Maps for the management plan that depend on data collected during the inventory will have these characteristics:

- updated road and trail locations and widths,
- updated village locations and populations,
- updated forest boundary locations including markers,
- updated important watercourse names (and possibly seasonality),
- distance to nearest large markets, and
- the vegetation types encountered with the number of hectares in each.
- a scale of 1:25 000

Also desirable are:
- identification of important point resources (fishing dam, mining area, sacred forest...),
- identification of areas with important sawtimber resources, if that is the biggest potential source of revenues for villagers,
- anything to do with cattle grazing (such as waterholes or commonly-used trails) that might conflict with agroforestry activity, and
- anything important that is physically close to the classified forest that has a bearing on its use (train station, factory...).

For most of these elements, traversing important roads and finding important points is done with a GPS receiver. The technology is too easy and too cheap to ignore.

The maps should be simple and avoid using an over-elaborate legend that has to be studied and memorized before the map can be understood. A dense vegetation type represented in red, for example, might be really hard to understand for someone living in the area, who probably sees it as dark green.

In an ideal world, the scale of the map will be 1:25 000 for planning purposes. Photos and images are usually ordered around that scale for management plans and monitoring purposes. If it is a question of SPOT imagery at 10-meter resolution (black and white), you will still be able to count and delineate fields and fallows inside the forest, along with most features needed. LANDSAT color imagery at 20- or 30- meter resolution, however, should be avoided, since often it is hard to differentiate between 2-year-old fallows and lightly-stocked savannas.

It may even be preferable to use satellite image or photography to chart out areas of operations for each user group, since people already can read such documents handily. Then a film printout of type boundaries would simply be placed over the image to represent the different types. A paper map may simply be used to calculate areas and provide a backup of the photograph of that forest at that point in time.

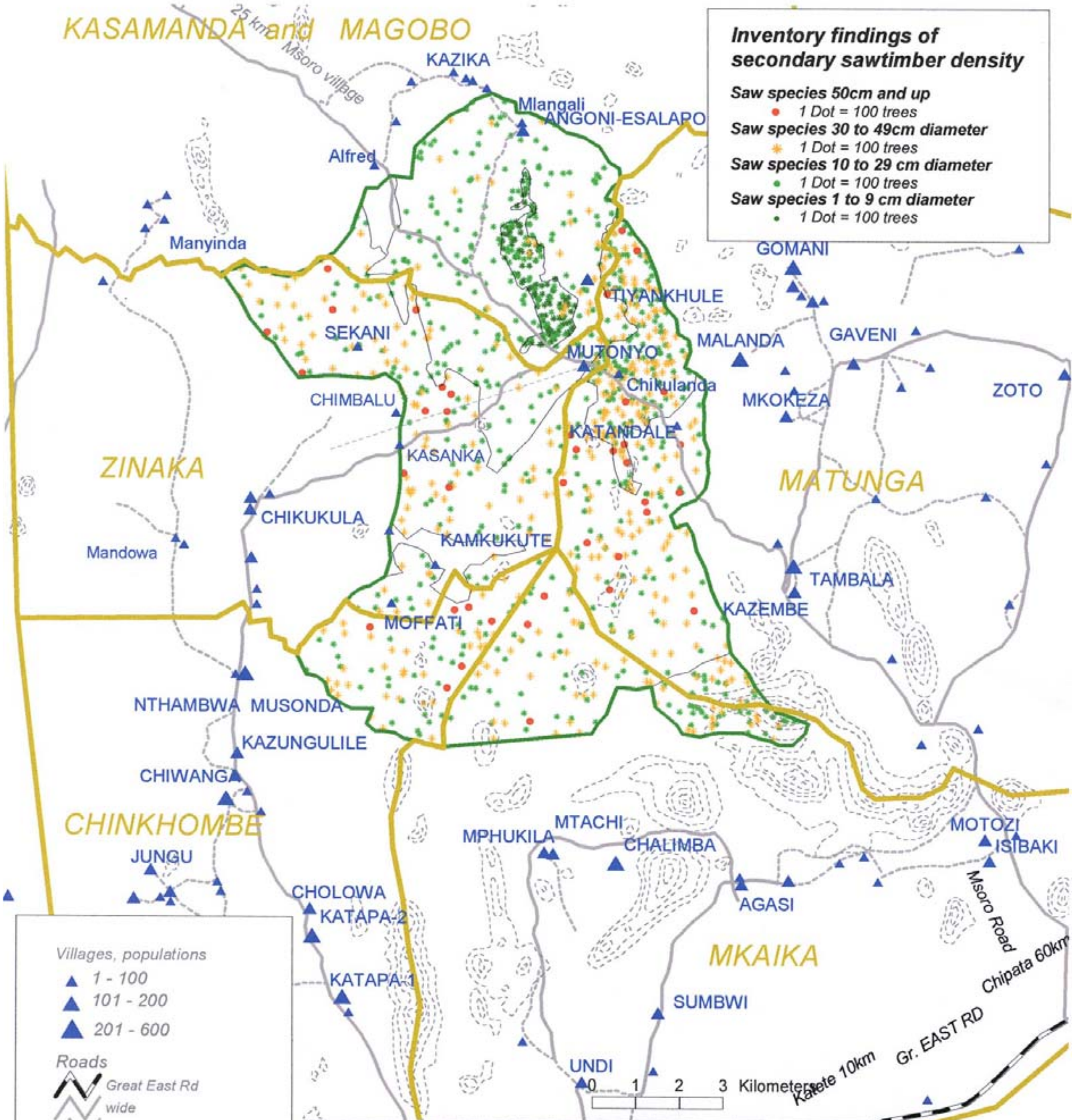
Another example of presented results is in the following sawtimber map. This one is probably more attractive to foresters than villagers; nonetheless, by pointing out the extreme shortage of “red dots” that represent trees of legal harvest size, the message can be passed that the current rate of cutting is not sustainable.

CHIULUKIRE LOCAL FOREST SECOND-CHOICE SAWTIMBER:

Kirkia, Terminalia sericea, Burkea, Brachystegia bussei

DENSITY BY DIAMETER CLASS BASED ON JULY 2000 INVENTORY

(see legend below) Forest area: 10,800 ha



MGMT AREA	Sawyers	Hectares	diam 1 - 9cm	diam 10 29cm	diam 30 - 49c	diam 50cm+
CHINKHOMBE	15	1083	0	3,376	3,587	528
MAGOBO	11	2461	10,139	18,299	3,775	84
MATUNGA	13	2662	0	19,221	17,428	1,650
MKAIKA	7	1369	0	6,159	5,467	558
ZINAKA	37	3222	0	12,126	8,947	1,168

2.6. USING PRA AND INVENTORY RESULTS TO CALCULATE ANNUAL HARVEST

(Some of the following discussion is synthesized from the Muzama Crafts Ltd Community Forest Management Plan, Volume 2 of Muzama's Responsible Forestry Programme, third draft, October 1996, in Zambia.)

The tables resulting from the analysis of inventory data are meant to help in deciding what can or can't be harvested annually from each hectare of forest. The managers will be working with one of the following assumptions:

(1) The status quo will be maintained, that is, the present distribution of species and diameters is satisfactory and it is only a question of estimating the number of trees that can move into the usable diameter classes each year, and harvesting those after allowing for mortality.

(2) The present distribution of species and diameters is not optimum, and the objective of management will be to manipulate the distribution in favor of certain ones so that the future forest will provide the desired products or habitat.

Either assumption requires management decisions on the desired "vision" of the forest or stand of the future.

Methods using no projections

There are different ways to approach the problem of deciding how to maintain an equilibrium. The following procedures are examples used in Zambia:

(number of existing, quality, exploitable trees[3] in each operating area, based on year 2000 inventory averages per hectare)[1] X (number of hectares)

minus

"seed trees"

to be left standing at the rate of 10% of sawtimber trees >30cm in diameter

→

minus

(any deficiency in the diameter class of next-rotation's sawtrees)[2]

divided by

(NUMBER OF YEARS the trees have to last) [3]

---

[1] "EXPLOITABLE TREES" are those with actual sawtimber content in them. During the inventory, roughly half of the potential sawtimber trees contained saw products in them. A deduction is also made for area in fields and roads.

[2] Regeneration can be estimated by using year 2000 inventory average estimate x hectares in operational area.

[3] Trees have to last longer when the next lower size class is deficient in number.

EXAMPLE OF CALCULATING ANNUAL CUT FROM STAND 5 INVENTORY:

→ Stand 5 has 150 hectares under reserves, and 600 hectares currently cultivated.
Total forested hectares in this stand = 6300 – (600+150) = **5550 hectares**

→ Total **primary sawtimber trees** (mukwa, mubanga) 30cm + in diameter in the stand:
0.4 + 0.3 + 0.2 = **0.9 trees per hectare**

→ (0.9 trees per hectare) x (5,550 hectares in stand) = 4,995 trees

→ Subtract the number of trees that are not of acceptable quality (70%):

4,995 – (.70 x 4,995) = **1,498 trees**

→ Subtract the number of quality seed trees that should be left (10%):
1,498 – (.10 x 1,498) = **1,348 trees**

→ Divide by the number of years these trees have to last (15 years*):
1,348 / 15 = 89.9 or ***90 trees per year in stand 5***

(NOTE: *this number must be adjusted according to the needs and policies of the local pitsawyer groups.)*
**If there is a low number of trees in the next lower diameter class, the trees have to last longer.*

THEORETICAL TABLES OF MAXIMUM ALLOWABLE HARVESTS

PRIMARY SAW SPECIES (MUKWA AND MUWANGA):

(1) MGMT AREA OPERABLE HECTARES / TOTAL HECTARES (allowing for galleries and reserved areas = 5% of hectares removed)	(2) TOTAL mukwa and muwanga >30cm diam = (from inventory, less 5%)	(3) POOR QUALITY TREES allowing for half, as per inventory = ½ X (2)	(4) STANDING GOOD QUALITY SAWTREES THIS YEAR = (2) – (3)	(5) SEED TREES = (10%) of (4)	(6) DEFICIENCY IN NEXT LOWER SIZE CLASS [A] = 1/2 x (4)	(7) TOTAL EXPLOIT-ABLE TREES STANDING THIS YEAR = (4) – (5) – (6)	*(8)* ***TOTAL PRIMARY SAWTREES EXPLOITABLE EVERY YEAR FOR THE NEXT 15 YEARS = (7) divided by 15 years***
CHINKHOM. 1030/1083 ha	902	451	451	45	226	180	***12***
MAGOBO 2340/2461 ha	162	81	81	8	40	33	***2***
MATUNG 2530/2662 ha	4257	2128	2128	213	1064	851	***57***
MKAIKA 1300/1369 ha	2450	1225	1225	122	612	491	***33***
ZINAKA 3060/3222 ha	2009	1004	1004	100	502	402	***27***

[A] STAND 5 (6000 hectares) had an average 0.9 mukwa + muwanga per hectare >30 cm diameter, and an average of ZERO mukwa + mubanga in the class 20 to 29 cm diameter. Therefore, in stand 5, the trees >30cm diameter have to last 30 years.

Overall, mortality rates between youngest to middle size class was 41%; between middle to small saw class, mortality was 87%; and between the small saw class and large saw class was 75%. Since normal uneven-aged forests tend to have constant rates of mortality and loss between age classes, the estimated shortage of the middle to small saw class is at least a half. That is, there are not enough younger trees to replace all the older trees presently in the forest. Therefore, current trees have to last longer to satisfy local needs "sustainably".

EXAMPLE: USING INVENTORY DATA WITH VILLAGE RESOURCE ASSESSMENTS TO CALCULATE THE NUMBER OF SAWYERS THAT CAN BE SUSTAINED WITH CURRENT AND FUTURE TREES

Based on the 1999 village profile sheets, the forest regions have the following numbers of sawyers:

CHINKHOMBE	15
MAGOBO	11
MATUNGA	13
MKAIKA	7
ZINAKA	37
TOTAL	***83***

During the November management plan workshops, area representatives stated that they would ask for 20 trees per sawyer per year. *This is for individual sawyers, applying for individual licences; not organized sawyers with a monthly fee required by a group license.* This also assumes that each sawyer works individually; **if sawyers work in pairs, then the following calculation would represent 2 times as many trees as needed to sustain the trade.**

20 trees x 83 sawyers = 1660 trees to be cut per year.

Over the 10 years that it will probably take for the 35-centimeter size class to reach the minimum 40-centimeter cutting size, this will be **16,600 trees**.

The question may be answered: *are there this many trees out there in the forest, year after year? Are there 16,600 trees 40 centimeters and greater out there?*

STAND 4 contains an estimated (0.5 trees per ha x 2800 ha =) **1400 trees** in the 40-centimeters and greater diameter class.

STAND 5 contains an estimated (2.1 trees per hectare x 6300 ha =) **13,230**.

The total in these stands = **14,630 trees**.

There is one stand remaining to be inventoried, stand 6, where a narrow band of harvestable trees was found. There are at least a few hundred trees contained in this and other pockets around the forest.

The answer to the above question is most likely then "yes". It is then a question of ***controlling tree poaching and monitoring regeneration and fire damage***.

The following is an example of sustainable harvest using a **nontimber product**, a shrub used to make attractive brooms harvested from forest slopes and sold in large population centers in the area, bringing thousands of dollars into the local economy each year.

PROPOSED RATE OF BROOM HARVEST BASED ON INVENTORY, NUMBER OF BROOMMAKERS, HECTARES, AND CURRENT LEVEL OF EXPLOITATION

AMOUNT CURRENTLY IN THE FOREST: Based on year 2000 inventory, the numbers of brooms currently in the forest described by age (bud) class are as follows:

STAND	AREA NOT RSRVD	NO. OF PLOTS	1 – 3 BUDS		4 – 7 BUDS		8+ BUDS		DEAD PER HA
			PER HA	TOTAL (thous.)	PER HA	TOTAL (thous.)	PER HA	TOTAL (thous.)	
1	100	8	*1637*	163.7	*752*	75.2	*221*	22.1	1681
2	260	8	*973*	253.0	*221*	57.4	*133*	34.6	2522
3	300	8	*0*	0.0	*0*	0	*0*	0.0	0
4	2570	56	*543*	1395.5	*316*	812.1	*133*	341.8	1314
5	5890	52	*221*	1301.7	*88*	518.3	*27*	159.0	549
6	200	(NO PLOTS)	-	-	-	-	-	-	-
7	415	8	*0*	0	*0*	0	*0*	0	0
TOTALS		***132***	***3113.9 thousand***		***1463.0 thousand***		***557.5 thousand***		

If we divide the current stock TOTALS by the estimated rotation length of 20 years to maturity, we get the following ***annually available stems***:

TOTALS DIVIDED BY 20 YEARS	1 – 3 BUDS	4 – 7 BUDS	8+ BUDS
	155,700	***73,150***	***27,875***

It may be assumed that plants with 1-3 buds are usually too short to exploit, and that a good percentage of plants with 8 or more buds may be in the vegetative propagation stage and thus off limits to harvest. This leaves the bulk of the crop to be harvested in the 4-to-7 bud group.

SUNDE NEEDED TO SUPPORT CURRENT BROOMMAKERS:

To arrive at a reasonable allowable harvest, it is proposed to make an objective "to sustain at least 80 broommakers from sunde in the forest and buffer zone". The average annual need per single broommaker, according to the year 2000 survey, is about **100 to 400 plants per year,** summing for 5 months of rainy-season production plus 7 months of dry-season production. The annual need to be sourced is thus

(80 harvesters) x (200 to 400 plants per harvester) = 16,000 to 32,000 plants per year

According to the inventory, these sunde do exist currently inside the forest and buffer zone.
It is therefore recommended that the mgmt areas be provided with sufficient permits for each of the first two years for A MAXIMUM 400 PLANTS PER PERSON x 80 PERSONS = 32,000 PLANTS, to be divided proportionately among the number of BROOMS (NOT number of broommakers) per area:

MGMT AREA	NO. SUNDE 4-7 BUDS INSIDE FOREST	NUMBER OF PERMITS/YR	MAX NUMBER BROOMS/YEAR
CHINKH.	92,800	4.76 OR **5**	2,000
MAGOBO	763,700	39.13 OR **39**	15,600
MATUNGA	172,100	8.82 OR 9	3,600
MKAIKA	98,100	5.03 OR 5	2,000
ZINAKA	434,500	22.26 OR 22	8,800
TOTALS	***1,561,197***	***80***	***32,000***

The reason for proportioning the number of permits by VRMA density of brooms, and not by number of broommakers, is to avoid overexploiting the brooms in VRMAs that are already in short supply. Thus broommakers are still assured of meeting their needs, while doing so in the best-supplied VRMAs.

Methods using projections of future trees

It may useful to develop a table of "projected" numbers of trees per hectare based on how the forest in question grows. The easiest way to develop such a table is to use past inventory data, ideally from permanent sample plots set up for this purpose. Even data from only five years of measurements can help. You find the average difference between current and past diameters for trees in each diameter class; then divide the difference by the number of years between measurements. Then you have an idea of how many centimeters of growth occur on each tree from year to year, and at what point the tree reaches a desired product size. Mortality rates are applied to each diameter class to arrive at a final projection table. Other examples are cited below.

Maintaining the status quo requires subtracting the present volume from the future volume of trees and dividing by the number of years between the two volume estimates. The Muzama example is given here for data from a permanent sample covering 3 HECTARES:

ALL TREES MOVE UP ONE DIAMETER CLASS IN TEN YEARS

AT TIME ZERO	DIAMETER CLASSES (cm)				
	1-4.9	5-9.9	…	25-29.9	30+
TREES PER HA	140	57		3	2
MORTALITY	90%	80%		10%	5%

→

IN TEN YEARS	DIAMETER CLASSES (cm)			
	5-9.9	10-14.9	…	30+
IN-GROWTH TREES PER HA	.10 X 140 = 14	.20 X 57 = 11	…	(.90 X 3) + (.95 X 2) = 5

For the area of the sample plots, a net of (2+3) = 5 trees have been added to the stock of trees in the 30 centimeter-plus class. Five trees divided by three hectares in the plot area equals 1.7 trees per hectare. In the ten-year period, that represents a gain of .17 tree per year, or an allowable cut of **1 tree per 5.9 hectares per year.**

Another approach cited from Groome et al. (1957) follows:

	DIAMETER CLASSES						
	1-4.9	5-9.9	10-14.9	15-19.9	20-24.9	25-29.9	30+
TREES AT YEAR 0	140	57	17	9	4	3	2
MORTALITY RATE OVER TEN YEARS	90%	80%	70%	50%	15%	10%	5%
TREES IN 30+ CM DIAMETER CLASS AT YEAR 10	.3(1)	1.2(2)	1.9(3)	3.3(4)	2.9(5)	2.5(6)	1.9(7)

(1) 0.3 = 140 x .1 x .2 x .3 x .5 x .85 x .90 x .95
(2) 1.2 = 57 x .2 x .3 x .5 x .85 x .90 x .95
(3) 1.9 = 17 x .3 x .5 x .85 x .90 x .95
(4) 3.3 = 9 x .5 x .85 x .90 x .95
(5) 2.9 = 4 x .85 x .90 x .95
(6) 2.5 = 3 x .9 x .95
(7) 1.9 = 2 x .95

- TOTAL TREES IN LARGEST DIAMETER CLASS ON SAMPLE PLOTS AT YEAR 10 = 0.3+1.2+1.9+3.3+2.9+2.5+1.9 = 14.0

- TOTAL TREES PER HECTARE IN LARGEST CLASS AT YEAR 0 = 2t/3ha = 0.7
- TOTAL TREES PER HECTARE IN LARGEST CLASS AT YEAR 10 = 14t/3ha = 4.7
- 4.7 (FUTURE) – 0.7 (NOW) = 4.0 TREES GAINED IN 10 YEARS
- 4.0 DIVIDED BY 10 YEARS IN THE ROTATION = 0.4 TREES PER YEAR, or 1 TREE PER 2.5 HECTARES

→ The one tree per 2.5ha is distributed among species according to their relative abundance.

Manipulation of forest composition requires comparing current descriptive tables to forest potential stated by local and drawn on maps, in order to estimate:

(1) Whether enough regeneration of the desired species is present, and if not, how regeneration can be encouraged through management operations (thinning to increase light, controlled grazing, planting…)

(2) Whether reasons for low numbers of desired species should be further investigated (climate, disease, illicit felling, overgrazing…) and treated in the management plan.

The most straightforward way to deal with insufficient stem numbers for a given species is to harvest small percentages of the annual growth rather than the full growth as calculated above. Diseased or malformed trees making up a small percentage of the species can be harvested and processed as fuelwood or some other product, leaving healthier trees to grow larger and produce high-quality seed. If the descriptive tables include a breakdown of diseased and malformed trees, the prescription becomes even more straightforward.