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Developing Forest Management Plans with High-Tech Tools and Traditional Knowledge in Zambia

Cecilia Polansky and John Heermans

ABSTRACT

Simply transferring to other settings developed countries' sophisticated tools of modern forest management can be inappropriate. In a pilot program in Zambia, traditional knowledge of forest products is combined with satellite images, GPS, and GIS to adapt inventories and maps for forest management planning. The example used is the Cooperative League of the United States of America's Natural Resource Management Program. Development projects that place more emphasis on existing technology and input from local forest users and extension agents—and less on technical training and equipment—have the potential for more success in slowing the conversion and exploitation of tropical forests.

Keywords: Africa; international forestry; technology transfer

Since gaining independence from colonial powers, most African governments have not had the means to staff forestry departments to manage their huge forest estates. During the past two decades, aid donors have sought to help by sponsoring "joint forest management" or "comanagement" (Catterson 2002). The idea is that if villagers are allowed greater legal control over who harvests local forest products and how, they will feel a sense of ownership that leads to more sustainable use of the resource—and that relieves government foresters of some law-enforcement work.

We in the United States have been practicing joint forest management since the 1960s. Although glitches in the planning process remain, the notion that communities meet with government foresters to address management issues is now familiar. In Africa, forestry departments are still struggling with the idea of giving up some control. Nonetheless, thanks to donor pressure, legislation in the majority of countries in Africa today allows some degree of village participation in forest management (Wily 2002).

Community participation in the United States is facilitated by modern technology: Researchers use sophisticated visual and analytical technology to identify management practices, satellite imagery and specialized analytical programs detect changes in forest fragmentation, and automated tree-growing software models expected revenues from specific long-term management practices.

It is tempting to ask the same modern technology to facilitate forest management in the developing world. After all, satellite imagery is widely available, mapping and analysis software are getting user-friendly, and the level of competence of national foresters is rising. But donor-sponsored foresters can be-

***Above:* The village headman (left) studies an image before joining the inventory team to begin fieldwork.**

come so engrossed in the "gee-whiz" aspects of GPS, GIS, satellite imagery, and Internet research that they lose sight of how to use that technology to facilitate village-based management. Mastering new technology can mistakenly become a substitute for working on the ground, in the forest, with people.

Higher technology also requires higher investment. Too often, project managers budget heavily for acquiring the latest software and overseas training, and neglect to balance these with practical field adaptation. As a result, many forestry projects end after four or five years with highly trained technicians but nothing to show on the ground. Having witnessed many cases of this overmarketing of supertechnology, we are reminded by Cunningham (1998, p. 662) that

> At this stage we are more dependent on the efforts of developers and users to define the proper use of these technologies for use in the field . . . than . . . on improvements in computer technology, batteries, cableless GPS, etc.

This article reports a case study in which village-generated forestry knowledge is incorporated into the use of GIS, GPS, and satellite imagery. The combined high-tech and no-tech approach has been used to write 10-year management plans for pilot forests in Zambia under the Cooperative League of the United States of America Natural Resource Management Program (CLUSA-NRM), working with Zambia's Ministry of Tourism, Environment, and Natural Resources' Forestry Department; funding came from the US Agency for International Development (USAID).

Forest Management in Zambia

Zambia is in dry tropical south-central Africa and straddles latitude 11 degrees south. Most of its uneven-aged forests are of the regional type called miombo, getting 800 to 1,400 mm of rain during six months of the year; trees typically reach maximum diameters of less than 50 cm. Miombo is a mix of Brachystegia, Isoberlinia, and Julbernardia, hardwoods that are excellent charcoal and beekeeping trees. Valuable hardwoods, including ebonies and Pterocarpus, are present but declining in numbers, especially since the minimum commercial sawtimber diameter has been legally set at just 30 cm. Miombo forest is also famous for its edible caterpillars, a dozen varieties of wild mushrooms, bark rope fiber, natural medicines, beehives and brooms, and a host of other traditional and commercial uses well known in the surrounding villages.

For conservation and local use, 4 percent of Zambia's 753,000 square kilometers has been declared state-owned and managed (GRZ 2002). The rest is considered to be under the authority of local tribal chiefs, to be allocated for agriculture and other uses.

At least 39 percent of Zambia is still forested (CIA 2001). However, FAO (2001) reported that Zambia has the world's third-largest annual area of deforestation, at 850,000 hectares (8,500 square kilometers) per year, though some believe this is an exaggeration. Either way, conversion of forest to agriculture uses is rampant.

The composition of remaining forests is also changing. The bulk of the best hardwood sawtimber has been removed by overexploiting colonial powers, speculators, and government entities strapped for cash. Thus, forests have lost their former income-producing quality as well as their former extent.

The removal of the high-value exportable timber base and the lack of regeneration efforts have revealed to donor-sponsored development projects the economic and cultural importance of nontimber forest products. These products provide not only food security, construction materials, and medicine but also cash for basic household and educational needs. Yet nontimber forest products have never been incorporated into national inventories or management plans.

Farmers living near forests spend about eight months a year clearing land, planting, weeding, harvesting, and selling or storing excess crops; the dry months are filled with income-generating activities, such as sawing planks and harvesting honey. Those who participate in agricultural development projects are thus the same people who can be approached to resolve forestry issues. CLUSA-NRM has capitalized on this close link between farming and forest management. It uses field facilitation and extension to address farmers' short-term, agricultural needs first, and then it addresses longer-term forest management issues.

Objectives and Strategy

CLUSA-NRM's principal objective (assigned by USAID) is to alleviate the poverty of rural farmers, with improvement defined as an increase in their cash income (CLUSA-NRM 2002). A second objective is to reduce pressure on forestland by increasing crop yields on existing farms. Third, CLUSA-NRM is charged with assisting the government's Forestry Department to work with villagers on forestry education and writing management plans.

The strategy to attain increased incomes and crop yields begins with choosing worksites where some hundreds or thousands of hectares of forestland remain and where local chiefs agree to support the program. CLUSA-NRM then provides training on soil and water conservation farming; distributes improved seed; adds value to harvested crops (by, for example, pressing groundnuts into oil); and organizes farmers into a cooperative with a board of directors in charge of hiring labor, buying crops, and finding markets.

By the end of two seasons, farmers' confidence in the cooperative is such that they can be convinced of the benefits of organizing to manage forest as well as farm products. In addition, the advantages of controlling anarchic forest use at the local level have been understood by both the villagers and the Forestry Department, and together they write a forest management plan.

As of the third season, the farmers' cooperative members have begun to sell two forest products on the local market: hand-sawn planks and honey produced from traditional hives. Other products are targeted for further ecologically sustainable commercialization, such as mushrooms and thatch. At some point, a separate forest products cooperative may be formed. CLUSA-NRM will continue to provide extension training in adding value to timber and nontimber forest products.

The Forestry Department is CLUSA-NRM's main development partner. It is learning how to achieve its mandate for sustainable harvests by working with CLUSA-NRM's field personnel and mapping office to write 10-year management plans using village input. It receives training from CLUSA-NRM as it struggles to transform its traditional role of policing forest resources into providing extension and applying appropriate technology.

Extension and training in working with villagers, and in working within legal requirements, are just as urgent for "old-school" foresters as for rural farmers; therefore, CLUSA-NRM staff at all levels work with the agency at all levels. To cover the technical aspect of forest management, extension and district-level officers are being trained in adapting satellite imagery interpretation, GIS, and GPS to participatory timber and nontimber forest inventories to be used in the support of forest management plans.

The High-Tech Tools

Satellite imagery. Medium-scale aerial photography offers the best resolution for the features needed for local forest management maps. But recent photographs are often unavailable or, at $0.02 to $0.06 per hectare of coverage (Aldrich 1979; H. Lerdorf 2002, pers. commun.), prohibitively expensive. With flight costs, the expense can easily exceed $1,000 for a single 10,000-hectare forest. This would be a hefty investment in Zambia's case. Even when photography is available, hilly terrain can require complicated office measurement, photomosaic assembly, and field checks to get accurate areas and distances. These specialized photogrammetry skills are rarely available among local foresters.

Satellite imagery might be thought of as an alternative to aerial photography. Foresters in many projects use color Landsat images with 30-meter resolution covering more than 3 million hectares at scales of 1:100,000 or less. The cost is estimated to be less than $0.01 per hectare (CTFT 1989), but a large number of hectares outside the project target area may be included.

Although small-scale, low-resolution satellite imagery is appropriate for regional work or research, it is not suitable for village-based management: (1) The small scale and low resolution do not reveal the village features and forest types needed to map and plan; (2) spectral signatures for fallow fields overlap with those for lightly stocked tree savannahs, leading to erroneous estimations of encroachments and forest cover (USDA Forest Service 1984); (3) computer storage space and management are problematic; and (5) digital image classification for forest typing requires sophisticated overseas training, so forestry officers who undergo the training are usually office-based and qualify for field allowances that forestry departments can rarely pay.

As an alternative to using high-cost photography or low-resolution imagery, CLUSA-NRM uses panchromatic SPOT images with 10-meter resolution at the 1:25,000 scale. As long as the image data are from a time of year that maximizes differentiation between field and forest (such as two months before or after the rainy season), the resolution is sufficient to detect fields and paths in the forest, small villages, and forest types. The image covers 60 kilometers square (360,000 hectares). Processed to the "2B" level in hard copy and allowing for a duplicate copy, this image costs less than $0.02 per hectare (SAC 2000). It is worth noting that ordering panchromatic (visible band) hard copy eliminates the need for sophisticated training in classification as well as the need for massive computer storage capacity.

Besides cost, this type of image has several advantages:

- It is laminated and can be cut and carried in the field.
- It can be ordered with the centerpoint and month of one's choice, so whole forests can fit on one sheet.
- The standard format is 1:50,000; for $500 extra, the image scale can be blown up to 1:25,000 to imitate aerial photography.
- With local 1:50,000 topographic maps, features can be georeferenced: Any tracing off the map will overlay directly onto the image, and vice versa.
- Provincial Forestry Department personnel familiar with mapping concepts can order the correct imagery with little training, and interpretation is easily learned and shared with villagers.
- The processed image arrives within weeks of ordering.
- Villagers recognize their areas quickly even if they can't read or have never seen a map or aerial photograph.

CLUSA-NRM and Forestry Department staff have used these images to develop an inventory that includes both timber and nontimber forest products, show village committees the level of agricultural encroachment inside forest boundaries, make comparisons with older photographs to demonstrate the urgency of more controlled land management, calculate how much uncultivated land is left to allocate, point out nearby areas of contiguous forestland for potential land swaps, update roads and villages on 30-year-old topographic maps, and draw boundaries of forest areas using features that villagers recognize.

Each stage of using an image with villagers is an opportunity for discussion about the history and the fate of local forests. At one project site, the chief has authorized village headmen to delimit nearby "permanent community forests" that will remain off-limits to agriculture; so far, nine community forests ranging in size from two to several hundred hectares have been established. The image is a portable archive recognized by the Forestry Department and participating villages; it assists in resolving territorial and boundary issues, and the unbiased truth it depicts sets the tone for agency and village interaction.

GPS with desktop mapping. To update names and locations of land features, CLUSA-NRM field facilitators first tried "sketch mapping" with villagers—using stones and twigs to represent nearby features on the ground and then transferring the information to paper. The sketch maps were limited, however, by their ever-changing scales, varied level of detail, and lack of geographical tie-in with neighboring areas.

A more efficient map update was accomplished by studying the image with local residents and then visiting sites together, carrying a GPS with downloading capability. To obtain detail over larger areas, a simple template traced from the old topographic map—showing streams, hills, roads, and villages—was presented, and villagers were asked to add and correct current names and locations. Then the nearest features and the actual forest boundaries were visited, recorded in the GPS, and downloaded for mapping (fig. 1).

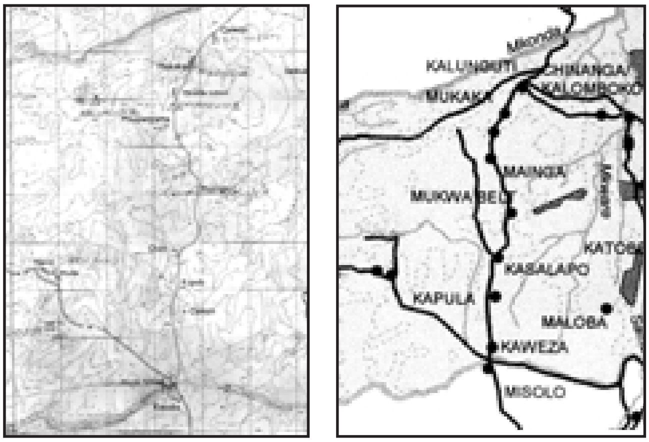


Figure 1. **A topographical map from the 1960s (left) and a simplified, GPS-updated version from 2002.**

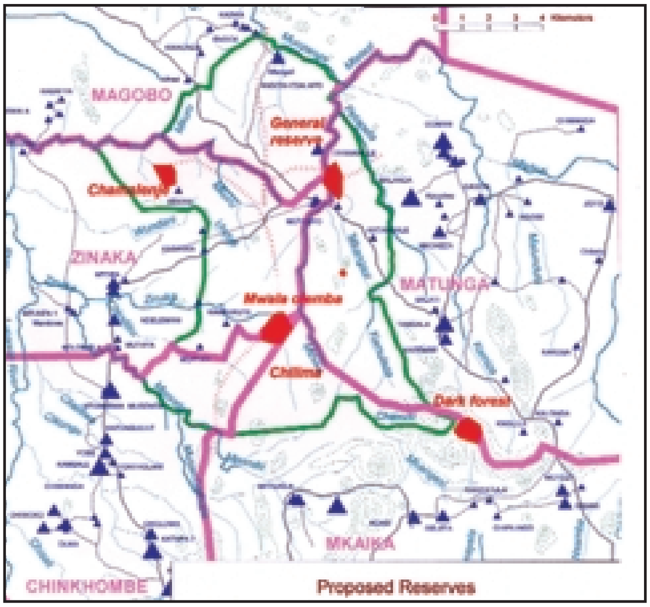


Figure 2. **Villagers used GPS to record wildlife habitat "reserves" inside forest boundaries.**

Forest boundaries are recorded in different ways. For government forests, CLUSA-NRM and the Forestry Department record the boundaries as villagers perceive them, even if they are different from those drawn on published maps or described in legal text.

For the permanent community forests mentioned above, boundaries are recorded as a combination of traverses and GPS-registered polygon pivot points and land features recognized on the image (fig. 2). Instead of mapping the smaller PCFs by running traverses with tape and compass, foresters simply walk the perimeters with villagers. The GPS is either left switched on continuously to record the entire track as a line (producing an exact record), or it is used to register waypoints at major angle changes.

GPS software can convert downloaded data into a format recognized by the digitizing software (.dxf) as a polygon, point, or line file. The digitizing software allows one to clean up the polygons or lines and build them as polygon coverages. A script in the mapping software calculates the forest area, which is then presented on a background of features traced off the updated topographic maps. Villagers recognize their areas on these maps.

Desktop mapping and GIS. One feature of the CLUSA-NRM pilot program is the "decentralization" of mapping assignments from Forestry Department headquarters to the provincial office, where training was done onsite on a skills-as-needed basis. The cost for the province-based desktop mapping system (software, large monitor, PC, roll-up digitizer, large-format printer) is around $11,000 (ESRI 1997).

The skills to operate desktop programs like MapInfo and ArcView are easily adapted to fit local forest management needs. In the best formula that we have found, one mid-level agency staff member is dedicated to mapping activity at the provincial headquarters, while field-based extension agents gather data at management sites.

Besides depicting topo map updates and permanent community forests, the GIS is used for two other forest management activities: calculating the level of field encroachment into state-owned forests and depicting inventory results.

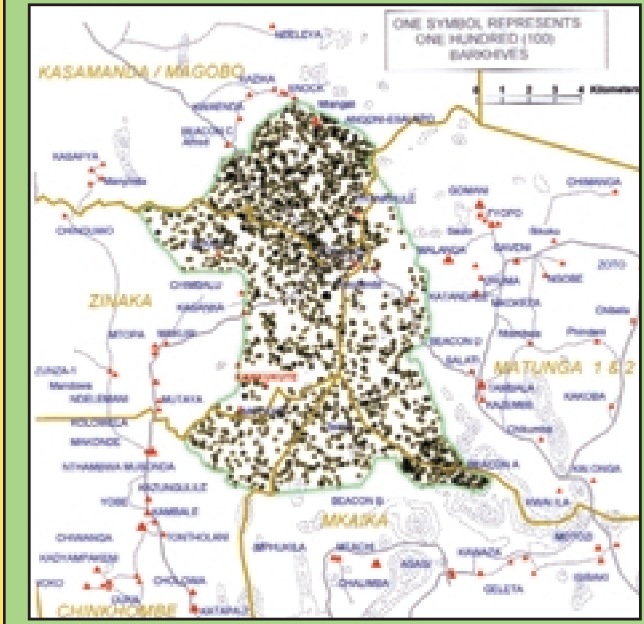
To calculate hectares of fields within government forest boundaries, the level 2B SPOT image georeferenced to existing 1:50,000 topographic maps is studied and ground-truthed if necessary. Fields within the forest boundary are traced from the image onto a clear overlay, then digitized as a polygon coverage. Total field area inside forest boundaries is calculated through the mapping software. CLUSA used the encroachment map to prioritize forestry activities and to verify placement sites for extension personnel in villages closest to deforested areas.

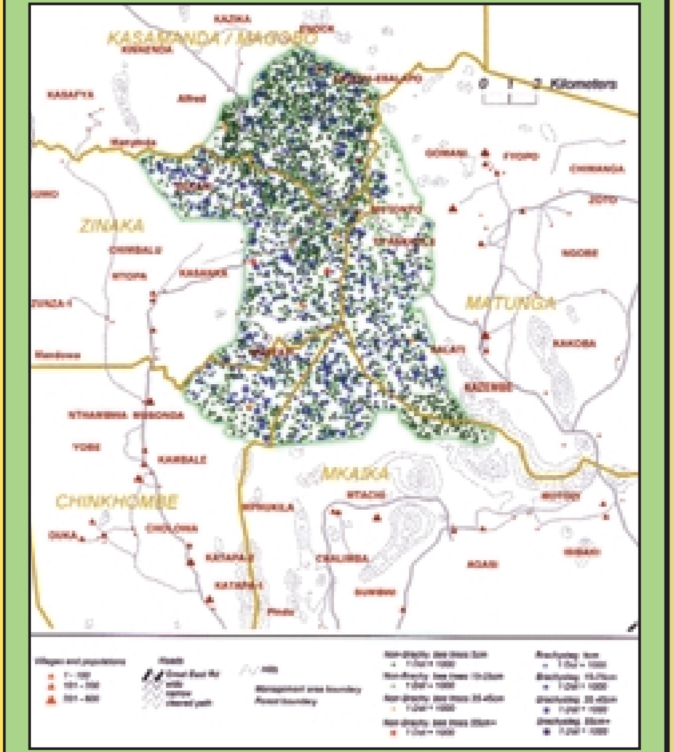
For depicting inventory results, the GIS-automated union, intersect, and buffer operations were invoked. Village population data, forest stand polygon layers, and per-hectare inventory result tables were combined for total-per-stand estimates. Maps of tree populations of interest to specific user groups, or of forest products contained in the forest, were produced by combining several processes:

- In a village forest resource assessment, villagers count the number of people whose incomes depend on specific forest products. Examples are hunters, charcoal makers, beekeepers (who make traditional hives from bark), and pit sawyers. Each user group then lists the preferred forest trees for their product.
- The forest is stratified into broad stand types from the imagery. Stand inventories are carried out with crews composed of agency staff and the local forest users. The users are the ones who measure the trees and give information on the product content of each indi-

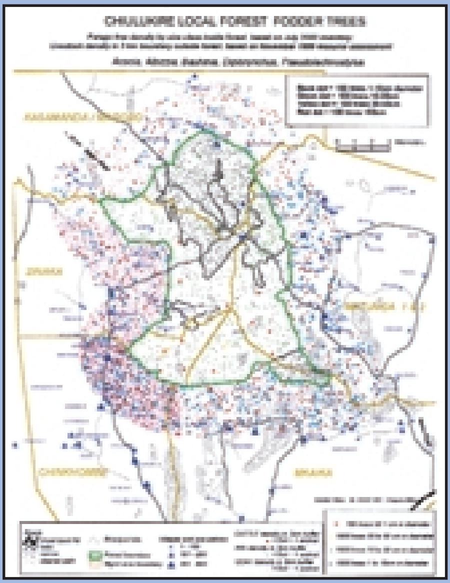
How High-Tech and No-Tech Work Together

Example 1. The appropriateness of traditional hive-making from bark was proven by (1) a map showing the high density of top-ranked hive trees throughout the forest, coupled with (2) a map showing the high density of top-ranked bee forage trees. The maps show heavier honey production potential on the north half of the forest, which is indeed the case.





Example 2. The need to control grazing in areas with higher cattle populations was supported by a map showing the cattle density in a buffer zone of 3 km outside the forest combined with the top-ranked forage species inside the forest. As a result, a grazing chapter in the management plan requires establishment of corrals and forage plantations outside forest boundaries.



Example 3. The highest-ranked charcoal species are abundant throughout the forest and can generate revenue to finance forest resource guards.

vidual tree in the sample plot. Prism points in woodlands, or rectangular plots in fallows, are used to determine trees per hectare by species and diameter class. Concentric circular plots provide information on species in decline and on the other commercial forest products not captured in the inventory, such as bamboo clumps and natural broom bushes.

- Standard spreadsheets are used to calculate trees (and then products) per hectare by species and diameter class, based on user group input.
- The mapping software is used to calculate hectares in each stand. The trees per hectare from inventory are used to estimate the total number of trees in each stand by species and diameter class.
- The species ranked highest by each user group are then extracted from the inventory tables and their totals are depicted by dot density within the polygons of a map of forest stands. This shows areas where overused species or certain size classes are becoming rare and where attention must be given to regenerating, protecting, or controlling their use.
- Intersecting management subunits with stand polygons allows the automated calculation of numbers of trees available to user groups. These data directly support prescriptions written into the management plan in chapters arranged by user group (CLUSA-NRM and Zambian Forest Department 2001).

The user group maps require little time to understand for foresters, who can then interpret the maps to community members during the mandatory post-inventory feedback. The maps do support management plan prescriptions and are easier to read and relate to the field situation than simple tabular reports. CLUSA-NRM considers this an adaptation of technology to a community-based joint management situation.

Because reliable local growth data are missing, the calculation of sustainable (allowable) harvest has been simplified to incorporate the information provided during the village forest resource assessments and tree inventories. It is included here because so many forest management programs get hung up for lack of agreement on how to include sustainable harvest in their plans; it also completes the process of incorporating village-generated data. It uses a simple formula:

> Number of existing, quality, exploitable trees in each operating area is based on [(inventory average trees per hectare) × (number of hectares)] minus (seed trees, to be left standing at the rate of 10% of trees >30 cm diameter) minus (any compensation to be made for a deficiency in the smaller diameter classes, based on shape of the curve from small to large diameter classes) divided by (number of years the trees have to last, based on the number of people in the user group and the number of trees they use each year).

The most obvious application is for saw trees, but the formula can also be used for other whole-tree uses, such as bark hives and carving trees.

Conclusion

The CLUSA-NRM experience in Zambia has demonstrated a way to develop community-based forest management plans. Conservation-oriented farming and forestry extension is followed by gathering and using village forestry knowledge. Affordable existing technologies are adapted to that knowledge to calculate and map the available timber and nontimber forest products Provincial as well as field-based Forestry Department personnel can assimilate the adapted technologies and ensure a more sustainable local process.

The cheapness and availability of higher-resolution satellite images, GPS, and GIS software and hardware make these technologies alluring, but it is important to keep them in their place and not let them become an obstacle to achieving results on the ground. We hope that the Zambian example has helped in the definition of a proper use of these technologies for use in the field.

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