# VANUATU NATIONAL FOREST INVENTORY

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## ABSTRACT

The Vanuatu National Forest Inventory commenced in 1989. Field survey activities were primarily undertaken through the Vanuatu dry season and were completed in 1991. The primary objective of the forest survey was to provide information on type, distribution and volume of forest resources to enable national planning for development and conservation.

The first step in developing the sampling strategy was the typing of vegetation from aerial photographs (API). Geographic information was collated and then overlain to compile discrete polygons known as resource mapping units (RMU). Forested RMU were then stratified within each of the 12 principal island groups.

A variable probability approach was used with at least one representative RMU sampled from each strata in most cases. The selection of RMU for sampling was essentially random and within selected RMU at least two randomly selected plots were located. At each plot tree data were collected at 20 points along a transect. All trees over 10 cm diameter at breast height (1.3 m) over bark (dbhob) and within the range of a wedge prism with a basal area factor of 10 were measured at each point and other individual tree data were recorded. Additional information on the occurrence of non-timber forest products such as bamboo and rattan was recorded.

A number of problems were encountered in the course of the field survey. In the custom land ownership system which operates in Vanuatu, the need for intensive public awareness campaigns to facilitate field operations was apparent early and appropriate extension systems were developed. The frequency of cyclones and historical garden areas combined to increase the variability of the forest. Volumes were adjusted at a rate derived from the level of disturbance indicated from the API to account for these factors.

Although results are not yet available for publication, the level of precision obtained and the efficiency of collection indicate that the methodologies used in this survey were appropriate and probably have wider application to countries with similar environments to Vanuatu.

## INTRODUCTION

The Archipelago of Vanuatu is situated in t;he south west Pacific Ocean between New Caledonia, the Solomon Islands and Fiji. It is located in a tropical region between 13.04 and 20.16 latitude south and 166.32 and 170.14 longitude east (Fig. I). The archipelago consists of 83 islands with a total area of approximately 12 190 km$^2$. The 1989 national census gave an estimate of population of 142 944 people with a 2.8% annual growth rate (NPSO, 1991 ).

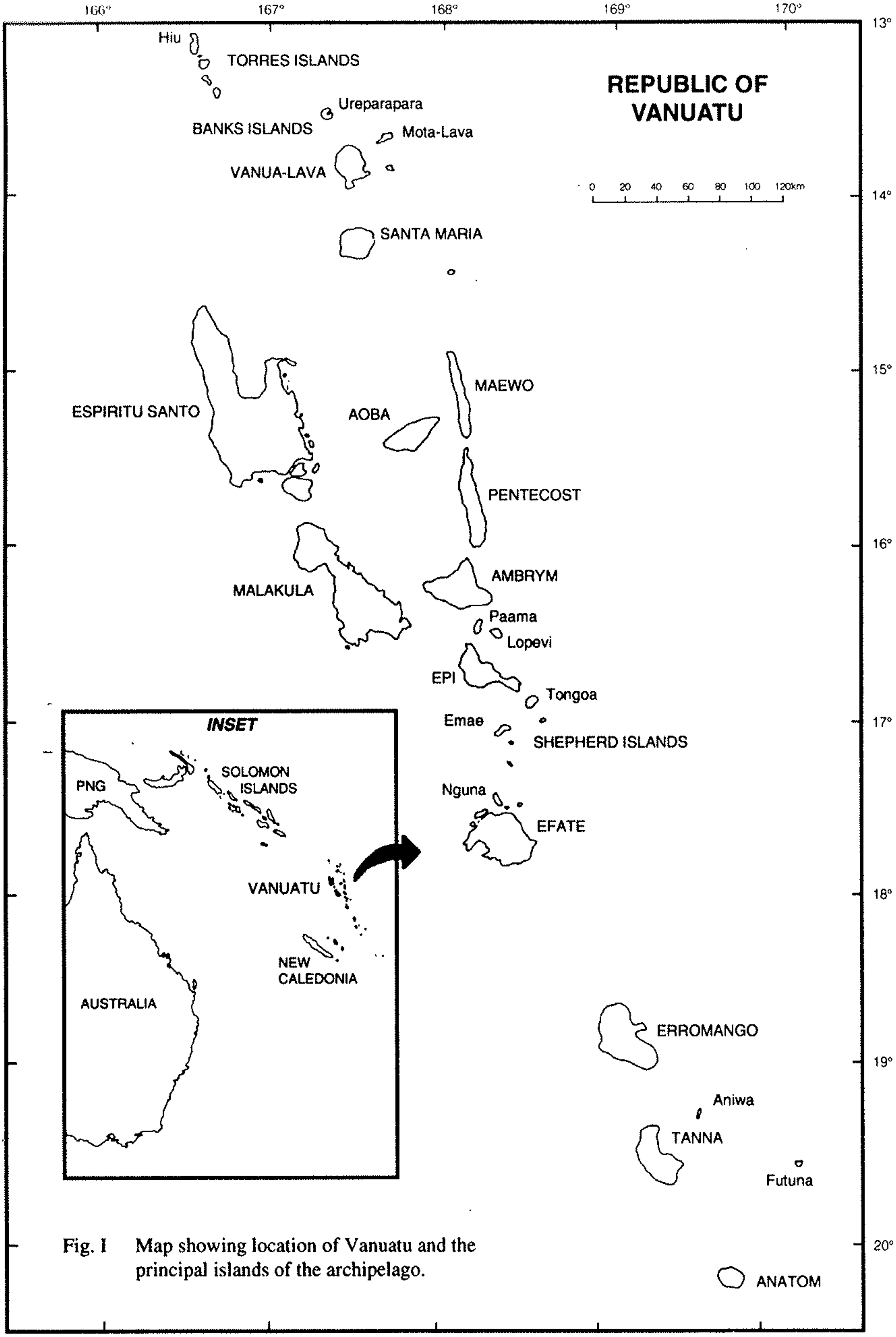


Fig. I Map showing location of Vanuatu and the principal islands of the archipelago.

The islands consist of predominantly volcanic eruptive rocks, raised coral plateaus and sedimentary terraces. Because of their youth, and deposits of volcanic origin, many of the soils are very fertile. Although the soils are fertile, the forests of Vanuatu are not generally considered to have the diversity or quality compared to those of its closest neighbours, the Solomon Islands and Fiji, probably due to the combined effects of geological youth and regular cyclones. The production economy is primarily in agriculture with copra, coffee and cocoa being the major exports. Increased exports of forest products and an improvement in tourism are showing potential as important contributors to the economy. Forestry in particular is seen as an industry capable of reversing trends of rural-urban migration which can be a problem in developing countries such as Vanuatu (Bule and Jenks, 1988).

The Government of Vanuatu realised that a rapidly increasing population can put pressure on its limited forest resource and give rise to conflicts in land-use. In addition, in a small developing country like Vanuatu, accelerated economic development could have negative impacts not only on the forest resources but on other natural resources as well. It was also realised that there was a lack of basic information to enable proper plans to be prepared for the use of the country's natural resources. In March 1987, the Vanuatu Government requested the assistance of the Australian Government in carrying out a survey of its natural resources, particularly in the Agriculture and Forestry sectors. Following design and selection of consultants to conduct the project by the Australian International Development Assistance Bureau (AIDAB), forest inventory commenced in September 1989 and most field survey was completed in December 1991.

This paper describes the field survey component only. However the project has a comprehensive land resources data-base which relates the forest survey data to associated resources (e.g. soils, climate) and land-use. This geographic information will aid government agencies and resource planners in drawing up development plans and management strategies for the efficient and practical utilisation and conservation of the country's natural resources.

## SURVEY DESCRIPTION

### Reasons for project promotion during forest field survey

Because of Vanuatu's geographical situation and strong emphasis on land ownership in Melanesian culture, it was considered at the very beginning of the project that a strong and effective extension campaign must be planned and put in place. The need for such publicity and extension has been recognised in other similar situations in Vanuatu and the National Population Census conducted in May 1989 also placed emphasis on this point (NPSO, 1991 p. 15). The main reasons for a strong extension campaign are:

1. <u>Project Awareness</u> To give the local government councils and village people, especially landowners, an idea of the aims of the project and the benefits it can bring individually, regionally, and nationally.

2. <u>The Courtesy of Seeking Permission</u> Out of common courtesy, there is a need for Department of Forestry staff to go to landowners to seek permission to enter their land to establish survey sample plots. With the rapid development drive in most developing countries, most land-owning individuals and communities are cautious or suspicious in dealings affecting their resources. This difficulty can be aggravated in cases where field staff enter people's land without full explanation or justification of their motives. It is essential that the appropriate landowners are identified and consulted before any field work is planned in an area.

3. <u>Community Work Program</u> In the rural communities of Vanuatu a lot of community activities are conducted on a regular timetable in the village. Specific week days are allocated for different activities such as health day, church day, public building maintenance and sporting events. Prior planning of project work days and meetings is important to avoid

clashes with these days. If little notice is given before hand, nothing can be achieved in terms of work and mutual co-operation. Linked to this is the vital importance of having access to local workers. The value of local knowledge of walking tracks alone added considerably to the efficiency of the survey.

## Methods of project promotion

Various means have been employed to promote the project and communicate the general progress of the project and movements of field crews. Below is a summary of the methods used and the groups targeted by the promotion.

1. Regular Radio Programs With co-operation from the Department of Agriculture and the Environment Section of the Department of Physical Planning and Environment the project has been able to conduct interviews and make announcements over two programs on Radio Vanuatu: "Insaed Long Nakamal" (in the meeting room) and "Aelan Blong Yumi" (our islands). To enhance the presentation on radio, a local band was commissioned to compose and record a project song. Generally project staff were interviewed to describe the project but several interviews were held with island leaders to inform people that field parties would soon be visiting their area. Service messages broadcast at different times of the day are also an effective means of communicating with isolated communities and project field staff.

2. Static Displays A very effective means of project promotion has been the assembly of a laminated display of colour photos with captions to explain the project. This display has been exhibited on several special occasions in Vila and has been transported around the islands for display in local government council headquarters when field crews are working in an area. This display continues to grow as more photographic material becomes available and will continue to be used to inform people of other aspects of the Department's work. To complement the photographic display a single page leaflet in Bislama (the common language of Vanuatu ) has also been distributed to explain the project.

3. Promotional Tee Shirts In Vanuatu, printed Tee Shirts are an effective means of promotion of health programs and agricultural extension. In the early stages of the project a competition was held among Departmental staff for the design of a project logo for a tee shirt. These tee shirts are worn by staff working in the field and are presented as gifts to village leaders and local government councillors.

4. Promotional Video The advent of a comprehensive land resources database is new to Vanuatu and a video has been produced to help demonstrate the potential of the database in assisting planning. Video machines are becoming more and more accessible to people throughout Vanuatu (usually in group screenings) and the video will become a powerful tool in the near future for "selling" such projects as this inventory.

## Airphoto interpretation

The most recent aerial photography available for Vanuatu is black and white cover that was flown between 1984 and 1986 by the Royal Australian Survey Corps at an approximate scale of 1:30 000. A few small areas which had cloud cover at the time of earlier photography were rephotographed in 1990 for use in this airphoto interpretation (API).

A rapid API covering the whole country was conducted initially to stratify and map natural vegetation types and land use intensity using the 1:30 000 photography. Initial mapping of forest type and land use intensity for areas obscured by cloud or not covered by this photography were interpolated using the vegetation map in Quantin ( 1972-78).

Natural vegetation types were delineated on the 1:30 000 aerial photographs and compiled as a map overlay to the 1:50 000 topographic map base. The natural forested areas have been classified into forest types on the basis of certain characteristics of the vegetation exhibited in the photo pattern. The principal criterion is the apparent height of canopy with four classes being recognised, namely: tall forest (>30 m); mid-height forest (20-30 m); low forest (10-20 m); and thicket (<10 m). Other photo pattern characteristics used for distinguishing forest types include: canopy density; presence/absence of emergents; crown size; recognisable dominant/emergent species, etc.; and topographic location. Where there was a distinct pattern of vegetation which may have incorporated mixtures (e.g. forest and thicket which might arise because of human or cyclonic influences), these were identified as mixtures with the predominant type named first.

Ground and aerial checking were used extensively to verify API. The results of the field surveys are also now being used to further confirm API and to assist with formulation of more detailed vegetation/ecotype descriptions.

### Delineation and description of resource mapping units

The basic spatial unit of the forest resource inventory, the resource mapping unit (RMU), is a relatively complex area of land characterised by a common set of geographic attributes that are unique and hence in some way different from those on other adjacent land areas. RMUs were delineated for use in the forest inventory on the basis that each RMU is unique in terms of one or more of seven selected criteria, namely:

- Natural vegetation type;
- Land use intensity class;
- Landform/relief type;
- Rock type;
- Slope class;
- Altitude class;
- Rainfall regime.

These criteria were chosen on the basis that they are relatively time-constant variables that best reflect differences between land areas with respect to the natural forest resource and its long-term management and development potential.

The specific sequence of steps involved in the delineation of RMU's was as follows:

1. An initial set of spatial units was generated manually by the sequential overlaying of maps of: forest type/land use intensity; (from API); landform/relief/slope; altitude; geology; and rainfall regime.

2. Small "slivers" (generally less than 300 metres wide) formed by the near coincidence of boundaries were not delineated as separate spatial units but included in the most appropriate adjacent area.

3. Each spatial unit was then allocated a unique reference number on an island or island group basis to create a RMU map. Spatial units which were identical in terms of the seven criteria but having different locations and no common boundaries were delineated as separate RMUs and allocated different reference numbers.

### Stratification of mapping units

Once the RMU boundaries were generated, each RMU was then described in terms of its location, area, forest and related natural resources, population and land use attributes. These descriptions were recorded in coded form and were the basis of the forest resource inventory.

As there were too many RMUs to sample each one individually as part of a national forest inventory, the RMUs for each island group were aggregated on the basis of a landform, climate, forest type and land use intensity classification to provide a stratified random sampling framework. This stratification maximised the reliability and practicability of extrapolation of information from limited field survey data. The stratification was based on the following criteria:

A. Exclusion of all RMUs that are considered to be either inaccessible, and/or of non-forested vegetation type and/or high land use intensity, that is RMUs with any one or more of the following attributes:

(i) Dominant slope class of >30 degrees (because logging would generally be unacceptable in such areas on environmental and practical grounds.

(ii) Natural vegetation type of:

- Freshwater swamp communities
- Mangrove communities
- Thicket dominated by *Leucaena leucocephala*
- Thicket dominated by tree fern
- Thicket dominated by *Hibiscus tiliaceus* (bourao)
- Low forest with dense small crowns. Mossy forest
- Natural vegetation not present

(iii) Land use intensity class of:

- Very high with tree crops or pasture ( <25% forest cover )
- Very high with gardens (<25% forest cover)
- High (<50% forest cover)
- Moderate (50-80% forest cover)

B. The stratification of all remaining RMUs is based on:

(i) Natural vegetation type;

(ii) Climate type (i.e. wet (>1800 mm) or dry (<1800 mm));

(iii) Aggregation of landform/rock type.

In total, 43 forest sampling strata were identified for the island of Espiritu Santo based on this stratification (Fig II). By way of comparison Ambrym had only six sampling strata. Table 1 provides details of strata numbers for each island group.

## Field survey technique

A variable probability approach was used in this inventory based on techniques as presented by Dilworth and Bell (1985). This system was considered to be more appropriate than others because of the environmental conditions prevailing, particularly the variability of forest cover in Vanuatu. The steps followed in the actual inventory were:-

1. Plot location selection

While selection of RMU for sampling was essentially random, some criteria were applied to reject some RMU, within a strata, from selection. This was essentially done on the basis of practical accessibility to ensure that excessive expenditure of time, money and effort was not made in the pursuit of sampling an RMU in a strata which may be represented in a more accessible location elsewhere. Other RMU were rejected on the basis of size (if too small to allow at least two plots).

In general the guiding principal was to select at least one RMU from each stratum for sampling, however in a limited number of instances, practical considerations came to the fore. Where all RMU in a stratum only amounted to a small area (in some instances the strata could be made up of one RMU of less than 20 ha in area) it was given a low sample priority. This usually meant that data from a similar stratum would be used to represent the forests in the unsampled stratum. Similarly, strata with a large total area were accorded a high priority and where possible had more than one RMU selected for sampling.

Fig II. The island group of Santo with a total area of 4 248 km$^2$. There are over 1, 300 RMU on these islands. A total of 43 strata were defined for sampling and 134 plots were established in RMU's representative of these strata (shown hatched).

Table 1 Detail of inventory sampling strategy in relation to major island groups in Vanuatu.

| Island | Area (sq. km) [1] | Estimated Population 1989 [1] | 'Forested' Area (sq. km) [4] | No. of Sampling Strata | No. of Plots Located | S.E. of Vol. Estimate |
|---|---|---|---|---|---|---|
| Efate ( + offshore Is) | 923 | 30 868 | 489 | 38 | 49 | 12% |
| Espiritu Santo (+ offshore Is) | 4,248 | 25 581 | 1874 | 43 | 134 | 10% |
| Malakula | 2,053 | 19 298 | 811 | 38 | 92 | NA |
| Erromango | 887 | [2] | 507 | 35 | 82 | 11% |
| Tanna | 561 | 22 423 [2] | 146 | 22 | 22 | NA |
| Epi | 446 | 3628 | 216 | 9 | [3] | - |
| Paama, Lopevi | 60 | 1696 | - | - | - | - |
| Aniwa, Futuna | 19 | [2] | - | - | - | - |
| Banks, Torres Is | 882 | 5985 | 298 | 10 | 42 | 19% |
| Shepherd Group | 86 | 3975 | - | - | - | - |
| Pentecost | 499 | 11 341 | 198 | 7 | [3] | - |
| Maewo, Aoba | 699 | 10 958 | 144 | 9 | 17 | 28% |
| Ambrym | 666 | 7191 | 128 | 6 | 17 | 12% |
| Anatom | 160 | [2] | 50 | 8 | 18 | 37% |
| | 12190 | 142944 | 4861 | 225 | 473 [3] | |

[1] Source: NPSO, 1991.

[2] Total population of Tafea Local Government Region which includes the islands of Erramango, Tanna, Aniwa and Anatom. Tanna has the largest population density.

[3] Sampling not processed.

[4] Forested area is that used in stratification and so excludes non-forest (e.g. grassland, (coco-nut plantation etc.), highly used forest and forest on land over 30 slopes.

Likewise the number of plots which were recommended for establishment within an RMU was influenced by such a priority allocation system. At least two plots were established in low priority RMU/strata while in some cases over five were established in high priority RMU/strata.

Location of the starting point of plots within RMU was determined in the office using a grid and random number tables. This point was marked on both map and aerial photograph with an appropriate physical feature also indicated as a reference point with distance and bearing to the plot given to allow the survey team to traverse to the starting location.

2. Plot measurement

The starting location became the first measurement point followed by nine other measurement points located at 30 m intervals along the transect (usually across the contour). At the tenth measurement, a right angle offset of 50 m was made and a further 10 measurements were made along the reverse transect bearing. Thus a total of 20 measurement points are located in each plot covering a grid of 270 m by 50 m.

At each measurement point a glass wedge prism with a basal area factor (BAF) of 10 was used to determine which trees are measured. Thus the plot size was variable depending on the size of the tree. All trees over 10 cm diameter at breast height (1.3 m) over bark (dbhob) identified as "in" the plot and borderline trees ( so selected because of difficulties of vision or because they are "close calls" ) had the following data recorded:-

- Six letter species code.

- dbhob recorded in 1 cm classes (i.e. dbhob 20 = 20.0 up to and including 20.9 cm). If the tree was "borderline" the slope and distance from the wedge to the tree was measured and recorded.

- For buttressed trees, the diameter above the buttress was measured if possible. If it was too high, a visual projection of the diameter above the buttress to where it can be measured "by eye" using the reverse (lineal measure) side of the diameter tape was made.

- Assessment of the quality of the stem and recorded as either;
  S = sawlog
  M = minimum log length (2.4 m) only available
  U = useless based on bad form or defect (not on species)

- Assessment of the availability of the stem based on its distance from the nearest stream or the ocean or whether it is unavailable due to inaccessible terrain or in a garden. Recorded as either;

  1 = < 10 m from a stream
  2 = 20 m " " "
  3 = 30 m
  4 = > 30 m

  A = < l0 m from the ocean
  B = 20 m
  C = 30 m
  D = 40 m
  9 = > 40 m

  T = inaccessible due to terrain
  G = inaccessible due to garden

- Assessment of the "forkiness" of the tree and recorded as either;

  1 = Forks above 80% of total tree height
  2 = Forks between 80% and 60% of total tree height
  3 = Forks between 60% and 40% " " "  "
  4 = Forks between 40% and 20% " " "  "
  5 = Forks at less than 20% of total tree height

Other information is also recorded to help describe each plot, including information on valuable non-timber plants such as giant bamboo and rattan, the accessibility of the area and the level and type of disturbance (e.g. cyclone, garden etc.).

3. Timber volume estimation

One-way volume equations based on dbhob are used to derive volume estimations. These equations were determined from field measurement of standing trees and mill yard measurements. Volumes are adjusted to account for the stem quality assessment made in the field of either sawlog or minimum length log. Analysis of results suggest that the use of one-way volume equations gives satisfactory results given the difficulties and costs of obtaining accurate height information in surveys in tropical rain forest which would be required if two-way equations were used. In this survey field data collected across different forest types for particular species showed common equations could be applied and confirmed the use of the one-way equations used.

Extrapolation of volume estimates

While the stratification process ensures that all RMU within a strata have the same forest type, the proportion of cover of this forest type may vary between these RMU due to historical land-use (gardening) or variable impacts of cyclones. Thus within the strata the simple extrapolation of timber volumes on the basis of RMU area is not always possible. In order to adjust volumes some knowledge of the extent of cyclone and human influence on the forest is required for each RMU. An estimate of the extent of this influence is derived from the API which, in addition to pure forest typing, also provided land-use intensity estimates and vegetation mixture classifications, which are a complex of forest and non-forest within an RMU. Reductions to volume estimates for an island, region or group of RMU's is made on the basis of this information. The system of land use intensity classification used is a modification of that used in similar environmental and social conditions in Papua New Guinea (Bellamy, 1986; Saunders, 1990).

## FIELD SURVEY LOGISTICS

### Inventory teams

A team of four or five proved to be the most efficient. The leader of each team received training in API, botany, inventory techniques and navigation. The team leader usually participated in the RMU and plot selection procedure or may have done it himself. His role was to record all information and to assist and confirm where required, in tree identification, stem quality assessment etc., depending on the level of training other team members have received. Most team members have received training in inventory techniques, navigation and botany in courses which were run annually as part of the project. Generally speaking " quality control" was the most critical duty of the team leader.

Other team members included the "compass-and-chain" man who cut the transect line and marked the measurement points. Following him was the "prism man" who used the BAF 10 glass wedge to identify trees which should be measured. Then either one or two people measured the dbhob of the trees so identified and informed the team-leader of other details such as stem quality, species etc. One of these team-members may also have carried the clinometer and 30 m tape to measure details of "borderline" trees however if the team was only four then the "prism man" carried this equipment and helped the measurer.

From the time of arrival at each plot the time taken to complete the plot usually varied between one and two hours depending mostly on terrain and the number of unknown species for which collections are required. In most instances two or three plots could be completed in each day while the team was at a general locality. However in some instances the distance to the general area and then the traverse to the start point limited teams to completing only one plot in a day.

### Accessibility and transportation

Transportation between the larger more populous islands in Vanuatu was by small aircraft. Among the smaller islands and where roads are non existent travel was by small boat. These means of transportation limited the size of field crews and the amount of equipment which they could carry. As a result it was found that a crew size of four or five was optimum. Where areas were too difficult to get to lift by helicopter was employed. This gave rise to extra costs and so crew size became more critical. Communication with base was critical and thus all field crews were issued with 2-way radios and had a regular call timetable with their base in Port Vila.

## DISCUSSION

### Sampling technique

The variable probability sample technique is relatively little used in tropical rain forest according to surveys conducted by Wood (1990) which indicated <20% of countries used this methodology. Most countries favour fixed area strip samples despite analysis which shows this method requires up to 3 times the amount of sampling to achieve a similar standard error (SE) than point sample systems similar to those used in this survey (Banyard 1975).

Although no direct comparison was made between strip sampling and the method used in this survey, the results suggest high levels of efficiency and accuracy in the inventory method adopted. The principal advantage in this technique is in the more even distribution of trees selected for measurement over the range of size classes and so time is not wasted oversampling a particular size class.

The reasons often cited for not using variable probability sampling (or angle-count sampling), such as training requirements and poor light (Wood 1990) were not insurmountable problems in this instance and these problems perhaps relate more to when a Relaskop is used rather than a wedge prism. Difficulties with visibility through the wedge prism were only encountered under heavy rain conditions. Training was of absolute necessity, however forestry staff in Vanuatu were able to pick up the techniques readily.

### Information dissemination

Although a program of project promotion was employed it was found that additional effort must be put into explaining the project in more isolated areas. Most rural people have very limited access to reading material and hence read little. In distributing the information explanations must be comprehensive and entertaining to assist the receiver and to capture his interest. The level of this interest should be gauged by the number of questions asked.

The small number of staff in the Department of Forestry was a limiting factor in the number of meetings which could be arranged and considerable reliance was placed on influential people to help to explain the project activities at a level which is comprehensible to people at the local level.

## Previous Inventories

While the history of forest inventory in Vanuatu has not been significant, there have been a number of intensive efforts, particularly on the islands with more important commercial forests (e.g. Johnson, 1971 - Erromango; Thorpe, 1985 - Erromango; Bennett and Kichikichi, 1977 - Aneityum). The results of these inventories have been useful in providing some support or confirmation of the results of the current inventory, however for a number of reasons direct comparison has not always been possible. For example, serious discrepancies with the results of the Johnson (1971) inventory gave rise to further analysis which ultimately indicated that the impact of Cyclone Ouma in 1987 had reduced standing volumes by some 30%. (Applegate, 1991). Other factors which reduced the potential value of existing inventory data were the localised areas investigated, the focus on commercial species, the focus on species in larger size classes and the lack of information on methodologies used.

What is generally clear from the inventories is that they gave Vanuatu little or no capacity for ongoing inventory such as may be desirable after events such as cyclones. There appears to have been little training of local staff in field methodologies and even less in the design of follow-up inventory or analysis of results. The current inventory aims at ensuring that inventory will be ongoing as required by providing intensive training and leaving an easy-to-use computerised data entry system with analytical capacity. This will allow forestry staff to re-sample or increase the sample size in particular areas and to produce reports, such as stand tables with volumes and standard errors from the new data entered to allow more effective forest management.

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# AUTHOR'S NOTE

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