by Michon Scott
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On December 31, 2001, a land dispute in the Mambilla Plateau of northeastern Nigeria turned violent. The U.N. Office for the Coordination of Humanitarian Affairs reported that at least 40 people died, and hundreds were displaced after fighting broke out between local farmers and nomadic herders.

Who was at fault?

According to some analysts, the real culprit was desertification. The conflict arose after a shortage of acceptable pasture pushed desperate herders into farming regions.

French plant ecologist Andre Aubreville popularized the term desertification in a 1949 paper. He wrote that the desert "is always present in the embryonic state during the dry and hot season." Sufficient human pressure, Aubreville observed, can transform tropical rainforest into savanna, and savanna into desert. Desertification now threatens more than a billion people worldwide, although its impacts are most severe in Africa. A major impediment to food production, degraded land means roughly $42 billion each year in lost income. Outside the immediately affected areas, it can cause flooding, reduce water quality, create dust storms, and increase incidences of respiratory illness and eye infection.

"But as serious as desertification is, it's only part of the problem. The phenomenon we're concerned with is actually bigger," said Dr. Hank Shugart of the Department of Environmental Sciences at the University of Virginia. "We're interested in land systems that can change from something desirable to something undesirable, then stay that way."

Africa's fragile ecosystems make the continent especially vulnerable to unwanted environmental changes. Shugart compared Africa to parts of the United States and Europe. "In a place with rich soil, if you change the ecosystem and you don't like the result, you can stop, and the system will more or less restore itself. In parts of Africa and Australia, if you change the land and start seeing results you don't like, you might get to look at them for a long time."

Shugart developed an interest in large-scale ecosystems as a graduate student. As a researcher in the Southern African Regional Science Initiative (SAFARI 2000), he studies the big picture by looking at interactions between the Earth, the atmosphere, and people. Shugart suspects that Africa supports two kinds of savanna. One form produces palatable vegetation that the wildlife eats and recycles locally, so the ecosystem's nutrients (nitrogen and phosphorus) remain in the system. The other form of savanna produces less palatable vegetation; rather than being consumed by animals, this

Heavy rainfall enables the Kalahari sands to support lush rainforest (top), but substantially reduced rainfall in the south leads to sparser vegetation. Southern Botswana (bottom) is dry savanna. (Images courtesy of Hank Shugart, University of Virginia)

Data from the SAFARI 2000 project are archived at the Oak Ridge National Laboratory DAAC, which focuses on providing biogeochemical and ecological data for studying environmental processes.

For more information, visit the following:
Oak Ridge National Laboratory DAAC
Langley Research Center DAAC
Land Processes DAAC
SAFARI 2000
SAFARI 2000 Data Search
United Nations Convention to Combat Desertification
From the Dustbowl to the Sahel

vegetation accumulates, providing fuel for fires that transport nutrients somewhere else.

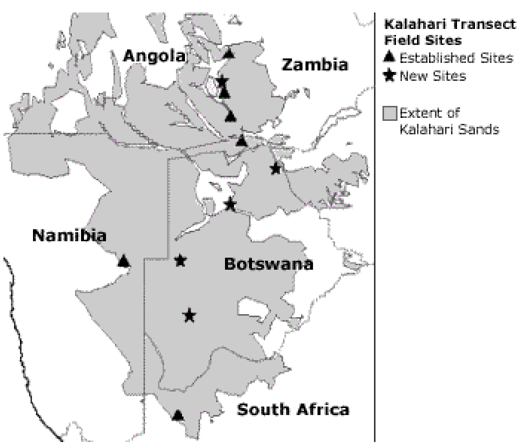
"If the low-nutrient ecosystems lose their nutrients, and the high-nutrient systems keep theirs, are landscape processes robbing the poor to give to the rich?" Shugart asked. If so, this reinforces a serious problem. Once an ecosystem that's easily grazed becomes an ecosystem that's easily burned, it rarely reverts to its previous grazable state. Exactly how ecosystems make this transition is not fully understood, but Shugart cites two lines of evidence that fire-adapted ecosystems exist in places that could support more benign vegetation: (1) previously forested regions have become fire-prone savanna, and (2) high- and low-nutrient communities exist on similar soils and under similar climatic conditions.

Sobering examples of unwanted ecosystem change can be found outside Africa. Introduced plant species have substantially changed ecosystems in North America. "Cheatgrass burns like crazy, and its seeds can withstand fire. It isn't good for anything else, so it's been kind of a scourge in the western United States," said Shugart.

Livestock grazing has also produced problems. "When people first encountered the Chihuahuan Desert in New Mexico, it probably had small shrubs and aridity-tolerant grasses. Once cattle grazed it, everything turned to creosote bush, which sends roots out 50 feet from the plant and sucks up all the nutrients. So now the system is either high-nutrient with a bush growing on it or low-nutrient desert. There are no nutrients between the bushes, so the grasses can't come back — even if you stop the livestock grazing."

A variety of natural grazers can keep an ecosystem in balance, but livestock grazing has had far-reaching effects in Africa's dry regions. "Africa has a beautiful assemblage of antelope, giraffes, and other big animals that eat different kinds of plants," Shugart said. "But cattle are preferential grass eaters, so once they start grazing, the vegetation can turn thorny and shrubby. Is that a reversible condition? We'd like to know."

Ecosystems unlikely to recover from human pressures require more cautious management. Making informed land-use decisions for such unforgiving ecosystems means understanding the complicated relationship between environment and vegetation. But such studies usually involve long time periods, making controlled experiments difficult. The trick for Shugart and his fellow SAFARI 2000 researchers was to find natural experiments already in place. They found what they wanted in the Kalahari Transect.



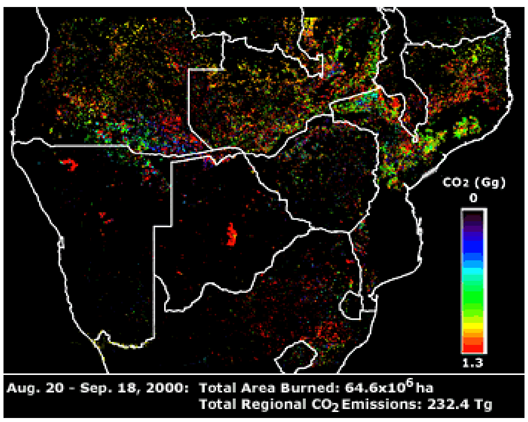
The Kalahari Transect extends from Angola and Zambia south into South Africa. It is characterized by uniform sandy soils, heterogeneous vegetation, and a strong rainfall gradient. Mean annual rainfall varies from nearly 1.5 meters (5 feet) in

When the Dust Settles

Image in title graphic courtesy of Hank Shugart, University of Virginia the north to virtually no rain in the south. (Image courtesy of Hank Shugart, University of Virginia)

"In most places where vegetation changes over hundreds of miles, as in the transition from the eastern forests to the Great Plains in the United States, there's a change in climate, but there's almost always a change in soil as well," Shugart said. "The Kalahari has one type of soil top to bottom — windblown sand. The rainfall changes in a very regular way. These variables are naturally controlled along this thousand-mile line."

Another controlling factor in the Kalahari Transect is land use. Much of the area Shugart is studying is devoted to farming or game preserves, where the land is essentially unused. Therefore, Shugart can compare the effects of fairly basic differences in land use. Yet studying southern Africa has presented Shugart with an uncommon problem. "Ecologists want to see how an ecosystem works naturally, and that usually means without people," he said, "but we evolved in southern Africa. The current land use patterns probably didn't evolve there, but there's been a human presence for a few million years." As humans have long known how to start fires, they have augmented naturally occurring fires.



Scientists working with Christopher Justice at the University of Maryland collaborated with Shugart's team to use MODIS imagery as the basis for calculating fire emissions of carbon dioxide. The team calculated that emissions from woodland fires totaled 180 Tg (teragrams, or a trillion grams), and emissions from grassland fires totaled 52 Tg. (Image courtesy of Stefania Korontzi and David Roy, University of Maryland Department of Geography)

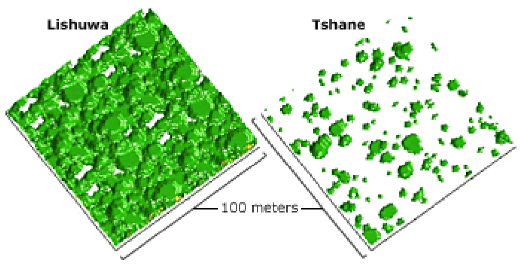
Research conducted so far has already given Shugart valuable insights into land-atmosphere interactions. Shugart's first expedition with SAFARI 2000 started in Zambia and headed south through the Kalahari Transect. Joined by members of the Moderate-resolution Imaging Spectroradiometer (MODIS) land validation team, he sampled vegetation intensively at six sites. Field Data from the Kalahari Transect are available via the ORNL DAAC's Mercury system.

The MODIS sensor monitors, among other factors, aerosols and land surface changes on the Earth's surface every 24 to 48 hours. For fire emission detection and vegetation mapping, Shugart uses MODIS imagery archived at NASA's Land Processes DAAC. In addition to the standard size of 1,200 by 1,200 kilometers, the Oak Ridge National Laboratory DAAC has prepared 7-by 7-kilometer subsets of MODIS products over field investigation sites in southern Africa. The subsets are used for validating individual MODIS pixel values against measurements made in the field.

MODIS images vary between 500-meter and 1-kilometer resolution, so a single pixel (the smallest visible unit in the image) actually represents a large area. Five hundred square meters can easily contain a mix of grasses, bushes, trees, and bare rock, yet the pixel can only record one type of ground cover. "The satellite's going to average something out of the picture," Shugart said. So he has supplemented MODIS data with higher-resolution images and modeling techniques.

The SAFARI 2000 project obtained AirMISR imagery by flying the sensor on an ER-2 aircraft over southern Africa during the study period. AirMISR data is archived at Langley Research Center (LaRC). For historical data, Shugart relies on newly declassified 2-meter resolution images taken by the CORONA spy satellite between 1962 and 1972, now archived by the U.S. Geological Survey (USGS). "We're trying to make comparisons between satellite imagery, aerial photos, and ground-truth data," said Shugart.

Shugart has also worked toward a model-based understanding of Kalahari vegetation. A dozen bushes might display as the same shade of green in a satellite image, regardless of their spatial distribution. Yet those bushes may behave in very different ways depending on whether they're clumped together or separated by several meters. For this reason, SAFARI 2000 researchers have begun making detailed models, known as stem maps, of fine-scale variations. Refining these stem maps will be an ongoing process for Shugart and his team.



Changes are obvious when comparing vegetation in Lishuwa Village, Zambia (left) and Tshane, Botswana (right). At the top of the transect, Lishuwa enjoys much greater rainfall. (Image courtesy of Hank Shugart, University of Virginia)

As the study progresses, Shugart will examine fire models, burn scar models, and emissions models to better understand what nutrients are lost to the atmosphere across Africa. He is also involved in producing a special journal issue of *Global Change Biology* devoted to SAFARI 2000 research.

"It's easy to get isolated if you're a working scientist in Africa," Shugart said. "Africa doesn't have a huge number of scientists yet, and the ones doing research are under a lot of pressure because they're in the middle of the problem. SAFARI 2000 has been a remarkable project in that it's arisen through grassroots coordination among scientists. By working together, we've been able to pool our resources and share information very quickly. It has been very refreshing."

U.N. Office for the Coordination of Humanitarian Affairs. Accessed March 21, 2002.

United Nations Convention to Combat Desertification. Accessed March 21, 2002.

Desertification: Myths and Realities. IDRC Briefings. Accessed March 31, 2002.

Desertification: A Review of the Concept. Center for International Earth Science Information at Columbia University (CIESIN). Accessed March 21, 2002.

SAFARI 2000. Accessed March 21, 2002.