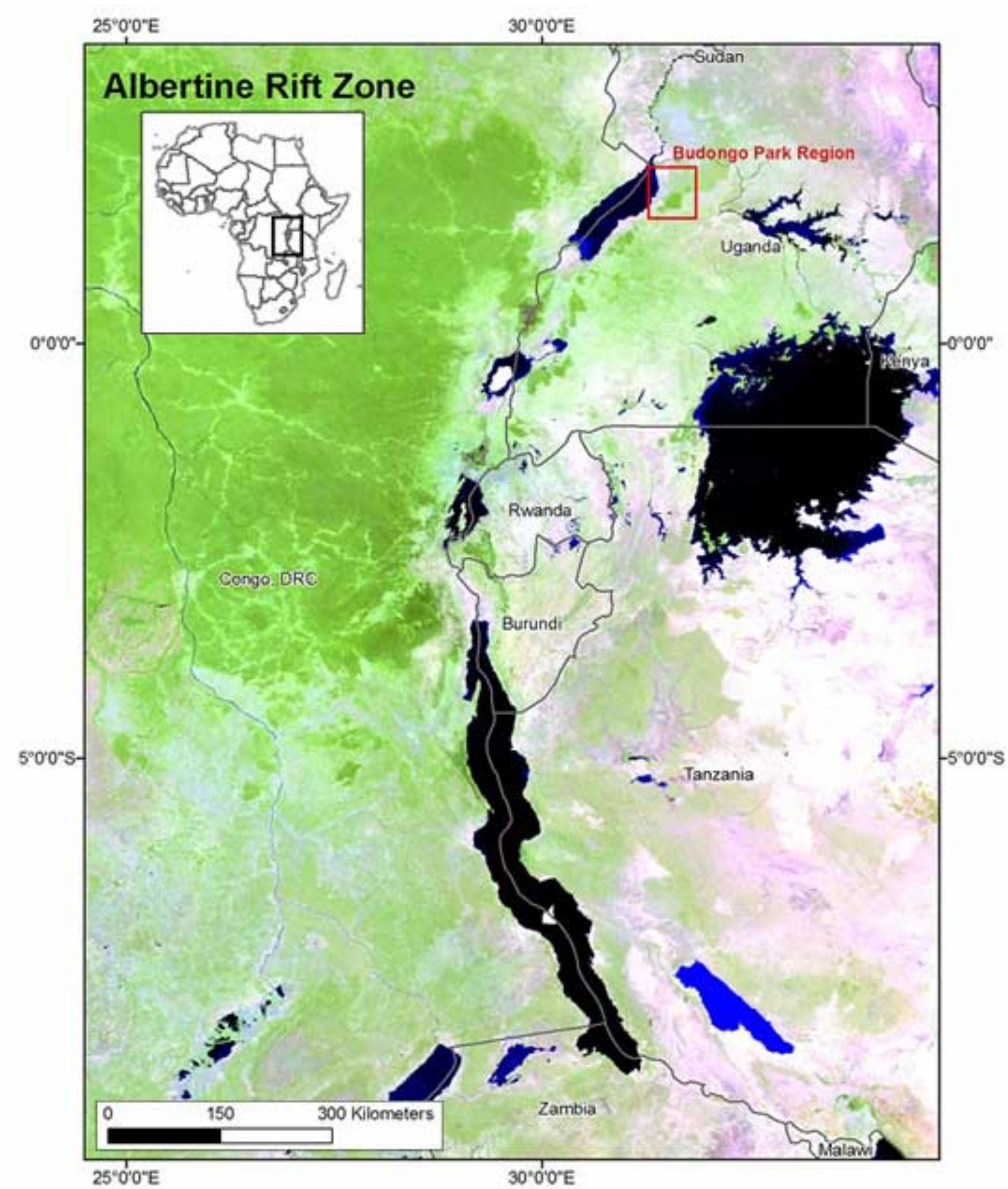
Laporte said, "That is why it's important to know the type of forest. Using MODIS imagery, we can determine the biomass of particular forests; then we know how much $CO_2$ is released when those forests are burned." However, to effectively use satellite imagery to estimate the biomass that a forest represents, scientists first need some sample field data to check against. Baccini said, "We need to know how much biomass we have on the ground in a particular spot. Then, using this field data, we can calibrate the relationship between actual biomass and the remote-sensing data."

Richard "Skee" Houghton, a carbon modeler at the Woods Hole Research Center and collaborator on the project, agreed. "We're going to try to link the land-use change finely enough in space, at a specific location, to attach a biomass to it. That's what makes this map so much more difficult to produce, and it ought to be that much more accurate, too."

Once Laporte and Baccini have produced the biomass map and checked its accuracy, Houghton will use the information to model, or predict, the sources and sinks of carbon in Africa's forests. "The model is based on the processes of disturbance and recovery," Houghton said. "It tells us that if you cut down a particular area of rainforest, here's how much carbon was held in the rainforest, here's how much carbon would be held in a field of shifting cultivation, and here's how much carbon was released to the atmosphere when the forest was cleared." The model will be comprehensive enough to account for different land-use changes, including whether the forest is cut down for building materials, burned and farmed, or even replanted.

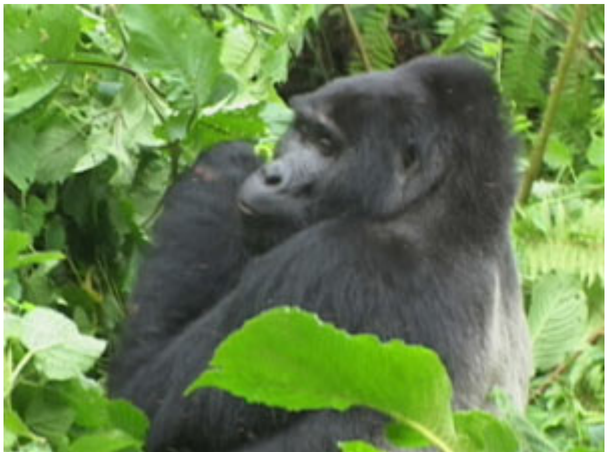
Using the completed model, Laporte will begin the analysis in earnest. "Starting with Central Africa, we'll be able to break down the contribution of $CO_2$ by region and country." This information will help scientists understand the sources and sinks of carbon, as well as the role of land management in controlling carbon emissions from land-use change.





This map shows a detail of the Moderate Resolution Imaging Spectroradiometer (MODIS) data set that Laporte's team used to map biomass in Central Africa's Albertine Rift Zone. The dark green indicates higher biomass, light green indicates lower biomass, and lavender indicates savannas. The red rectangle highlights the Budongo Forest Reserve in southwest Uganda, where many of the surviving Great Apes are protected. (Courtesy Nadine Laporte, Alessandro Baccini)

## Helping conserve the Great Apes



Great Apes, like this silver-back gorilla in Uganda's Bwindi forest, are struggling to survive in the diminishing forests of Central Africa. (Image above and in title graphic courtesy Andy Plumptre)



People are not the only ones affected by land-use change in Africa. Three of the four species of Great Apes—gorillas, chimpanzees, and bonobos—dwell in the forests of Central Africa and rely on the forests for their survival. They are under grave pressure because their habitat is diminishing as increasing numbers of people burn or cut down the forests. Laporte said, "In Uganda, only two small pockets of mountain gorilla habitat remain in vast areas converted for agriculture." According to House testimony from Marshall Jones, Deputy Director of the United States Fish and Wildlife Service, gorilla, chimpanzee, and bonobo populations have been reduced by half since 1983.

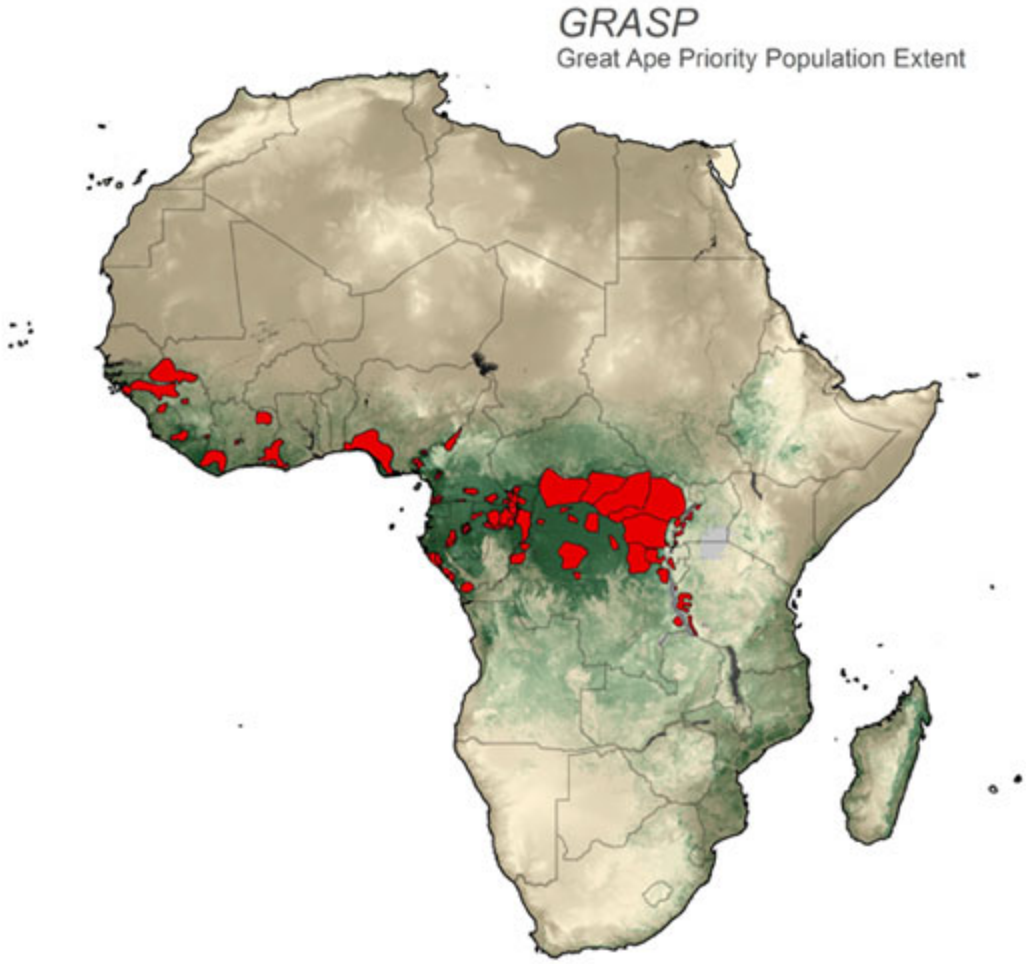
Central African Great Apes live in forests and occasionally in bordering woodland or savanna areas. Their main staples are forest plants and fruit. Gorillas are the largest of the Great Apes; males may be 180 kilograms (400 pounds) and almost 2 meters (6 feet) tall when standing upright. Maintaining this large bulk requires extensive vegetation in which to forage. Chimpanzees and bonobos, although much smaller than gorillas, also require substantial and largely undisturbed tracts of forest for their survival. However, their forest habitat is rapidly vanishing, which is isolating populations and reducing their ability to survive.

The biomass map of Africa will be of great benefit to conservationists who are working to save the Great Apes from extinction. The Integrated Forest Monitoring System for Central Africa (INFORMS) project, which Laporte created in 2000, established the use of remote sensing to monitor Great Apes habitat change. Laporte said, "The Africa biomass map project could be seen as a natural continuation of INFORMS, but more oriented towards better information on the stock and volume of biomass throughout Africa."

The application of the biomass map to Great Apes conservation is clear. "The Great Apes are found in high biomass forests. Forests that have been degraded have lower biomass and are less likely to be good habitat for these animals," Laporte said. "Using the biomass map of Africa, we can predict potential habitat or prime habitat for them."

The biomass map will also help conservationists pool their efforts to save the remaining habitat that is most suitable for the diminishing populations of Great Apes. "The biomass map can be used as a layer of information as people who are monitoring the apes decide which areas of forest to focus on for protection," she said.

Feedback




The Great Apes are scattered over an increasingly fragmented forest landscape. The United Nations Great Ape Survival Project (GRASP) is now using satellite imagery and field surveys to identify priority populations, indicated in red, to guide conservation actions. Green indicates forest density. (Image above and in title graphic courtesy Nadine Laporte, Greg Fiske/WHRC)

## Improving forest management

Subsistence agriculture in a tropical forest in Mozambique sends plumes of smoke and carbon dioxide into the atmosphere. (Courtesy Frank Merry)

Conservation of the forest for the benefit of Great Apes is closely tied to forest management. Forest managers must balance the needs of other species with those of our own. This means monitoring deforestation, carefully planning reforestation, and providing incentives for wise use of the forests.

Millions of people rely on Central African forests to survive lives of extreme poverty. Each year, individual farmers burn significant areas of forest to plant food crops for their families. In subsequent years, subsistence farmers may allow land cleared previously to regrow into savannas, woodlands, and forest. However, overall, more forest is being destroyed than is being created.

The biomass map of Africa that Laporte and her team are working to produce will be valuable to forest managers in African countries, including Uganda. "Most of Uganda has been converted to agriculture, and they don't have much forest left," Laporte said. "Most of the logs that they use are imported from outside the country." In a country with few and dwindling forest resources, forest managers want accurate, current information that will help them determine how to manage the forest and where to focus planting efforts. Government officials could also use the information to determine where to provide social assistance or incentives for sustainable use of the forest.

The biomass map of Africa has already pinpointed some interesting information for forest managers. "We've been catching areas that used to be savannas with few trees and which are now like woodlands, with higher biomass," Laporte said. "We think that might be associated with regrowth." Comparing future versions of the map would help forest managers monitor the success of forest conservation and forest restoration projects.

The possibilities for applying the biomass maps to future forest management efforts are extensive. "One future direction for the work is that I would like to develop the link between biomass and poverty," Laporte said. "If we find low biomass in an area that we would predict should have high biomass, we can predict fuel wood scarcity. And the poorer you are, the more you depend on natural resources like forests for land, food, and fuel." The indication of a high-risk, high-poverty area could help identify places that need rapid, focused attention by forest managers, national governments, and international aid groups.



"Once the forest is gone," Laporte said, "starvation and increased poverty follow."

## Mapping Africa into the future

Nadine Laporte teaches a quick geography lesson to children in Uganda while she waits for a tire on her vehicle to be repaired. (Courtesy Nadine Laporte)

Given the urgency for forest managers and conservationists, the more frequently Laporte's team can update the biomass map, the more relevant and helpful it will be.

"In June, I'll be in Uganda to do some validation work on the map," Laporte said. "We're hoping that maybe in a year or so, we'll be able to produce these biomass maps on a routine basis for the Uganda National Forest Authority." The current version of the biomass map took the team six months to produce, with calibration and polishing still left to do; they hope to finish the map sometime this year. Laporte hopes her team will eventually be able to provide maps annually to conservationists and forest managers.

Once the team has used the polished map and deforestation rates to develop the carbon model, the focus will be on understanding specific areas of the carbon story. "We hope to get a better estimate of $CO_2$, establish an annual rate of deforestation, and calculate how much $CO_2$ is going into the atmosphere," Laporte said. "We'd even like to predict $CO_2$ on an annual basis."

These details will be of interest as scientists compare carbon sources and sinks within and among regions and continents to better understand global warming. Plus, Baccini said, "If the technique works well in Africa, maybe we will expand it and have something more extended to cover other continents."

A better understanding of carbon's sources and sinks could also be useful as governments attempt to sort out policies to curb global carbon emissions. Houghton said, "In a world of carbon credits, you can imagine that countries will get credits or debits for sources and sinks of carbon that result directly from their land management practices." Being able to quantify a nation's carbon cycle would be an important part of that system.

Whether it's a government official, an international conservationist, or a forest manager, Laporte said, "I want to identify what the needs are—what people need so they can do a better job. And after we produce a finished product, then we will know that it has filled a real need." The MODIS biomass map of Africa is already on its way to addressing not just one need, but three: improving our understanding of the carbon cycle, adding to the knowledge-base of Great Apes conservationists, and providing a tool to help forest managers use their nations' resources wisely.

## References

Sever, M. Tracking Gorilla Habitat Changes [3].
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Frequently Asked Questions about the Science of Climate Change [4].
Meteorological Service of Canada. Accessed June 14, 2006.

Testimony of Marshall P. Jones, Deputy Director, United State Fish and Wildlife Service [5].
U.S. Fish and Wildlife Service. Accessed June 14, 2006.



## Related Links

- NASA Land Processes DAAC [6]
- NASA Terra satellite [7]
- SPOT image [8]
- Woods Hole Research Center's Africa Program [9]

| **About the remote sensing data used** | |
|---|---|
| Satellite | Terra |
| Sensor | Moderate Resolution Imaging Spectroradiometer (MODIS) |
| Data sets | Nadir Bidirectional Reflectance Distribution Function (BRDF)-Adjusted Reflectance (NBAR) [10] |
| Resolution | 1 kilometer |
| Tile size | Regional |
| Parameter | Biomass |
| Data center | NASA Land Processes (LP DAAC [2]) |
| Science funding | NASA |

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[5] http://www.fws.gov/laws/TESTIMONY/109th/2005/Marshall_P_Jones_subcommittee_fisheries_06-23-05.html
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