Method of forest monitoring in Nigeria
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R.G. Lowe

In Nigeria during the 1980s, methods were developed for monitoring natural tropical high forest -- including laying out permanent sample plots, field assessments, and processing and analysis of data. The purpose was to observe changes in the tree population of the forest, with the intention of obtaining sustained yield management for timber. The methods were evolved from field procedures previously used in Nigeria, adapted for the use of a personal computer. There is a brief description in Commonwealth Forestry Review 76(2): 107-113 (Lowe, =1997).

It was necessary that the plots should be quick to lay out, easy to find again for subsequent re-measurements, rapidly measured, and enable individual trees to be identified. Plots were each to cover 1 hectare, and it was considered that a sampling intensity of about 1% would give acceptable error (for growth increment). In fact 2 plots were laid out in each square mile compartment, equivalent to 0.77% sampling intensity.

In more or less undisturbed forest it is normally possible to see about 20 metres distance. Hence it was decided that a plot should extend 20 metres either side a centre line, and consequently be 250 metres long. Because small trees tend to be more frequent than large trees, although the errors of measurement for large trees are greater, it was decided to sub-sample smaller size classes. This was achieved by limiting the measurement of various size classes to within different distances from the centre line, viz: 5 - 20 cm DBH to 2½ m either side the line 20 - 40 cm DBH to 5 m either side the line over 40 cm DBH to 20 m either side the line. Previous inventories had indicated that this might even up the numbers of trees in the various size classes.

The plots were arranged systematically, because of the difficulty of finding randomly located plots after an interval of years; no indication was obtained that this increased statistical error. Each plot was placed at 800 m intervals along a baseline (approximately ½ mile) offset at right angles and at a distance of 50 m from it. Six numbered concrete pillars measuring 10x10x45 cm (moulded in the forest using stream sand) were placed at 50 m intervals along the centre line.

With a team of 8 persons, using a 50 m surveying chain and (diameter) girthing tapes, all trees of 5 cm bole diameter or above were measured at breast height (1.3 m from the ground); or if buttressed to within 30 cm of this point or higher at 2« m from the ground; and if higher than this at 30 cm above buttress. Bole height was estimated in metres by counting the number of 2 m sections up the bole (the forestry workers seemed able to do this remarkably accurately). Where a plot was being re-measured, newly recruited and missing trees were noted. Selected trees belonging to species exploitable for timber, which appeared to be potential final crop trees, were girthed with a steel diameter tape and, using alphabetic/numeric codes, a note was made of their canopy status, stem class, crown class, extent of climber infestation, extent of damage (if any) and whether buttressed, fluted or having stilt roots.

It could normally be judged by eye whether a tree should be included in the sample or not, but marginal trees were ascertained to be in or out by using a 2½ m pole for trees less than 40 cm diameter; and by off-setting with a measuring tape from the centre of the plot for trees over 40 cm diameter. This made it unnecessary to demarcate plot boundaries. Trees were identified individually by recording their species and diameter, whether to the right or left of the centre line, in which 5 m segment along the line they occurred, and if they were within the 2½ m or 5 m margin from the centre line. After measuring, a horizontal line was drawn in scarlet enamel paint

at the point of measurement on the side facing the centre line. (These marks last at least 3 years). The selected trees were also numbered in scarlet paint at face height, and a numbered aluminium tag was attached to 15 cm of wire (to allow tree growth) nailed 1 metre below the point of measurement.

Regeneration sampling was carried out for listed species (i.e. usable for timber) concurrently in 5 m quadrats along each side of the centre line. The sides of these were demarcated with poles 2½ m long leapfrogged along the line as sampling proceeded. Within each quadrat one stem was selected that was considered most likely to reach final crop size, and its species and category (i.e. sapling 1m to 3m high, or pole 3m high to 5 cm DBH) were noted. The number of all saplings and poles of listed species within the quadrat was also noted, viz: whether up to 1, 2, 5, 10 or 50 respectively. In fact, generally speaking, regeneration was sparse and it was uncommon to find more than one or two stems within a particular quadrat.

After completing the tree inventory and regeneration count, while returning along the centre line to the start, at intermediate points of 225 m, 175 m, 125 m, 75 m and 25 m along the line, we made a basal area assessment using an angle gauge prism with a factor of x2.5, counting the number of trees subtending an angle equal to or exceeding the given angle to obtain basal area in mý/ha. At the same points the nature of the terrain was noted (whether level, valley bottom, lower slope, middle slope, hill top or ridge) and percentage of the area dissected by ravines or gulleys, or composed of rocky outcrops, water courses, swampy ground or tangled undergrowth. We used a clinometer to determine the slope down the centre line, and the aspect of the terrain using a compass; and took soil samples using an Edelmann auger, at the same time noting the texture, depth and colour of the soil horizons (with a Munsell colour chart). If the forest in the area had previously received silvicultural or other treatment, or exploitation (if known), this also was recorded.

The specially designed field sheets were carried back to the office for entry into the computer using a program written in FORTRAN, and other programs were written to analyse the data. These were found to be quicker and more reliable then spreadsheets. It took 3 days to lay out and assess a plot for the first time, and one day to re-measure it -- normally after an interval of 2 or 3 years (before the paint marks had peeled off the trees). Another program compared the previous and the subsequent measurements for the plot and indicated discrepancies – so that corrections could be made from the field sheets. If the discrepancy could not be accounted for it was left, and adjustment made in predetermined ways during analysis in order to avoid bias. When a plot was being re-measured, a printout of the earlier measurement was carried to the field on which the new measurements could also be entered. This was both to help locate trees and to assist in correcting errors.

For each plot, determinations were made of numbers of standing trees of each species, their basal areas, volumes and volume increments. The volume increments were also divided into utility classes, and calculations made for statistical error of the volume increment per hectare for the forest. This was obtained by calculating volume individually for each tree using a bole taper function for each species, which had been estimated by H. Sutter. These only required a knowledge of the breast height (or above buttress height) diameter and the length of the bole. Taper functions did not appear to be sensitive to locality nor require adjustment factors to be applied (as might be necessary if multiple regressions had been used).

Because all trees are being identified, the use of an expert field botanist is essential, together with back-up from a forest herbarium. Numerical field keys relying only on vegetative characters were also found to be extremely useful -- unlike the dichotomous keys based on flowers and fruits

normally incorporated in Plant Flora. Local villagers can constitute a half of the members of the field teams if they are literate, but the assistance of experienced forestry workers is also needed, and in our case the latter were already semi-familiar with the use of botanical names -- which is helpful in countries where a multitude of languages are spoken.