NON-WOOD FOREST PRODUCTS

13

Resource assessment of non-wood forest products

Experience and biometric principles

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Foreword

The last decade has witnessed a steep increase in interest and activities concerning NWFPs. The current interest in NWFPs amongst conservationists, foresters, development workers and indigenous peoples' groups has prompted numerous initiatives aimed at promoting NWFP use and commercialization as a means of improving the well-being of rural populations and, at the same time, conserving existing forests.

Rarely are these initiatives linked to studies on the sustainable exploitation of the products that are promoted, and no accurate information is available on the resource abundance, distribution, and reproductive biology, which is necessary for the determination of the biologically sustainable harvest levels of a product.

Although there is often considerable indigenous knowledge for specific NWFPs, formal resource assessment of NWFPs, especially in tropical countries, is relatively new and has received little attention to date. The multitude and variety of NWFPs, the multiplicity of interests and disciplines involved in NWFP assessment, the organizational and financial constraints, the lack of globally, or even nationally, recognized common terminology and units of measurement all contribute to make the assessment of NWFPs, and of the resources providing them, a difficult task.

The purpose of this publication is to raise awareness on the importance of accurate and precise resource assessments at all levels of forest use for NWFPs, and to provide guidance on the design and selection of appropriate methods for resource quantification in different situations and for different products. It does so through the review and analysis of the wide range of approaches used and developed to date to measure NWFP resources.

The book builds mostly on experiences in forest ecosystems in tropical countries, but we are convinced that it will be of relevance and use to all regions and all products. The prospective audience of this publication includes practitioners, researchers, natural resource managers and all development workers with an interest in sustainable forest utilization.

This publication is based on the outputs of the Forest Research Programme's (FRP) pre-project ZF0077 (of the United Kingdom Department for International Development - DFID), on the biometrics of current NWFP resource assessment methods. FAO undertook the publishing in its Non-Wood Forest Products Series, within the framework of a current partnership programme with the European Commission aimed at developing methodologies for NWFP assessment.

Work on NWFP assessment is an important activity in the FAO Forestry Department, involving expertise from various technical units, in particular the Forest Resources Division (and its flagship programme for the Global Forest Resources Assessment – FRA), and the Forest Products Division (through its Non-Wood Forest Products Programme).

DFID and FAO believe that sustainable harvesting and use of NWFPs may contribute to improved household nutrition, income and employment and, therefore, are committed to continue providing assistance for the

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by

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development of methods for the accurate evaluation of NWFPs and the resources producing them.

It is a pleasure for us to release this publication as a common effort. We hope that it will encourage more research and development work from other institutions in this important aspect of sustainable forest management.

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The review paper was written by Jenny Wong and the final draft of this publication was prepared by Jenny Wong, Kirsti Thornber and Nell Baker.

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Acronyms

AA	Adaptive allocation
ACP	Africa-Caribbean-Pacific
ACS	Adaptive cluster sampling
C&I	Criteria and indicators
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DFID	Department for International Development (United Kingdom Government)
EC	European Commission
ETFRN	European Tropical Forestry Research Network
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRP	Forest Research Programme (DFID)
FSC	Forest Stewardship Council
GIS	Geographical information system
ha	hectare
IUCN	World Conservation Union
JFM	Joint forest management
kg	kilogram
MCP	Mount Cameroon project
MRI	Multi-purpose resource inventory
MUL	Management unit level
NFI	National forest inventory
NGO	Non-governmental organization
NTFP	Non-timber forest product
NWFP	Non-wood forest product
PLA	Participatory learning and action
PRA	Participatory rural appraisal
PSP	Permanent sample plot
RRA	Rapid rural appraisal
RSS	Rank set sampling
RVA	Rapid vulnerability assessment
SFM	Sustainable forest management
SRS	Simple random sampling
TRAFFIC	Trade Records Analysis of Flora and Fauna in Commerce (WWF-IUCN)
WWF	World Wide Fund for Nature

Glossary

Accuracy - a measure of how close the sample estimator is to the true population value. It is impossible to measure accuracy directly without knowing the true population value. It is assumed that accuracy should be high if a sample estimator is unbiased and precise.

Bias - the difference between the expected value of a sample statistic (known as an estimator) and the population parameter (or true population value that the statistic is intended to estimate). Note: bias implies systematic distortion, as distinct from random error, which balances out on average; a sampling process involving such a distortion is said to be biased (Helms, 1998).

Biodiversity inventory - a list of biological entities from a particular site or area (Stork & Davis, 1996).

Biometric - the application of statistical methods to the measurement of biological objects (adapted from Shorter Oxford English Dictionary).

Enumeration - the listing of data. In forest inventory - the process of measuring the specific parameters required by the protocol. Enumeration data are the results of an enumeration (Helms, 1998).

Herbarium/Herbaria - a place where reference collections of plants are held, often associated with botanical gardens or natural history museums.

Forest inventory - 1) a set of objective sampling methods designed to quantify the spatial distribution, composition and rates of change of forest parameters within specified levels of precision for the purpose of management. 2) the listing (enumeration) of data from such a survey (Helms, 1998).

Life cycle - the successive stages through which an organism passes from fertilized ovum or spore to the fertilized ovum or spore of the next generation (Helms, 1998).

Life history - the continuous, descriptive account of an organisms habits and life cycle i.e. activities and duration (Helms, 1998).

Life table - an age-specific summary of the mortality and survivorship of a population, usually specifying the mortality agents (i.e. harvesting) operating (Helms, 1998).

Matrix models - mathematical models that predict future populations using probabilities to calculate the likelihood of individuals surviving, growing, dying or reproducing.

Mensuration - in forestry - the determination of dimensions, form, weight, growth, volume, age, etc., of trees, individually or collectively, and of the dimensions of their products (Helms, 1998).

Multi-disciplinary - from a broad range of disciplines, e.g. ethnobotany, agro-ecology, human ecology.

Phenology - the flowering and fruiting of plants.

Plot - derives from the physical unit of a plot of land. Its interpretation is now very much more general according to the subject matter of the particular survey (cf. sampling unit) (Marriott, 1990).

Population - the entire aggregate of individuals or items from which samples are drawn (Marriott, 1990).

Precision - a measure of the degree to which sample estimates cluster tightly together about their own average. A precise estimate has a small sampling error.

Protocol - the formal procedure for the implementation of a specific inventory. These are used at two levels: 1) field - concise, usually written, instructions which leave no ambiguity in how to deal with common field difficulties (i.e. where to measure a leaning tree, or how to measure distances on slopes) and used in training and for reference during the course of the work. 2) reporting - very concise description of sampling design which gives sufficient detail of field methods to enable replication of the study (Helms, 1998).

Qualitative data - descriptive data which is classified by type, i.e. grouped into low, medium, high, etc. (Porkess, 1988).

Quantitative data - data which is classified by some numeric value, i.e. the actual weight of an animal (Porkess, 1988).

Random selection - a sample selected from a finite population is said to be random if every possible sample has equal probability of selection (Marriott, 1990).

Recruitment - new individuals joining the population, i.e. through birth or germination.

Regression equation - the mathematical relationship between two variables, i.e. weight against length, usually a linear (straight line) relationship derived using a least squares method. The coefficient of determination r^2, is a measure of the strength of the relationship (Porkess, 1988). Regression equations are often used predictively, i.e. to estimate a characteristic (e.g. weight) using measurement of another, independent characteristic (e.g. diameter).

Replication - the execution of an experiment or survey more than once so as to increase precision and to obtain a closer estimation of the sampling error (Marriott, 1990).

Representative sample - in the widest sense, a sample which is representative of a population. Some confusion arises according to whether 'representative' is regarded as meaning 'selected by some process which gives all samples an equal chance of appearing to represent the population'; or, alternatively, whether it means 'typical in respect of certain characteristics, however chosen'. On the whole, it seems best to confine the word 'representative' to samples which turn out to be so, however chosen, rather than apply it to those chosen with the object of being representative (Marriott, 1990).

Sample - a part of a population which is provided by some process or other, usually by deliberate selection with the object of investigating the properties of the parent population (Marriott, 1990).

Sample design - used here to mean: a set of rules or specifications for the selecting of a sample in an unequivocal manner (Marriott, 1990).

Sampling error - the difference between the true value of a parameter of a parent population and that estimated from the sample. This error is due to the fact that the value has been calculated from a sample rather than from the whole parent population (Marriott, 1990). This is different from error due to imperfect selection, bias, and observational or recording errors. It is a measure of how much the estimates vary between different plots, and is usually given as a percentage of the overall mean.

Sample estimator - the population parameter value estimated through sampling a population, e.g. the mean.

Sampling units - units in which the population is divided or regarded as divided that are available to be selected in the sample. Each unit is regarded as an individual and indivisible when the selection is made. The definition of unit may be made on some natural basis, e.g. households, persons, units of product, etc., or upon some arbitrary basis, e.g. area of defined by grid co-ordinates on a map (Marriott, 1990). Sampling units can also be fixed units of time during which samples are taken.

Stratification - the division of a population into parts, known as strata; especially for the purpose of selecting a sample, an assigned proportion of the sample then being selected from each stratum (Marriott, 1990).

Sustainability - the capacity of forests, ranging from stands to ecoregions, to maintain their health, productivity, diversity and overall integrity, in the long run, in the context of human activity and use (Helms, 1998).

Sustainable yield - the use of living resources at levels of harvesting and in ways that allow these resources to supply products and services indefinitely. Sustainable yield means living off the interest, rather than the capital, of a resource base. It aims to: maintain essential ecological processes and life-supporting systems; to preserve genetic diversity; and to maintain and enhance environmental qualities relevant to productivity; it seeks not to disadvantage future generations (Gilpin, 1996).

Voucher specimens - botanical specimens collected during a survey for comparison with reference material in order to determine its identity.

Yield - the harvest of produce, actual or estimated, from plants or animals expressed by numbers or weight, or as a proportion of the standing crop, over a given period (modified from Helms, 1998).

Yield determination - the calculation of the amount of produce that may be harvested annually or periodically from a specified area over a stated period in accordance with the management objectives (modified from Helms, 1998).

Yield table - a table which can be used to estimate the yield based on a simple measure of size, i.e. a table which can be used to estimate the volume of timber from the diameter of a tree; the table is usually derived from a regression equation.

Glossary References:

Gilpin, A. 1996. Dictionary of environment and sustainable development. Wiley. 247 pp.

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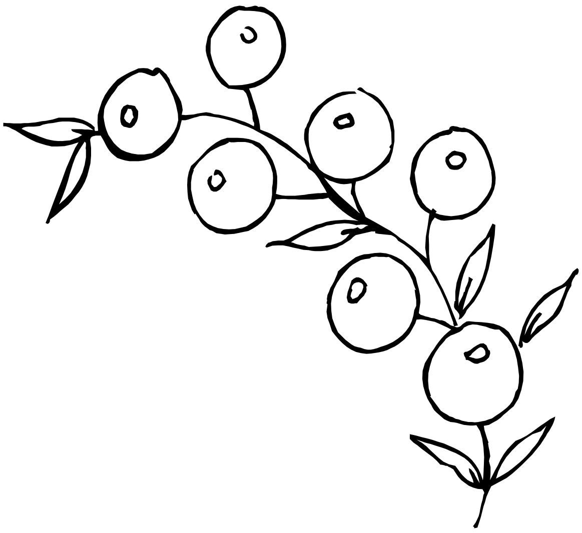


Executive summary

This publication is intended as reference material for practitioners considering inventory of non-wood forest product (NWFP) resources. Through review and analysis of experience it provides an overview of biometric issues in the design of NWFP inventory in the following areas:

- a description of the range of approaches used and developed to date and their biometric adequacy; and
- a suggested method for selecting appropriate biometric methods for resource quantification in different situations and for different products.

After introducing the subject and background Section 1, Section 2 discusses the role of and need for biometrically reliable NWFP assessments. It considers: why resource assessments are needed; what a biometric resource assessment looks like; the biometric qualities of current methods for inventory of NWFPs; and why resource assessments might need to provide biometric data.

Section 3 reviews the quantitative methods currently used in inventory, whilst Section 4 reviews the potential contributions of non-quantitative approaches to biometric assessments. A key issue is that quantitative and qualitative approaches can and do complement each other, if used properly.

Approaches to designing biometrically reliable assessments are discussed in Section 5. It covers: the relevance and application of biometrics in designing an inventory; a decision-support framework as a step-by-step approach to inventory design; planning needs for data analysis and presentation; and some research needs.

This publication will be of most interest to people with some previous knowledge of the basics of inventory. It is based on the outputs of the Forest Research Programme's (FRP) pre-project ZF0077 on the biometrics of current NWFP resource assessment methods.

Section 1 **Introduction**

This section introduces the objectives of this publication, provides some background, and outlines the approach used in preparing it.

1.1 Objectives of the paper

This is a resource for people who want to know more about inventory for measuring and planning management of non-wood forest products (NWFPs).

This publication is intended as reference material for practitioners considering inventory of NWFP resources. Through review and analysis of experience it provides information:

- on the range of approaches used and developed to date and their biometric adequacy; and
- to help the practitioner decide when biometric methods are necessary;
- to guide the design and selection of appropriate biometric methods for resource quantification in different situations and for different products.

This publication will be of most interest to people with some previous knowledge of the basics of inventory. It is not a textbook - forthcoming FAO publications will provide manuals of how to implement inventory (e.g. FAO, in press).

1.2 What is a NWFP?

Despite much discussion there has, as yet, been no agreement on terminology to describe NWFPs. Many different terms have been developed for them. Even the terms ‘forest’ and ‘product’ can be debated.

A key component of definitions of NWFPs is that they exclude timber, and that the product, benefit or service should come from a forest, or from trees on other land. The central part of the concept is that the product of interest is of use to human society. As such, any part of any plant or animal harvested for use can be described as an NWFP.

The FAO has adopted the working definition that:

“Non-wood forest products consist of goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests.” (FAO, 1999)

The term NWFP differs from the commonly used non-timber forest product (NTFP) in excluding all wood while NTFP includes wood for uses other than for timber, although there are still many grey areas.

Classification systems for NWFPs

Many efforts to classify NWFPs have been made, but there is no single, commonly used classification. Developments to date have usually used a unique classification to suit particular purposes. Classification systems are useful to: aid reporting; provide a basis for developing an understanding of the uses and demand for products or help match methodologies to resources. There are a wide range of classifications for NWFPs, though there is some consistency within disciplines. There are a number of general approaches which classify varyingly according to products, end uses, taxonomy, management characteristics, or life-form (see Annex 1 for more details).

Classifications based on products or end uses tend to ignore the product source, but can facilitate tracking through the market. This can be useful in determining their importance in national and international economies. These are also often the *only* source of statistics on NWFPs and as such are, at least, important starting points for NWFP resource assessments.

Very few NWFP classifications have been constructed for the purpose of resource assessment or inventory. Those available generally distinguish plants based on broad life-form groups – e.g. herbs, trees, shrubs, rattans, etc. - and reflect a predominantly forestry-based approach. Adequate classification is difficult, but some type of grouping of the diversity of NWFPs is needed – it is not realistic to develop and recommend a different method for each species. Section 5 deals further with this problem in the context of designing a NWFP inventory.

Definitions

For the purpose of clarity, some key terms are defined below. The glossary at the front provides a more complete description of other terms used in the publication.

- *Resource species*: the species from which a product is harvested.
- *Resource assessment*: an evaluation of some aspect of the resource based on information gathered from a variety of sources. It can include socio-economic issues, market issues, or the quantity and quality of the resource.
- *Biometrics*: the application of statistical methods to the measurement of biological objects.
- *Product:* any part of a plant or animal that is harvested for human use or consumption.
- *Sustainable harvest:* the harvest which can be removed from the forest in a sustainable manner, generally determined in advance using a yield model and prescribed in management plans.

1.3 Background

Why are NWFPs important and why measure them?

Historically, a wide range of products from forests have been used by people. However, the development of forest management has focused on timber, thereby marginalizing other products. ‘Forest management’ has come to mean ‘timber management’.

The timber focus has arisen as wood has increasingly been seen as the major economic crop from forests. This change in perceptions has arisen for a number of causes:

- historically important NWFPs - such as rubber, chicle, and gum copal - have been substituted by synthetic alternatives;
- domestication of NWFPs - such as oil palm, rubber, and cocoa which are now grown in large-scale plantations as agricultural crops, rather than harvested from the natural forest; and
- institutional lack of regard for local people and their dependence on NWFPs for subsistence and enterprise.

The recognition of the role of NWFPs in community-level livelihoods has been important in stimulating interest in bringing NWFPs back into forest management. There is currently a lot of interest in NWFPs amongst conservationists, foresters, development workers and indigenous people's groups. They are interested in the potential of NWFPs for:

- income generation for rural development;
- more equitable sharing of the benefits of forests; and
- sharing forest management with local people.

Development of NWFPs for subsistence or commercialization should ideally be based on sustainable exploitation of the products. For biologically sustainable harvest levels of a product to be determined, there must be a minimum set of good information available on the resource species': abundance, distribution, and reproductive biology.

This kind of information can be gained from a number of sources, including informal knowledge collected from indigenous people as well as formal, scientific investigations. Formal resource assessment of NWFPs in developing countries is relatively new and has received little attention to date. Researchers and practitioners have developed methodologies, but typically tailored to specific local situations and particular resource species, and often based on timber inventory methods. There is a need to consolidate this experience to promote common, appropriate and reliable methodologies. Biometrically sound approaches are key to ensuring statistically reliable data on which to base management.

1.4 Approach, scope and limitations

What information is the publication based on?
What are its limitations?
How is the publication organized?

This publication's history and basis

This publication is based on the outputs of the Forest Research Programme's (FRP) pre-project ZF0077 on the biometrics of current NWFP resource assessment methods. This project organized a workshop that brought together a range of people interested in NWFP assessment, to discuss the need for quantitative assessments and to decide on priority research themes. The workshop was informed by a background review paper, primarily concerned with the statistical reliability of results from resource inventory. Both the review and the workshop report are available on the CD-ROM enclosed.

The review covered material from the following disciplines:

- biodiversity inventory;
- social science techniques, e.g. indigenous knowledge and household surveys;
- anthropological methods, e.g. ethnobotany and quantitative ethnobotany;
- economic methods, e.g. valuation studies and market and income studies;
- quantitative plant inventory, e.g. forest inventory;
- wildlife management; and
- autoecology (the study of the ecology of a single species).

This publication is based on the review and the workshop debates. Similarly, its focus is consideration of the biometric properties of alternative approaches to NWFP inventory in current use. Whilst the review mainly covered studies in forested areas, the principles are also relevant to NWFPs harvested from agroforestry areas, farms and other areas. The material presented is intended for use in the tropics but will be of relevance elsewhere.

Scope and limitations

The review collated nearly 400 references with relevance to either inventory methods or the assessment of NWFPs (available in the enclosed CD-ROM). The criterion for including papers was that they should concern some plant or animal resource that is being exploited by people. The subset of 126 studies selected for biometric analysis had to include the enumeration of some characteristic of the resource, e.g. its abundance, growth rate, yield or describe monitoring methods. The enclosed CD-ROM contains a database that tabulates the protocols used in the 126 qualitative studies as a resource to be used in the identification of gaps and good practice.

The review on which this publication is based covered:

- global experience, from both tropical and temperate regions;
- plants and animals, including a wide range of life-forms (trees and tree-like plants being the most commonly assessed forms);
- different products: NWFPs include a variety of harvested parts of individuals, from fruits or bark to whole plants or animals;
- small and large studies: from single research plots through local, area, regional and national level efforts to international assessments;
- literature in English: the work was carried out from a United Kingdom base and only includes material available in English; and
- published research: the difficulties of obtaining less formal, or 'grey', literature without extensive travel meant that the review was heavily reliant on published reports.

The review paper limited its scope to NTFPs defined as:
"A*ll products derived from biological resources found on forest land, but not including timber or fuelwood*."

NWFP resource assessment is currently a field of confusion and complexity, with many and overlapping approaches. This is due to several reasons, including:

- diversity of different plants and animals (noted in Table 1) which can be NWFP resource species;
- variety of plant or animal parts that can be used (see Table 2);
- broad range of geographical and cultural situations;
- range of different disciplines undertaking studies (sociology, agriculture, zoology, forestry, botany, etc.);
- diversity in the scale of the resource assessments;
- differing aims for the assessments; and
- the level of resources available.

Table 1: Number of reviewed studies by life-form

Group	***Life form***	***No.***
Animals	Mammals	6
	Ungulates	5
	Primates	4
	Rodents	3
	Generic 'animals'	3
	Carnivores	7
	Insects	2
	Bats	1
	Birds	1
	Fish	1
	Insectivores	1
	Marsupials	1
	Shrews	1
	Squirrels	1
	Snails	1

Group	***Life form***	***No.***
Fungi	Mushrooms	10
	Truffles	1
Plants	Trees	31
	Shrub	20
	Palm	18
	Generic 'plants'	16
	Rattan	16
	Herbs	13
	Bamboo	10
	Climbers	5
	Epiphytes	1

Table 2: Representation of NWFP plant resource types and plant parts in review

Resource category	***Plant part***	***Studies***
Reproductive propagules	Fruit	24
	Nut/seed	2
	Oilseed	1
Plant exudates	Resin	1
	Sap	1
Vegetative structures	Stem	20
	Leaves	7
	Root	2
	Bark	5
	Tuber	1
	Apical bud	1

This publication considers only the biometrics of the approaches used to quantify NWFP resources in the forest. This encompassed four elements of NWFP resource management:

- knowing where and how much of a resource is present in the area being managed;
- determining the growth or replenishment rate of the present resource levels;
- calculating a harvest level; and
- monitoring to determine if harvesting is indeed meeting objectives.

To ensure scientifically sound management, data should be derived from studies with a basis in statistical principles – i.e. they should be biometrically adequate. This aspect has often been neglected in NWFP studies.

A 'route-map' through the document

The publication is organized into sections, which in turn deal with:

Section 2	**The role of biometrics in NWFP resource assessments**	Looks at: • why resource assessments are needed • what a biometric resource assessment looks like • the biometric qualities of current methods for inventory of NWFPs and • why resource assessments might need to provide biometric data
Section 3	**Quantitative studies on NWFPs**	Describes current experience in NWFP resource assessment. It covers: • inventory • yield measurement • growth studies • harvest determination and • monitoring
Section 4	**Contributions from other approaches to NWFP resource assessment**	Looks at approaches that are typically less quantitative and assesses their biometric value and relevance for NWFP inventory. Approaches include: • biodiversity inventory • social science techniques • cultural perspectives • ethnobotany • economic methods
Section 5	**Designing a biometric inventory for NWFP**	Helps the reader consider: • the relevance and application of biometrics in designing an inventory • a decision-support framework as a step-by-step approach to designing a biometric inventory • planning needs for data analysis and presentation and • some highlighted research needs

Section 6	**Literature resources**	Provides the reader with details of references cited and provides some useful information on relevant literature for further reading
Section 7	**Annexes**	• classification of NWFPs – examples of approaches used • understanding plots and subplots • example of NWFP inventory outputs • some currently used and emerging sampling methods and • useful institutions and Web sites

Section 2 The role of biometrics in NWFP resource assessment

This section looks at:

- **why resource assessments are needed**
- **what a biometric resource assessment looks like**
- **the biometric qualities of current methods for inventory of NWFPs and**
- **why resource assessments might need to provide biometric data**

2.1 The role of resource assessment in sustainable NWFP harvesting

Resource assessment can examine:

- which resources are useful commercially;
- what the consequences of exploitation are on the resource base itself;

and can inform sensible and appropriate management of NWFP resources.

Further reading: Peters, 1994; Peters, 1996a; Hall & Bawa, 1993

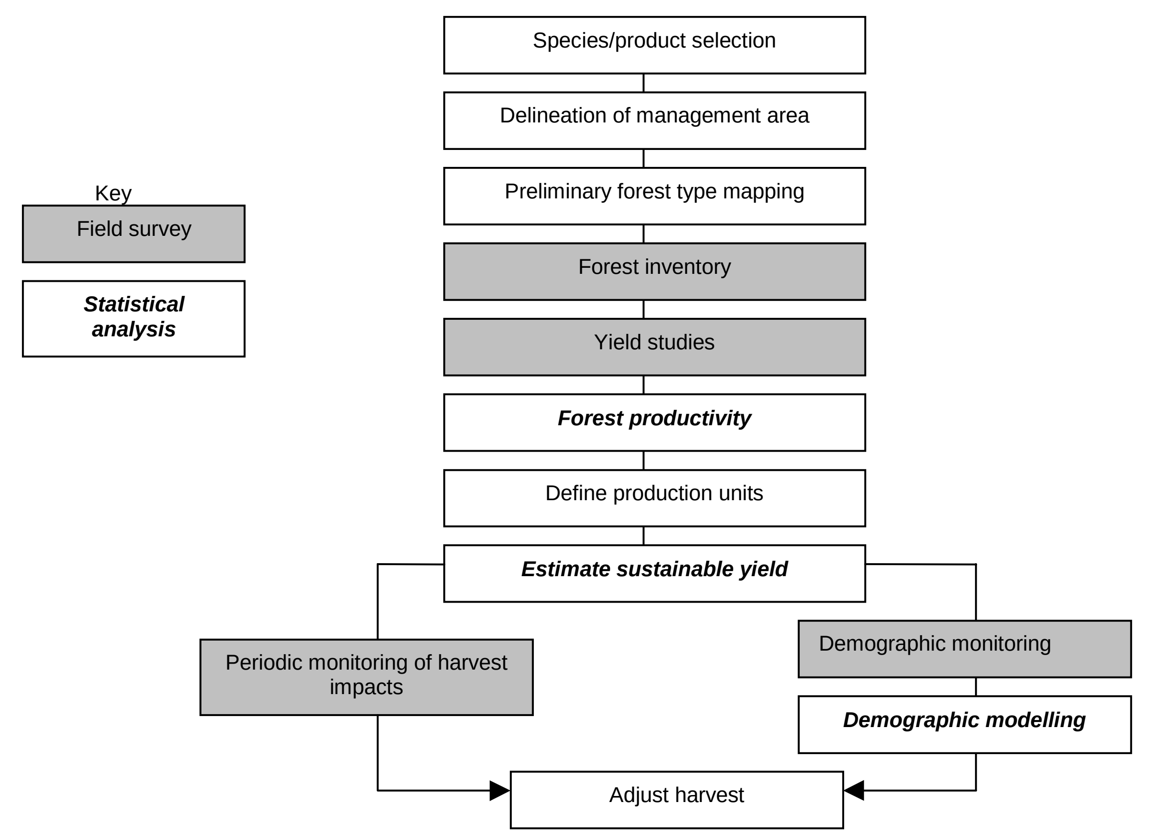
What is assessed?

There are different types of assessment or study that can inform development and management of NWFP resources. Approaches can focus on either:

- the NWFP resource itself, including its abundance or potential for future supply, through resource inventory; or
- its use in the market, such as market or product surveys, biodiversity inventories (or species lists), and cultural studies.

An ideal development process might begin with species/product selection, and include market research, resource inventory, growth and yield forecasting, determination of sustainable harvest rates, management planning and monitoring. One possible strategy is described by the flow chart in Figure 1, which describes the main elements of resource assessment requirements. Whichever approach is taken, resource assessment has a key role in the management of NWFPs.

Figure 1: Flow chart of a basic strategy for managing NWFPs on a sustained-yield basis



(After Peters, 1994)

Any NWFP development programme should involve assessment/study at all these stages. Not all stages require formal assessments, as information may already be available or can be collected through informal methods. The bold areas of the flow chart suggest where field assessment needs ideally to provide biometrically rigorous, statistically reliable data. In these areas quantitative methods should be used.

However, the simple adaptation of forestry techniques is hampered because of the variety of:

- objectives for assessments;
- life-forms of NWFPs; including ease of detection;
- distributions, often NWFPs are clumped rather than evenly spread across an area;
- seasonal productivity, which means that some NWFPs exist only in specific periods; and
- levels of time, money and skills available to do the assessment.

Who does the assessments?
The NWFP assessments have been carried out or commissioned by a range of stakeholders, including Forestry Departments, aid organizations and communities. Because there can be a wide range of reasons for doing assessments, the methods, knowledge and experience are scattered amongst people from very different professional disciplines. Sharing of experiences between disciplines is limited, and areas familiar to foresters may be unknown to wildlife specialists and vice versa.

This means that development of methodologies is uneven and patchy in terms of the ideal flow chart. In addition, some disciplines might miss products which are important to others – e.g. dealing with wildlife is typically not part of Forestry Department work, and quantitative assessment is rare in rural development approaches.

Interdisciplinary work is key to addressing some of these gaps. Collaboration will help to bring together needs and experiences and to develop and standardize both appropriate methodologies and terminology.

2.2 Why is quantitative resource information needed?

Who wants the information from resource assessments?

This is an important question, as the reason for doing the assessment influences how it is done.

The majority of published studies to date are at the local level. However, there are many national level NWFP inventories that have not been published. Table 3 indicates what the information from resource assessments is used for at different levels.

Although it is necessary to know the objectives of a specific study before judging whether biometrically rigourous methods are required, it seems certain that critical areas are how to sample, measure, monitor and analyse quantitative studies of NWFP resources. There is a particularly strong need for reliable methods for measuring the distribution and quantity of a resource at a range of scales, from local to international.

Table 3: Uses of information from resource assessments

Local level	• determining sustainable harvesting quotas • monitoring the state of the resource • demonstrating sustainability to persuade authorities to allow harvesting
National level	Strategic planning, including: • deciding whether to allow export quotas • considering promotion of resource-based industries
International level	Informing conservation of endangered species, e.g. CITES Note: This usually relies on national level data
Other (usually international)	Fora discussing: • criteria and indicators for sustainable forestry • certification • Convention on Biological Diversity

Local needs

Generally local level data are required in the preparation of detailed management plans for specific areas producing NWFPs. There is some debate about the level of biometric rigour needed for these data (see below). However, it seems that there is an urgent need for communities to be able to prepare 'sustainable' management plans. Without a sufficiently robust biometric basis to the plans many regulatory authorities are reluctant to release land for community management. This is the case in the negotiation of community access rights in at least Bolivia, Brazil, Mexico, Cameroon, and Zimbabwe.

In other countries, such as Indonesia, biometric resource inventory can be important to establish indigenous land rights and secure adequate compensation for loss of access to NWFP collection grounds.

National policy and strategic planning

At the national or regional level data are required for the following purposes:

- *Economic opportunities***:** Good data are needed in the planning for investment or the development of a sector. For example, in investigating the potential use of pine resin as raw material for chemical industries (turpentine, rosin), rattan for furniture, tannins as substitutes of imported polyphenols, glues for plywood production etc. Biometrically sound data also used to determine policy, for example, regarding financial incentives for import substitution or export promotion (e.g. import tariffs).
- *Social criteria:* Reliable data are needed to determine the potential role of NWFP in rural development programmes.
- *Environmental criteria:* Quantitative data should be used as the basis for conservation and sustainable exploitation of NWFPs.

Data requirements: details and constraints
Resource Status: The first consideration is deciding which species to collect information on. This requires some initial knowledge of utilizable species, their products and distribution. Basic information might also be required on what is being harvested, where it is coming from, how it is located, potential or actual yields, harvesting techniques and levels.

National Forest Inventories (NFI) (or agricultural census in case of domesticated products) may collect NWFP information. Inventory at this level requires high biometric rigour. At the management unit or operational level (MUL), lower biometric rigour may be acceptable depending on the size of the unit. Data collection can vary from the assessment of a few samples to a stock-survey type census. In addition to quantitative data, the following are often also required:

Social aspects. Information may be needed on:
- ownership and/or access to the resources/species (private, public ownership status and trends);
- level of dependence of livelihoods on the resource (who, where and how are resources harvested);
- impact of other sectors (agriculture, labour availability, farmers); and
- decision-making processes in the country (planning cycles).

Economic aspects. Information is needed on:
- how important is investment in NWFPs for the national economy, what are the trends;
- influence of (inter-) national markets (substitutes within and between NWFPs); and
- financial possibilities: joint ventures, World Bank loans and incentives, etc.

Institutional and policy aspects. Information may be needed on:
- (forest) legislation and rules (NWFP rights in ‘timber concessions’); and
- training/education needs.

Reporting to international/regional agreements. Statistics and other information on resource availability and use, e.g. distribution, quantity of resource base, production and trade data.

Criteria and indicators

The increasing international interest in sustainability of forests over the last few years has created a need for some way of measuring whether a forest is being managed sustainably or not. Criteria and indicators (C&I) for sustainable forest management (SFM) have emerged as a tool to measureand monitor progress towards SFM. At the end of 2000, 149 countries were participating in one or more C&I processes at ecoregional levels (FAO, 2001).

Criteria define the essential elements against which the quality of forest management is judged. Each criterion is defined by quantitative or qualitative indicators, which can be measured and monitored to determine the impact of forest management over time.

Indicators are in essence a form of monitoring protocols, and thus for NWFPs there is a need to develop assessment methodologies as recommended in this publication. Good NWFP resource assessments are critical to determining current status and as a basis for determining trends over time. A key question concerns the level of biometric rigour needed in assessments of the indicators, as this influences overall sampling design.

Certification

Over the past decade there has been a strong drive for certification of forests and forest products, partly in response to non-governmental organizations’ (NGOs) concern about poor forest management. Certification is the independent verification that certain minimum forest management standards have been achieved by the manager. A certificate covers a specific area of forest for a specific time period. It usually involves a connection to the market through chain of custody labelling of products from certified forests.

There are numerous approaches to certification of NWFPs:

- forest management unit certification – looks at a broad range of forest management issues, including environmental and social;
- environmental/organic certification – concentrates on the way the product is produced, certifying that no chemicals or unnatural additives are used; and
- people-orientated certification (fair trade) – ensures that local producers get a good deal out of the product.

The NWFP assessments are useful mainly in forest management certification, where assessing the impacts of management at the forest management unit level is important. Again, the question of biometric rigour can be critical, as certification inspectors need to know how to assess reliably and consistently harvest and monitoring data.

Monitoring endangered species

Monitoring of species endangered by overharvesting is critical to avoid further population decline.

Monitoring of species threatened by overharvesting is usually done through harvest and trade records. For example, international trade in CITES protected species is monitored through import and export statistics and TRAFFIC use elephant ivory seizures to indicate population levels.

This may be the easiest way of getting information on heavily traded species, but such assessments give no information at the field level, and may not be reliable reflections of the status of the actual populations.

Until better field level information is more widely available, it seems likely that broad international policy decisions will be made on the basis of market information of questionable reliability.

2.3 What makes a study biometrically sound?

What does 'biometrically sound' mean?
It is not just about collecting quantitative information – *statistical principles* must be met throughout the assessment. The main principles relate to:

- objectivity in sampling design;
- number of plots used; and
- independence of observations.

***Precision and accuracy*. Good quality data allows precision and accuracy to be estimated.**
***Precision* is high when errors are small.**
***Accuracy* is high when the estimated average value is close to that of the whole population.**
Ideally estimates from assessments should be both precise and accurate.

The main advantage of a biometric assessment is that the precision and accuracy of the results can be calculated. This means that it is possible to put some confidence in the results. Precision is how tightly clustered the sample estimates are while accuracy measures how close the estimates are to the true (or population) value.

Conventional statistics enables us to calculate the precision of the results (usually expressed as the sampling error – see box 1).

Box 1: Calculation of sampling errors

Sampling errors are a function of the variance of the data and express the chances that the 'true' mean lies within the error quoted. I.e. a mean of 12.5 with a SE% of 20 percent suggests that the true mean of the population is 95% certain to lie within 20 percent of 12.5, i.e. between 10 and 15. The sampling error can be determined using the following calculations:

$\bar{y}$ = Sample mean

S_y = standard deviation

t_{i-1} = t value at the 0.05 probability level

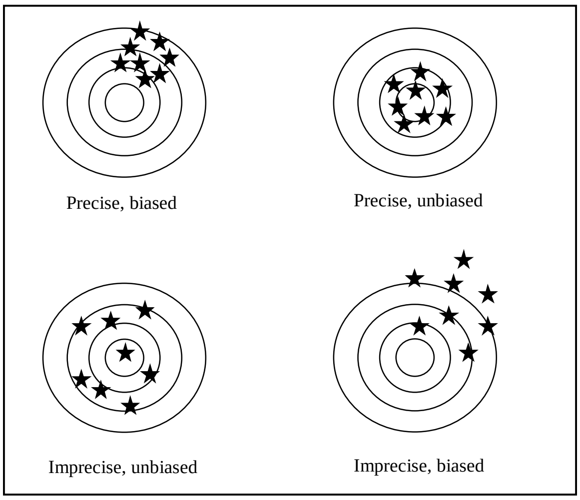
Standard error of the mean $S_{\bar{y}} = \frac{S_y}{\sqrt{n}}$

Sampling error SE% $= \frac{S_{\bar{y}} t_{i-1} 100}{\bar{y}}$

Note that the SE% is the 95 percent confidence interval expressed as a percentage of the mean.

However, it is impossible to calculate their accuracy without knowing the true value and if we knew this we would not need to sample. The way around this is to try to minimize bias in the sampling design and to make the study as precise as possible. If the answer is precise and we are reasonably sure there is no bias then we expect that the result is also accurate. Figure 2 illustrates these concepts in relation to hitting a target with the centre point representing the true value.

Figure 2: Precision and accuracy of a biometric study



The implication of this is that in order to be considered biometrically rigorous an inventory needs to be:

- unbiased - usually achieved by using an objective sampling design; and
- precise - usually controlled through plot numbers.

Note that a small level of bias may be acceptable if results are precise and the level of bias is known.

Objectivity

***Systematic sampling* uses a regular pattern of plots.**

Objectivity is about minimizing possible bias due to subjective choice of samples. In practice this means selecting samples using pre-determined and objective rules, such as taking random plots or ones falling at the intersections of a systematic grid. Random sampling, using random number tables to select sample plots at locations within a grid (or 'sampling frame'), should ideally be used. Systematic sampling ensures a regular spread of plots and can be useful for mapping species distributions. With systematic sampling, care must be taken to ensure that plots do not line up with some regular feature in the landscape, as this will bring bias into the results.

It is not acceptable to:

- subjectively choose samples – e.g. deliberately choosing a location because it is judged to be typical of the area;
- opportunistically choose samples – e.g. to select a location because it is accessible. Occassionally this cannot be avoided, for example in flooded Amazonian forest only accesible along navigable channels. In these cases the level of possible bias should be estimated; and
- haphazardly select samples – e.g. by throwing a quadrat over your shoulder.

Number of plots

The number of plots is critical in ensuring that the results are precise. Precision is measured through the sampling error of an estimate - the smaller the sampling error, the more precise the estimate. Large numbers of plots reduce the sampling error. Often inventories are designed to deliver a specific sampling error (typically 10-20 percent) and thus it is important to know how many plots to use.

The actual number of samples required depends on:

- level of precision required;
- how variable the resource is – highly variable populations require more plots than homogenous ones to give the same sampling error; and
- cost of accessing and enumerating each sample/plot.

There are methods of deciding how many replicates are required, (see box 12) but these require some initial knowledge about the variability of the resource. This is rarely available. A *very* general guide is that more than 30 is good, and less than five is probably inadequate.

Independence of observations

Sample plots should ideally not be close together, and certainly should not touch. This is to avoid the possibility of the presence of the presence of the species in one plot directly influencing whether it is present in another. For example, a large tree in one plot might influence the possibility of there being another tree or saplings in the adjacent plot. Touching plots also bring in dilemmas about how to deal with individuals on the touching edges.

2.4 How good are existing methods?

Are current methods biometrically adequate?

Methods reviewed were assessed against the above criteria to judge their biometric strengths and weaknesses in different areas.

Reporting of protocols

It was difficult to judge the biometric quality of many of the 97 reviewed NWFP studies because the protocols were not reported in enough detail (see the enclosed CD-ROM for details of the reviewed studies).

This is a concern because information from assessments is only useful to people not directly involved in the work if it is adequately reported, with a protocol that can be evaluated for different uses or replicated elsewhere.

Protocols should clearly report the following key elements:

Sampling design: without details of how plots are located, the reader can only assume that it may have been done subjectively and therefore be biometrically unreliable. Only 14 percent of studies reviewed gave adequate details.

Plot dimensions and numbers: Despite describing quantitative studies, 25 percent of the studies reviewed fail to say how many plots were used. Whilst in some cases this can be worked out from details of the systematic design used, this should not be necessary.

Enumeration techniques should give details of where and how each plant or animal was counted or measured, but such details are often poorly reported.

Objectivity in sampling designs

There is a range of sampling designs available, including: census, random, systematic, stratified and experimental designs, which are statistically sound and include adequate objectivity (see Table 4).

Table 4: NWFP sampling designs in reviewed studies

Design	Number	% of studies*
Census	5	6.0
Random	18	21.7
Systematic	24	28.9
Experimental designs	3	3.6
Stratified	21	25.3
Subjective	18	21.7
Opportunistic	11	13.2

** Percent of the 83 studies which reported sampling designs.*
Note percentages do not add to 100 as many studied combined designs, i.e. stratified random, etc.

The main failings in sampling design were the use of:

- *Subjective location of plots:* this is not uncommon, despite frequent recommendations to avoid it. Subjective selection of samples or plots reduces the reliability of estimates about the population, because sampling errors cannot be calculated. Subjective sampling can be justified, but will always result in data that are difficult to generalize. Justifications include:

  - locating rare, unusual or difficult to find individuals;
  - minimizing plot numbers (and thus cost) by sampling ‘representative’ areas;
  - difficult terrain and access problems; and
  - use of local knowledge.

  Subjective site selection may be acceptable if actual samples within the site or area are selected objectively.

- *Opportunistic sampling*: i.e. when samples are selected simply because they are highly accessible or are the only known sites. Whilst in some cases this may seem valid (e.g. sampling birds along a trail) bias is always a possibility.

Plot numbers

Assessments are often based on single plots. For example, ethnobotany studies often rely on 1-ha plots (originally this size was chosen using species-area curves but is now accepted as a standard), which are thought to be sufficient to capture most of the flora of a region. Whilst this method may be acceptable for describing a flora, it has limited value for management, especially as plots or samples are often subjectively chosen. Overall, 29 percent of assessments reviewed have less than 5 plots, 30 percent with 5 to 30 plots, with only 40 percent having more than 30 plots.

Plot independence

The distinction between plots and subplots is a common source of misunderstanding.

Plots should be independent of each other to avoid the risk of relationships between them. Plots which touch each other should never be treated as independent, but rather as subplots. However, many studies treat subplots and contiguous plots as independent plots - this is called ‘pseudo-replication’. Annex 2 provides a diagram to explain the difference between plots and subplots.

Biometric value of reviewed studies

Table 5 notes the biometric performance of different types of assessment reviewed. The main criteria used to judge whether a study was biometric or not were:

- adequate reporting of protocols;
- use of objective sampling designs;
- use of more than one plot; and
- use of independent plots.

Table 5: Biometric qualities of reviewed studies

Study type	*Studies*	*Protocols reported (%)*	*Biometrically 'good' (%)*	*Comments/Main concerns*
Biodiversity	3	66	0	Often subjective but justifiable?
Demographic	9	44	22	Often based on single study plots or stands
Ethnobotany	10	50	20	Including quantitative ethnobotany
Experiments	5	80	80	Insufficient replication of treatments
Harvesting studies	5	80	60	Insufficient replication of treatments
Resource inventory	42	69	57	Insufficient plots
Mapping	3	0	33	Biometric sampling not a major concern?
Market studies	2	50	0	Econometric not biometric criteria apply
Methodology	11	64	55	Problems with contiguous subplots
Monitoring	12	50	25	Different biometric criteria also apply
Rapid assessment	1	100	0	Rapidity and rigour not compatible?
Remote sensing	2	0	0	Do not report protocol for ground truthing
Use of secondary data	6	10	17	Do not report protocols for original data set
Social surveys	2	50	50	Sociometric not biometric criteria apply
Yield studies	13	46	8	Subjective selection of sample individuals
All studies	126	56	38	

Only 38 percent of the 126 studies reviewed are biometrically adequate according to the four criteria, whilst some 43 percent of resource inventories and 90 percent of yield studies appeared to fail. However, 56 percent of the studies were not reported in sufficient detail to make a judgement on biometric quality.

The major problems with the studies are:

- inadequate reporting of protocols;
- use of subjective sampling schemes;
- use of few or single plots; and
- confusion between plots and subplots.

The fact that both resource inventories and yield studies commonly fail to report protocol and/or use poor design is of concern. Both are used to inform management, and need to be biometrically sound. If this review reflects the general picture, much of the information provided appears to lack credibility.

Although not all studies need to be biometrically rigorous, it is useful for users to understand why biometrics is important so that they can judge whether or not they need it.

2.5 Is biometrics always necessary?

There is an intense demand for information on NWFPs, but not all of it needs to be rigorous. It depends on the objectives, needs and expectations of the users of the information from assessments.
So, why use biometric methods?

When is biometrics relevant?

Key debate: quantitative vs. qualitative data
For decades social scientists have argued about which of the approaches is better for recording social phenomena.
Combining advantages:
More recently there is mainstream recognition that there should be integration of the best elements of the two.

Biometric rigour is important because it provides reliable, good quality information. Such information is important in ensuring appropriate planning and management. It is critically important for:

Livelihoods – giving the right advice: Decisions based on resource assessments can influence the long-term survival of species and thus livelihoods (Cunningham, 1996b; Myers & Patil, 1995). Oversimplification of complex situations, risking giving poor recommendations, should be avoided. It is critical that community-based assessments provide useful and reliable information – advisers should see this as an ethical obligation.

Exploitation – avoiding overharvesting: Good quality information is important to ensure that decisions to not lead to decline of the target species, which may in turn put commercial ventures based on those species at risk. As yet, few NWFP enterprises base harvesting decisions on reliable data and overexploitation is not uncommon. In such cases, it is critical that robust monitoring systems are implemented to deal with any negative consequences and make corrective actions.

Valuation of tropical forest resources – allowing comparisons: The use of NWFP data by people not involved in the inventory requires some level of standardization of what is measured and data quality. It is difficult to compare results from assessments that are carried out differently. Table 6 shows common failings of biometric rigour and reporting protocols in NWFP assessments from the perspective of natural resource economists, and makes suggestions for how methods could be improved (Godoy *et al.*, 1993).

Strategic overviews – planning and prioritization: Often the data used for national, regional or international statistics come from local assessments of NWFPs. Often called ‘meta-analysis’ this synthesis of different studies is more than simple compilation of data, but rather involves further analysis for wider interpretation. Whilst it is a cost-effective way of generating large-scale data, it is only as reliable as the data it uses. It will only provide biometrically adequate results if the local assessments do.

Credibility – avoiding political bias: Ensuring that data are biometrically sound can add weight to recommendations based on that information. Where governments have to defend their reasons for setting quotas to those who lobby for higher (industry/trade) or lower (conservationists) levels, reliable data are important. Case study 1 provides a useful example of the role of reliable data in political debate concerning the national quota for *Prunus africana* bark in Cameroon.

Table 6: Summary of main failings of NWFP resource assessment for valuation studies

Information required	***Main failing***	***Suggested methodology***
Data representative of forest	Many studies only use one site and reasons for choice not given so not possible to use data for comparison or generalization	Ideally a sample of study sites (to allow calculation of variance) or failing this presentation of reasons for site choice
Population profiles suitable for generalization	Informants in anthropological studies not randomized and sample sizes small	Identification of main attributes of extractors (e.g. age, technology, income). Stratified random sampling of people in identified strata
Data representative of seasonal pattern of NWFP use	Few studies include more than 1 year's data	Random selection of same number of weeks and days from each month through at least one year. Careful examination of climate and other variable, e.g. larger economy to understand representativeness of study period
Quantification of product flows (quantities used by people)	Some studies value the stock (inventory) which relates to neither present or sustainable flows	Identify, count, weigh and measure products as they enter the village each day. Assess random sample of villages and households and either ask extractors or randomly observe and record their consumption
Product weight	Weights may not be measured	If products too difficult to weigh in bulk, take seasonal subsamples for mean weights
Product identification	Irregular use of scientific names or use of local names hinders comparison between studies	Collect specimens (vouchers, skulls, photographs) for definitive scientific identification
Catchment area for product extraction	Many studies do not record catchment area so not possible to determine yields per hectare	Direct observation, participatory mapping, travel time assessment, aerial photographs, Global Positioning Systems (GPS), etc.
Sufficient observations	Insufficient if reliant on single researcher undertaking all observations	Train and use extractors to collect information or keep personal diaries (be aware of possible biases)
Value of product	Some researchers use expenditure of labour or energy as a measure of value which is not consistent with modern valuation theory	Use prices that exist for the commodity concerned or that prevail in related markets, e.g. use marketed good bartered for non-market product, use value of close substitute. Use contingent valuation (willingness to pay) methods
Share of harvest going to the household and to the market	Few studies have done this but it is important as household and market goods are priced differently	Random sample of households asked to keep log books of daily income, expenses and amounts of NWFPs consumed or sold
Shadow prices	Important in providing an economic rationale for NWFPs that may not be financially profitable Required to estimate valuation from a national viewpoint	Adjust for taxes and subsidies that cause price to deviate from opportunity cost of resource
Environmental externalities	No study has done this which means that conventional valuations underestimate economic benefits of NWFPs	No suggestions made
Marginal costs of extraction and processing	No assessment of search times, cost of tools, etc., made for plant collection (has been done for animals in studies based on optimal-foraging theory)	Interviews, direct observation (instantaneous sampling, focal subject sampling), extractors diaries/records, log movements out of and into village
Wage rates	Some researchers have used country's official wage rate but this should not be done uncritically	Determine what people actually pay each other. Note that rural wages vary by season, age, sex and type of work
Cost of capital	Not often measured – use of market rate inappropriate	Use social discount rate – may be calculated locally otherwise use 4-5%
Sustainability	Three views a) Indigenous people manage forest sustainability b) Indigenous people do not manage sustainability c) Sustainability is result of special conditions that must be identified in each case	Indirect: comparison of distance, frequency and duration of collection forays, recall of yields over time, etc. Direct: comparisons of extraction and rates of reproduction/growth in the forest
Use of plant and animal extraction in single valuation	Not possible as botanists use returns per hectare while zoologists use returns per unit of labour	Multi-disciplinary team comprising natural resource economist/economic anthropologist, botanist, zoologist; as well as indigenous people and local scholars

Case study 1: Setting quotas for the Mount Cameroon Prunus bark harvest

Prunus africana is a tropical afro-montane tree that forms a significant proportion of the canopy in higher altitude forest on Mount Cameroon. Bark is stripped from the tree for export to Europe for the manufacture of a drug to treat prostrate cancer. Plantecam Medicam, a Cameroon subsidiary of the French company Laboratoires Debat, has been processing and exporting *Prunus* bark since 1972 but closed operations in Cameroon in 2000. The Ministry of Environment and Forestry (MINEF) regulates harvesting of bark through an annual quota and recommended harvesting practices. Best harvesting practice, removal of 50 percent of bark from opposing sides of the tree once every five years is thought to be sustainable but unlicensed collectors tend to remove all bark (which kills the trees) or fell the tree thereby compromising the resource. There are grave concerns about the long-term survival of the species and repeated attempts have been made to reduce the level of harvesting and promote cultivation of the species. The table below documents attempts to introduce new quotas and the role of resource assessment in the debate about sustainable harvesting levels.

Year	***Resource assessment***	***Information***	***Observation***
~1972	None	-	Quota set at 1 500 tonnes per year
1976	-	Concern with overexploitation	Nursery and enrichment planting started
1984-1985	Forestry Department study for Mount Oku, Bui Division	Measurement of 7 717 exploited trees	Yield per tree = 55 kg per tree
1985-1995	Plantecam records to MINEF+	Total harvest of 4 478 tonnes over period	Average annual harvest = 448 tonnes yr^{-1}
1986-1991	Plantecam records	Total harvest of 11 537 tonnes over period	Average annual harvest = 1 923 tonnes yr^{-1}
1987	ICBP* draw attention to threat to mountain environments posed by overexploitation	-	Partial ban on trade from February 1991 to February 1992
1991	Forestry Department 25x500 m plots at six subjectively located sites around Mount Cameroon (sample area = 45 ha)	Average density of trees > 20 cm d = 5.5 ha^{-1} Lack of regeneration, seedling density at 5 ha^{-1}	No quota set based on this inventory. Results biased towards high density areas and would have suggested very high quotas
1994	MINEF records	Plantecam harvest ~ 926 tonnes yr^{-1} Illegal harvest ~ 590 tonnes yr^{-1}	Annual harvest at 1 400 tonnes and unsustainable
1995	Kenya makes CITES listing proposal		Listing on CITES Appendix 2
1996	ONADEF* 1% systematic strip-sampling inventory for Mount Cameroon	Widespread mortality due to poor harvesting practice. Average density of live trees > 30 cm d = 0.76 ha^{-1} Yield = 68 kg per tree Annual quota = 300 tonnes per year ± 50% All stakeholders collaborated in inventory design and verified a 10% subset of the inventory in the field	Plantecam contend that this inventory is 'insufficiently intensive, inaccurate, was not completed in some areas and that average yields per tree are higher'. Claim that results are ONADEF and MCP* biased. Plantecam lobbied for higher quota but Cross-Ministerial Round Table Committee confirmed they were confident in the ONADEF quota Agreed with MINEF that future quotas should be set using RME rather than mean.
1996	Plantecam records	Yield per tree = 100 kg per tree	Need 1 500 tonnes yr^{-1} nationally and 700 tonnes yr^{-1} from Mount Cameroon to supply factory
1998	Independent professional forestry body to undertake 5% inventory	MINEF committed to adjusting future quota even if insufficient for Plantecam	Renewal of Plantecam's licence with a quota of 1 500 tonnes per annum in April 1998
1999	CITES Plants Committee meeting		Representatives of Plantecam and MCP attend to present alternative cases for *Prunus*.
	Trial of adaptive sampling for *Prunus africana* on Mount Cameroon		Plantecam pull out of Cameroon, because of insufficient supply
2000	ONADEF commence national inventory for Prunus		Proposal to use Prunus as a case study for a methodology for CITES non-detriment finding

International Conservation of Birds Programme; ONADEF: Office National de Développement des Forêts (parastatal with responsibility for forest inventory); MCP: Mount Cameroon project
+ Ministry of Environment and Forestry
Taken from: Acworth et al.,1998; Cunningham & Mbenkum, 1993; Acworth, pers. comm.

Section 3 Quantitative studies on NWFPs

This section describes current experience in NWFP resource assessment. It covers inventory, yield measurement, growth studies, harvest determination and monitoring.

3.1 Finding out *how much* of a resource is present

This is often called ‘**quantitative inventory**’.
Quantification of resources can mean something different to an ecologist than it does to a forester, and so on. But definitions boil down to it being: *A biometrically rigorous enumeration of the abundance and distribution of resource populations*.

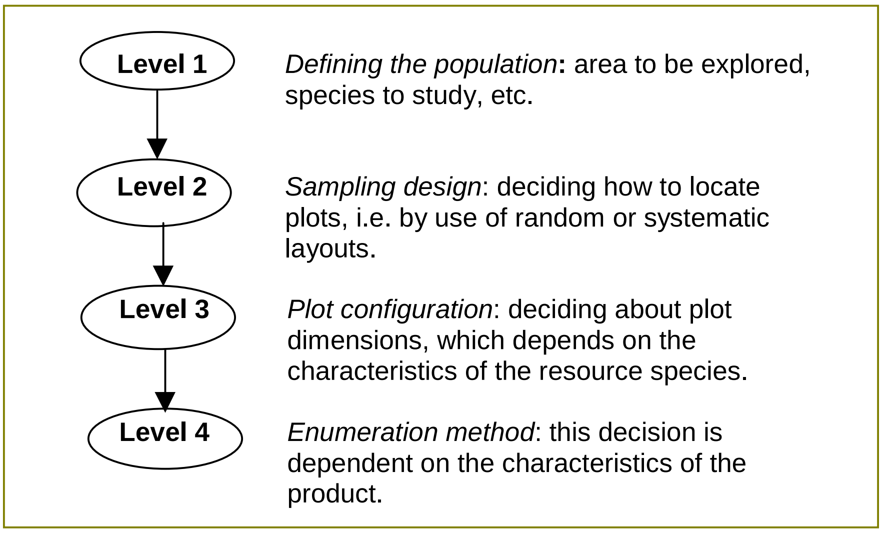
Many designs, single structure

There are very many different designs, partly because there are very many different types of NWFP – plant and animal. Whilst methods to inventory these appear to be very different, they all contain four basic elements, as Figure 3 shows. How to select one of the wide range of different methodologies that have been used at each stage in the design of quantitative NWFP inventory will be further discussed in Section 5.

Methodologies used for NWFP inventory are adapted from the wide range of experience available across the botanical and zoological sciences. NWFP inventory has used relatively few of the available methods because of:

- NWFP assessment being a relatively recent issue;
- nature of the NWFP resources that have been studied – e.g. the disproportionate focus on fruit; and
- context of NWFP assessments – whether the NWFP is the main focus of the inventory.

Figure 3: Basic structure of a quantitative inventory design



Methodologies can be adapted according to the species being studied and the availability of time, money and human resources. The level of adaptation also depends on the importance of NWFPs in the inventory. Three clear contexts can be distinguished:

- single resource inventory: where the inventory seeks to quantify the abundance and distribution of a *single NWFP species*;
- single purpose, multiple resource inventory: where the inventory looks at *more than one resource* for the same reason – i.e. a strategic inventory, for several different NWFPs; and

- multi-purpose resource inventory: where NWFP inventory takes place during *inventories for other purposes*, such as timber management or watershed protection.

Inventory for a single resource species

There are few inventories for a single species – it is a costly process so the product has to be very valuable (usually for export) or subject to specific legislation. Even then, few studies actually aim to quantify the species *in situ*, and methodologies are rarely tailored specifically to the characteristics of the species.

Six main reasons for carrying out single species inventory have been identified:

- provide new/initial knowledge about the consequences of harvesting a species (e.g. tapirs in Belize - Fragoso, 1991);
- assess the potential of specific species to support increased product demand (e.g. palm products in Namibia - Sullivan *et al.*, 1995);
- assess the potential of an area for viable harvesting of a commercial product (e.g. rattans on Barateng Island in India - Sharma & Bhatt, 1982);
- investigate where a commercial product can be found (e.g. savanna fruit trees in Benin - Schreckenberg, 1996);
- provide information for determining harvesting quota levels for species under national or international regulation (e.g. CITES listed species, such as caiman skins from Venezuela - Velasco *et al.*, 1996); and
- academic inquiry to better understand individual species, for ecological, historical or cultural reasons (e.g. understanding of the role of wild yams in historical human diets in central Africa - Hladick & Dounias, 1993).

Examples of the designs used in these studies are noted in Table 7. In summary, whilst single resource inventories are a good opportunity for developing reliable NWFP inventory protocols, there has been insufficient work done to make much progress.

Table 7: Inventory designs used by single resource studies

Product type	*Sampling design*	*Plot configuration*	*Enumeration*	*Author*
Tree bark	Systematic (1%)	50x50 m square	Diameter of trees >10 cm d	Acworth *et al., 1*998
Tree exudate	Aerial cruise, 2 flights	11 possible locations	Visual estimates	Zieck, 1968
Tree fruit	Subjective transects	10 m wide transects up to 1 km long	Diameter of trees >10 cm d	Shankar *et al.,* 1996
	Six systematic radial line-plot transects (plots every 100 m on transect 3 km long)	Point centred quarter	Diameter for trees >3 cm and stumps >50 cm	Schreckenberg, 1996
Palm fibre	Stratified: Oxisols and podsols: unreported plot layout Gleys: line-plot 600 m long, 20 m between plots	Oxisols and podsols: 100x50 m rectangular Gleys: point quarter method	Height measured for all stems in plot	Lescure *et al.,* 1992
Rattans	Subjective site selection	Single 3 ha (300x100 m) plot divided into 10x10 m subplots	Tally of clumps and stems	Stockdale, 1994
	Multi-stage sampling Random selection of 32 from 123 primary blocks	Three secondary 1 ha blocks selected from each selected primary block	Tally of commercial and non-commercial culms per plot	Sharma & Bhatt, 1982
Herb fibre	Line-plot transects, unreported distribution	Circular 50 m² plots every 10 m.	Tally and % cover of plants in plot	Cevallos undated
Tubers	Four sites – unreported plot location of 4-9 transects in each	Transects 4 m x up to 2.5 km long	Tally of yam stems	Hladik & Dounias, 1993
Large birds	Available trails and tracks (haphazard – biased)	180 variable width transects	Tallies of individuals	Silva & Strahl, 1991
Tapir	Randomly located line transects River transects	Line-intercept transects	Indirect (tracks)	Fragoso, 1991

Inventory for more than one resource species

In the studies reviewed, the multiple species are a range of NWFPs, and the single purpose for inventory is usually to provide quantitative information to assist management planning.

Using census methods for small areas

Some NWFP inventories have used methods developed for *stock survey* (the census of exploitable timber trees in a harvesting area). These methods can be used for measuring relative abundance of NWFPs in different land use types (e.g. Gronow & Safo, 1996). Although census methods provide truly accurate data, using them has drawbacks:

- does not take account of difficulties in finding species such as animals, small herbs or epiphytes;
- errors cannot be quantified, as it is a single sample; and
- such census type surveys are expensive unless over very small areas.

Using participatory rural appraisal (PRA) techniques (e.g. Poffenberger *et al.*, 1992).
PRA based methods were iused in Poffenberger's manual to guide inventory and monitoring in the Indian joint forest management (JFM) process. This advocates a mix of methods for scoring relative abundances, and quadrats and plotless sampling for looking at vegetation change. Whilst the recommendations made are sound, they are rather broad and do not include detailed protocols.

Using basic forestry sample plot techniques (e.g. Cunningham, 1996a).
This method was designed to allow quantification of key plant resources – trees and bamboo – to support management planning in a National Park in Uganda. In this particular study, only three or four plots were used at each of the three sites. The lack of replication means that data could be imprecise, inaccurate and biased. The results are more suited to strategic planning than detailed management planning.

Sampling across forest and non-forest land (e.g. Dijk, 1999a).
Sampling strata in southern Cameroon were identified using air photos. Data collected from plots in each habitat type were used to prepare NWFP stand density tables grouped by product types and marketability, and to map their distribution. Looking at NWFPs outside forest land is important as many NWFPs are actually sourced from 'farmbush' (farmland in cleared/regenerating forest areas). These areas are more usually assessed using a wide range of participatory approaches, such as described in Section 4.

Including NWFPs in inventories for other purposes

The mounting interest in NWFPs is driving a trend towards including NWFPs in inventories for other purposes.

For example, NWFPs can be incorporated into routine stock survey of commercial logging areas (e.g. Smith, 1995). Typically, routine forest inventory is becoming 'multi-purpose resource inventory' (MRI). This is to improve economic efficiency, as well as in recognition of the increasingly wide range of products and services for which forest is managed. Experience in State forests is important here – the forest authority generally has responsibility for maintaining up to date information on important forest resources, which may include important NWFPs.

Doing stock survey for timber management: **Immediately before logging operations, every timber tree in a forest management compartment is located, identified, numbered and measured. This usually gives a 100 percent enumeration in consecutive strips of the compartment. The stock survey data allows calculation of the volume of timber that can be harvested sustainably, and trees for felling are selected accordingly, to ensure future harvests.**

NWFPs are commonly included in routine forest inventory (typically every 10-20 years) across northern and eastern Europe, where berries, mushrooms, medicinal herbs and resins are traditionally important (Lund *et al.*, 1998). However, little literature is available outside these countries. Also, whilst stock survey provides useful and biometrically sound information on the distribution, abundance and potential of NWFPs in areas to be logged, it does not take account of difficulties in finding species such as animals, small herbs or epiphytes; or of seasonality.

Further MRI reading: Lund, 1998

In the tropics NWFP componenent of MRI focuses on

Traditional export products, such as bamboo and rattan – national assessment of resources by government forest agencies is often carried out, especially in South East Asia and India where exploitation is intense, with increasing interest in West Africa, as Case studies 2 and 3 show.

Case study 2: NTFPs in the Philippine national forest inventory

An example of the inclusion of NTFP is the Philippines MRI which included rattans, palms and bamboo. Here a national-scale stratified inventory used quite different plot configurations in different regions (presumably, partially as a result of different donor/advisory support). The basic design was cluster sampling on an 8x8 km systematic grid. In regions 10 and 11, the clusters were four 20x250 m strips arranged on the arms of a swastika 1 km across. In these plots rattans were sampled in a 10x10 m subplot centred on the plot mid-line at the start and every 100 m along the strips. In all other regions the cluster was a triangular arrangement of six Bitterlich point samples at 50 m intervals. In this design rattans were sampled from a 5-m radius plot at the corner points of the triangle. Given the large quantities of data for each configuration, it would be interesting to compare their performance in terms of the precision and accuracy of rattan densities.
(Serna, 1990)

Case study 3: NTFPs in the Ghana national forest inventory

In Ghana NTFPs were enumerated from 1 ha plots (20x500 m) and included rattans, climbers and herbs. In this case, as plants became less like trees the enumeration methods, due to the absence of botanical survey advice, became increasingly crude. For example, rattan stems and clumps were counted and tallied into juvenile, mature and cut categories while abundance of herbs was represented as a simple tally of clumps. The herb data are unreliable as it is difficult to determine clump boundaries in dense stands and the size of clumps varies widely between species. As a consequence the herb data had to be reduced to presence/absence of the species. With hindsight % cover or even relative abundance would have been a better measure of quantities.

The information derived from this inventory was intended for use by policy-makers and for national and international reporting requirements who required management-orientated interpretations. This was provided as tables and graphs illustrating the distribution and abundances of NTFPs across the country (see Annex 3). This type of analysis and presentation of inventory data are relatively rare.
(Wong, 1998)

Quantitative timber inventory. **At its most basic this is a count of all individuals of interest within plot or transect. Plot totals allow estimation of average density in a given area. If tree diameter is measured, then basal area per tree can be calculated and volume estimated per unit area through yield tables. Methods are common, well understood and usually included in professional forestry training.**

Getting beyond a timber focus

Typically, MRI inventories are carried out by forestry staff, and the primary aim remains timber management. This often restricts the range of products and interests, including recreation or agriculture, that can be included in MRIs. The focus on forestry can also limit the quality of the NWFP assessment, as it constrains:

- number of NWFPs included – generally only around 20 unfamiliar species can be identified without botanical expertise (Kleinn *et al.,* 1996). Species included are usually restricted to the most familiar and more heavily traded ones;
- including difficult to find species, which may require specific observational methods – for example, animals may be nocturnal or avoid

humans, fungi are seasonal. Some small herbs are difficult to see - detectability is recognized as a major problem;

- skill and effort with which they are assessed – forestry staff may be more skilled in tree enumeration, and plot enumeration often is limited to what can be accomplished in one day. Enumeration of NWFPs is often limited to a few subplots; and
- design of the inventory – this is determined by timber information needs, which may not be ideal for NWFPs. Protocols for including NWFP are not well developed, and yield tables to convert easily field data into resource estimates are not generally available. One of the biggest failings in MRI in tropical countries is that they do not include animals, despite bushmeat, for example, often being the most important product for local people.

Whilst separate inventories for different NWFP groups is usually impossible, due to cost and logistical constraints, to improve the value of the information gathered there should be some balance and co-ordination between different elements of MRI. For example, survey lines cut through tropical forest for timber inventory could also be used for animal inventory[1]. Making the most of such opportunities can reduce costs and improve information for forest use planning.

Picking NWFPs out of existing timber inventory datasets

In many cases, NWFP tree species are included in formal timber inventory. Sometimes it is possible to extract and analyse NWFP data from records of historical timber inventories.

Some single-purpose timber inventories have been re-interpreted to provide information on NWFPs, and demonstrate that there are some useful NWFP data in older tree inventories (see Case study 4). With a picture of what trees are in an area, predictions can be made of what other plants and animals are likely to be present.

Case study 4: Use of existing inventories

Southern Ghana. An excellent example of the use of a timber inventory is the analysis of the national forest inventory in southern Ghana. The ecological profiles of nearly 300 tree species were presented, based on information from the timber inventory. This thorough work provided information on NWFP trees. (Hawthorne, 1995b).

Uttar Pradesh, India. Re-analysis of Forestry Department stand table data provided an estimate of total, state-wide quantities of edible oil from 25 important oil-seed species.
(Rai, 1983)

Developing methods specifically for NWFPs – some examples

From the preceding sections it becomes apparent that NWFPs often fall between divisional responsibilities and professional expertise. This has contributed to:

[1] Cut lines will remain open only for a limited amount of time and communication between teams about access periods is important.

- limited success in using recognized inventory methods reliably for NWFPs; and
- a lack of established methodology specifically for NWFPs.

Some pilot studies on methodologies for plant NWFPs have been done, mainly for some of the more economically important ones such as rattan, mushrooms, medicinal plants – Box 2 and Case study 5 below give some examples. Studies have often been very innovative, but there are as yet few comparisons between approaches. What is clear is that different approaches suit different types of NWFPs – further complicating the development of standard methodologies.

Box 2: Developing plot layout and measurement techniques for rattan inventory

Rattans are the subject of a relatively large number of studies (12.6 percent of reviewed studies, see Table 6) and there are a number of researchers who have been investigating the relative efficiency of different plot sizes and shapes. Tandug (1978), Siswanto & Soemarna (1988, 1990), Siswanto (1991), Stockdale (1994) and Stockdale & Wright (1996) have all used basically similar techniques to determine optimal plot size and shape for rattan inventory. The technique used is to demarcate areas (ranging from 1 ha to 16 ha) into small (5x5 m or 10x10 m) square quadrats and to enumerate all rattan stems in the quadrats. The quadrat data is then aggregated to represent plots of different sizes and shapes and the relative efficiency of the different plot configurations compared in terms of sampling error and cost efficiency. This is apparently an efficient means of determining optimal plot dimensions but has a few drawbacks and some significant pitfalls. Although the chosen study site is large, it is effectively a single plot so the applicability of the results will depend on the representativeness of the study site which, in the absence of replication, is unknowable. Also, several studies have the test plots touching, which means that the "plots" are not independent (see p. 18).

Tandug (1978) measured cost-efficiency of different plot configurations by comparing the sampling error for the number of plots that could be enumerated within three hours in a 1-ha study area. The sample plots were laid out on a systematic grid to cover the area so that more time was spend travelling between plots as the plots became smaller. The optimal plot size emerged as a 10x10 m square plot at a 50 percent sampling intensity. However, later recommendations of Tandug (1988) suggest using two 10x200 m strips arranged in a cross formation at a sampling intensity of between one and three percent. Unfortunately, it was not possible to locate a larger scale application of these recommendations to judge their overall merit.

Identical studies were undertaken to determine optimal plot size and configuration in West (Siswanto & Soemarna, 1988), Central (Siswanto & Soemarna, 1990) and South (Siswanto, 1991) Kalimantan. The methodology employed was to subdivide a 16-ha study area into 10x10 m quadrats and to form these into a range of strip and line-plot configurations at a range of sampling intensities from 10 to 25 percent. In each case a 10-m wide continuous strip at sampling intensities of 25 or 20 percent was recommended.

Stockdale (1994) and Stockdale & Wright (1996) used a similar technique to that of Tandug (1978) and subdivided a 1.5-ha (300x50 m) study site into 10x10 m quadrats. However, there is an significant difference between Stockdale's work and that of Tandug, Siswanto and Soemarna in that Stockdale's trial plots are contiguous while the others used non-contiguous plots. Consequently, in Stockdale's study the variation in sampling efficiency is more a function of spatial pattern in the rattan clumps and their coincidence with plot shape and size than a true test of the efficiency of different plot configurations. Stockdale & Wright (1996) found that strip plots were more efficient than square plots and recommend that 5-m wide strips forming plots of 0.005 to 0.025 ha for enumerating stems per hectare.

Nandakumar & Menon (1992) developed a protocol for rattan inventory in Kerala State, India and recommended that 4x20 m strips be used in strips 100 m apart to give a 4-percent sampling intensity. However, they do not report any field work so it is not possible to judge the efficiency of their recommendations.

An investigation of optimal plot sizes and shapes in Lao (Evans submitted) arrived at a 5x50 m plot sizes using six replicates randomly located along a transect line. This overcomes the problem of contiguous plots but the level of replication is still not sufficient for work of this kind.

A methodology for estimating the length of rattan stems using a ruler hypsometer was developed (Stockdale, 1994; Stockdale & Power, 1994). This was tested against various other methods for estimating lengths and was found to be cheap, relatively easy to learn and significantly more accurate than visual estimation, internode counts (as used by Nur Supardi [1993]) and clinometer readings.

Case study 5: Developing protocols for mushroom monitoring

A team at the Forest Service Pacific Northwest Research Station in Corvallis of the United States Department of Agriculture (USDA) has been developing methodology to inventory, assess yields and monitor production of edible wild mushrooms since 1993. Their experience and process of development of ideas is very well documented in a series of publications and provides an informative case study of the problems of inventorying non-tree forest products.

The major problems facing the design team is that the target fungi (Matsutake, chanterelle and morels) occur as scattered colonies with patchiness at a range of spatial scales as well as being cryptic (largely invisible on the surface) and seasonal. It was recognized from the beginning that the patchy distribution would require the development of novel sampling schemes and analyses (Molina *et al.*, 1994). The first attempt at inventory used methods borrowed from fungus diversity surveys in three study forests (Molina *et al.*, 1994; Pilz *et al.*, 1996a; Hosford *et al.*, 1997). In each forest, three locations were selected to represent the three most productive vegetation types within the forest. At each location, three 225x225 m (5 ha) study sites were chosen to represent altitudinal, aspect and accessibility across the vegetation type giving nine study sites in each of the three study forests. Each site was surrounded by restricted access notices and, within each, six permanently marked strip plots 2x50 m were located systematically on a random orientation. The plots were located during the period when the fungi were not fruiting so as to avoid conscious bias. Mushrooms were enumerated by measuring cap and stem diameters, vertical distance from veil to cap, distance to nearest tree and volume predated. Measured caps were marked to avoid repeat enumeration. The plots were re-surveyed weekly through the fruiting period. After a couple of years' experience this method was largely abandoned as it was too expensive and time consuming, the sample area was also found to be far too small to adequately represent any individual species, the plots had been also compromised by illegal picking and vandalism, while legitimate pickers were intimidated and did not harvest the plots normally. In addition, off-site weather records did not correlate with yields. After this experience it was decided to change the sampling methodology. Japanese experience suggested that shiro (individual mycelium body or 'castle' in Japanese) monitoring would be a useful for Matsutake mushrooms (Hosford, 1996). However, this methodology is very time-consuming and could only be considered for research work and not for routine monitoring. There have been two developments in methodology based on this early experience.

It is proposed that regional monitoring should utilize volunteer enumerators drawn from the local pickers and a proposal to this effect has been circulated (Pilz & Molina, 1998). The plan is to use exclusive harvest agreements as an incentive for volunteers to make detailed harvest records from marked sample plots. Regional systematic stratified sampling is to be used to select local monitoring sites and the data used to investigate the relationship between forest management and mushroom productivity. Control sites are to be monitored by Forest Service staff. The programme is intended to be voluntary and based on flexible, decentralized collaboration encouraging volunteer ownership of the programme.

For Matsutake, a mapping approach has been adopted with mushrooms mapped to reference trees which are located using GPS (Pilz & Molina *et al.,* 1996). A cluster of mushrooms is taken to include mushrooms no further than 0.5 m apart with distances between clusters being at least 2 m. The demarcated clusters were assigned to experimental harvest treatments and monitored by Forestry staff with the co-operation of local pickers who kept the surrounding area well picked to discourage opportunistic collectors. The method of selecting reference trees is not given but this method would appear to be an efficient means of sampling for mushrooms.

The search is still on for a suitable protocol for monitoring mushrooms (Pilz *et al.*, 1997; Pilz & Molina, in press; Pilz *et al.*, in press). A manual describing present experience and best advice is under preparation (Pilz, pers. comm.).

3.2 Finding out *the yield* of a resource

What is yield?
'Yield' typically refers to the amount of product available and useful for collection or harvest at a given point in time (i.e. that which can be used commercially). However, it can also mean the total biological potential of a species (i.e. how much actually grows there). The difference can seriously influence the conclusions of an assessment, as the latter is typically much greater than the former.

Measuring yield

Measuring product availability is generally known as yield assessment. It is the quantification of the amount of a product that can be harvested from an area of forest.

How is it done? First, the product quantity is measured for a small sample of the population. This is then related to an easily measurable characteristic of individuals enumerated in the overall inventory, using models such as regression equations.

Measuring the product

Measuring parts. NWFPs can be almost any part of a plant or animal, and each needs to be measured using a different technique. Hence there are a huge number of different enumeration techniques in use – Table 8 illustrates a small range.

Methods for measurement. Specific methods are few, and there is little standardization even for the same type of plant part – for example, Table 8 gives three different ways of measuring fruit yields. Such differences can relate to:

- ecology: e.g. marking and repeat counts may be the only method if fruit do not fall when ripe, or harvesting might stimulate fruit production;
- tree structure: e.g. random branch sampling is only realistic if the branches can be reached, whilst ground level traps may be the only alternative for fruit which are inaccessible or difficult to see from the ground;
- objectives of the assessment influencing the units which must be counted: e.g. for marketing or legislation – rattan in India must be measured in terms of dry weight as that is what is used for permits, whilst in Indonesia it is quantified in lengths; and
- ownership and number of users: e.g. if a tree is owned and harvested by a single individual, they can be asked to count ripening fruit.

Deciding on a measurement technique thus involves consideration of the product type, characteristics, and objectives of the assessment along with pragmatism about what will work. Section 5 gives some guidelines.

Table 8: Examples of techniques used for quantifying product yield

Variable	***Methodology***	***Source***
Fruit yield per season	Ground level traps. Four isolated trees selected, 15 1-m² plots randomly located beneath crown. Number of intact, predated, immature and mature fruit recorded every 7-10 days in plot.	Peters, 1996a
Fruit yield per season	Fruit counted *in situ* on sample trees at frequent (weekly) intervals. Counted fruit marked with paint to avoid repeat counts.	Peters, 1990
Fruit, leaves, etc.	Randomized branch sampling. Branching pattern defined as numbered segments between branch nodes. Path from trunk to branch tip selected using random selection at each node. Fruit/leaf/etc. counts undertaken at distal end of path. Pooled results from several randomly selected branches is a non-destructive, precise and statistically reliable method of estimating fruit yield of tree. There are several refinements of method, e.g. path selection proportional to size of available segments at a node, importance sampling, etc.	Gregoire *et al.,* 1995 Jessen, 1955 Nguvulu, 1997
Leaves	Pipe model. Non-destructive regression technique for estimating leaf biomass and area from branch cross-sectional area. Pipe model based on observation that transpiration rate of canopy is proportional to leaf area, sapwood cross-sectional area and conductivity of water transporting tissue. Therefore size of stem is proportional to leaf mass and area. So can estimate leaf mass and area from measurement of stem cross-sectional area (NB: needs to be very accurate ~mm). Sample branches selected systematically to represent different branch heights. Regression analysis without constant.	Nygren *et al.,* 1993
Palm leaves	All leaves measured. Partially open leaves counted as fraction of open leaf. Leaf length measured monthly to track growth.	Cunningham, 1988
Palm stem increment	Leaf scars counted at monthly intervals. Stem growth quantified as height increment (cm) per leaf scar.	Olmstead & Alvarez-Buylla, 1995
Palm age	Count of leaf scars, assume constant rate of leaf production to give estimates of age and numbers of years to reach critical heights.	Pinard, 1993
Bulb size	Measurement of maximum width of largest leaf on each plant. Regression analysis performed on a random sample of 50 plants at each site indicated that the largest leaf's maximum width is strongly correlated to total leaf area. Total leaf area already shown to be an indicator of bulb size.	Rock, 1996
Bamboo biomass	Measure clump dimensions on orthogonal axes at ground level, 1 m and full canopy extent. Map these as concentric ellipses. Determine biomass as volume of cone projected upwards from the base of the clump. Site index = Σ clump volume/clump density in plot. Site clump area = Σ clump area.	Widmer, 1998
Bushmeat weight	Opportunistic records of weights of captured animals in three villages used to supplement animal census.	Lahm, 1993

Choice of sampling scheme

Whilst there are many ways of measuring yield, the choice of sampling scheme for selecting individuals to measure is more restricted. Subsampling of a small number of individuals within the overall inventory sample is usual – as making detailed yield measurements on every individual in the inventory is hard work. There are two main ways of sampling individuals on which to measure yield.

Double sampling: this is done separately from the main inventory, and does not need to use the main inventory's plots. Using a smaller, independent sample, detailed yield measurements are taken on individuals in the population. The data from these measurements are then used to form models of yield against an easily measured indicator of overall size. Yields for each unit area can then be extrapolated from the measurements taken in the main inventory. Case study 6 is a useful example, others include: a survey of bark thickness independent of the main inventory of *Prunus* trees; berry yields from research plots applied to MRI inventory in Finland; inventory to quantify animal biomass based on bodyweights from market records. Double sampling has some constraints:

- sampling of measured individuals must be statistically sound;
- the sample measured must have some predictive variable in common with the main inventory, i.e. at least one of the measurements taken should also be taken in the main inventory (e.g. tree diameter or leaf length);
- ideally, the yield sample should cover the full range of sites of the main inventory, i.e. should be representative of the whole inventory area.

Case study 6: Developing a biomass table for shrub bark in Nepal

Height and diameter at 30 cm above ground were measured for all samples of a shrub used in paper production. A subsample of each utilizable component was taken to a laboratory for oven-dry weight determination. The regression of utilizable dry bark weight against diameter at 30 cm above ground was selected as the best model. The results gave a basis for determining the rotation length for bark removal and allowed management recommendations to be made.
(Jeanrenaud & Thompson, 1986).

Multi-stage sampling: This takes place alongside the main inventory but uses 'nested' subsamples in each inventory plot, creating a hierarchy of plots within plots. The advantage of this approach is that the sample is evenly distributed across the area, making estimation of yields in certain parts of the area possible. Such site-specific estimation might be useful where conditions that influence yield vary across the assessment area, making a single subsample unrepresentative. Case studies 7 and 8 give examples.

Case study 7: Assessing the potential of cane products on Barateng Island, India

In an area of 123 primary blocks, 32 were randomly selected. In each of those 32, three secondary blocks were demarcated. Within the secondary blocks the number of commercial and non-commercial canes was counted. In a quarter of the secondary block, canes were cut then weighed every day until the weight was constant (i.e. until it was dry). The data was used to prepare cane stock tables by stem density, length and weight per hectare.
(Sharma & Bhatt, 1982)

Case study 8: Multi-stage bamboo enumeration protocol in India

Clumping species: three levels of sampling
Whole plot – all clumps counted
N-W quadrant (one-quarter of plot) clump diameters measured
One in eight clumps – culm number, age, soundness, size, condition, average culm height and quality recorded

Non-clumping species
One-eighth plot – condition, age, average height, total number of culms, etc., recorded

Utilizable green to dry weight relationship
One mature culm from each culm diameter class cut from the first clump in each plot. Length is measured 25 cm from ground to 1 cm diameter. Whole culm weighted in field and 30 cm section taken from bottom, middle and top of cut culm for determination of dry weight.
(Rai & Chauhan, 1998)

Disadvantages and difficulties include:

- detailed measurements may not be possible, for example if equipment is not mobile; and
- there may be insufficient samples of rarer but important individuals, such as infrequent large trees that contribute disproportionately to yield, for statistical analysis. If this is the case then additional subsamples might be needed or double sampling might be preferable.

Sampling decisions might be influenced by measurement practicalities. An example is if dry weights are needed, it might be preferred to sample in areas of high density to collect enough samples to efficiently use drying facilities.

The key factor to the adequacy of a sampling scheme is often in the number of subsample replicates. Often NWFP assessments use too few. For example, one using only 8-15 fruit fall traps per tree for eight trees can at best only give a rough guide to the total crop yield. For management purposes over wider areas, replications need to be much higher, for example, sampling at least 30 and preferably hundreds of trees in a number of several sites.

Conversion factors?
Usually the average amount of product per individual. Depending on the type of product, this can be the average size of an individual (e.g. for fruit or bushmeat), or the ratio of dry weight to green (undried) weight (e.g. for bark used in the dried form).

Working out overall yield estimates

Measuring the yield in the subsample area gives results that can be applied to the data on overall population densities from the main inventory to estimate a total product yield for the area. There are several methods, using conversion factors to relate individual yields to total product quantity. Table 9 below briefly describes some of them.

Table 9: Summary of alternative methods for calculating an overall yield

Method	*Description*	*Use*	*Example*
Single conversion factor	The simplest method is to multiply the average yield per individual by the total number of individuals estimated by the inventory. Adjustments can use only the accessible or commercially sized individuals from the inventory.	This method is most appropriate when size of individuals does not vary much or is not related to product quantity.	Bushmeat. Single average bodyweights can be applied to the whole population to estimate total bushmeat biomass (Lahm, 1993).
Yield as a function of size	Simplest methods involve dividing individuals into size classes and calculating a conversion factor for each class. Refinements involve relating yield to another measurable characteristic of the individuals, such as length or bark thickness, through regression equations.	Most appropriate where yield is strongly related to size – i.e. the bigger the individual the bigger the overall yield.	Traditional methods: Use of diameter at breast height as a predictor of tree volume yields. Bark yield of yew trees: assume the tree is conical and bark area is the cone's area. Bark volume = area x thickness. Bark weight is then estimated, using a dry/green weight conversion factor, as volume x 0.4 (Jong & Bonner, 1995).

Yield estimation models can become more sophisticated with more data and longer studies. For example, in northern and eastern Europe models for berry yields are highly developed from long-term studies using regular inventory and permanent sample plots. Case study 9 describes systems devised in Finland.

Case study 9: Inventory and forecast system of wild berry yields for Finland

Saastamoinen *et al.* (1998) and Salo (1999) describe what is termed the Marsi Enquiry which is a volunteer-based national berry production monitoring system.

Berries = cowberry (*Vaccinium vitis-idaea*), bilberry (*Vaccinium myrtillus*) and cloudberry (*Rubus chamaemorus)*
Yields of target species are observed in 1 110 permanent experimental plots in 57 municipalities across the country. In each compartment five plots of 1 m^3 for berry yield were located in suitable vegetation types or where shrubs occurred and permanently marked.

Enumeration
Berries – species, count of flowers, raw and ripe berries.

Site characters – timing of flowering and ripening, type of growing site, proportions of tree species, development class of trees.
Sites visited several times throughout the flowering and fruiting seasons.

Modelling
Models are yet to be developed as there are insufficient years of observation to characterize annual yield variability.
Previous models for Finland (Raatikainen *et al.*, 1984) are:
- *V. vitis-idaea* $\propto$ vegetation type, shrub cover, shrub height, stand age class, crown density and weather conditions; and
- *V. myrtillus* $\propto$ vegetation type, stand age class, tree crown density, method and degree of coppice control and weather conditions.

Dissemination
Information sent in electronic form to Joensuu Research Station where it was processed using MASI (= berry and mushroom system) and presented as thematic maps. These maps are intended to inform the berry pickers about the time of flowering and the development of raw and ripe berries across Finland. The maps and notes describe the kind of sites on which the main yields were to occur and the level of yield for each species during 1997.

Maps were distributed to media as five situation reports and were cited widely by press, radio and appeared as part of the evening news and morning television broadcasts.

Such systems may not be entirely appropriate for use in the tropics, but there are relevant features. Berry yields vary from year to year. To account for this, in their models the Finns considered:
- weather conditions for each year. Rainfall can be a particularly useful yield predictor;
- site quality;
- production data for a range of (good, medium and bad) years; and
- data from several seasons, to take annual variation into account.

Few NWFP yield models in the tropics use these factors. Instead they are typically very simple. The use of more complex methods has the potential to bring great improvements to predicting yields of NWFPs, particularly for fruit.

3.3 Measuring growth and production rates

A little about growth and productivity studies.

Inventory data provides snapshot information about the distribution and abundance of a resource species. Implementation of sustainable management plans also requires reliable data on the dynamics of the species, including information collected over long time periods on:

- population dynamics – recruitment, death rates, migration;
- growth rates and patterns;
- productivity; and
- impacts of harvesting on the species being harvested.

Methods used to determine growth and productivity for NWFP management are few, varied and mostly short-term studies. Most are based on forestry methods, and are only really suitable for trees and perennial plants – very few are designed specifically for NWFPs. Notable exceptions are for berry yields in Scandinavia (e.g. Case study 9). This section briefly describes the main types of method used for NWFPs.

Using permanent sample plots

For trees

Permanent sample plots (PSPs) are the most common way of monitoring tree growth and yield. Data from such plots are used for predicting and modelling timber yields. The PSPs are essential for use with long-lived trees where timber accumulates slowly. In several cases NWFPs have been enumerated in PSPs, and in some studies the PSP protocols have been adapted for NWFPs by:

- including phenological observations – i.e. of seed and fruit yields;
- focusing on early establishment rather than long-term growth; and
- using shorter time periods and seasonal observation to observe fruiting.

Using PSPs for timber. **All individual trees are tagged, mapped, identified and measured at periodic intervals (2-5 years) over long periods of time (+15 years). The aim is to quantify growth throughout the lifespan of the trees. In practice, the focus is on the growth of established trees, and observations of early growth and fruiting are often omitted.**

Further PSP reading:
Adlard, 1990; Alder & Synott, 1992

The use of PSPs has been adapted for fruit producing neotropical trees, palms and shrubs. Most have basically similar protocols (see Box 3). The protocols tend to focus on a single species, either because it is the only one in the stand, or the only one of interest. This is different from most timber PSPs, which include all species to provide a wider understanding of the dynamics of the forest as a ecological community, and to pre-empt changing demands for species.

Box 3: Permanent sampling plots (PSPs) protocols used for fruit production

Studies on Amazonian fruit from trees, shrubs and palms.
Sampling design: single plot subjectively located in dense stands of target species.
Plot configuration: arrangement of 20x20 m contiguous subplots into a 1 ha square or rectangle.

Enumeration:
Adult trees tagged, mapped and measured for diameter and height.
Seedlings counted in a number of random 1 m^2 quadrats within main plot and measured for height.
Phenology – direct observations of small numbers of tagged trees spread across size range at frequent (weekly) intervals.
Fruit – several protocols including fruit marking *in situ* and ground level traps observations repeated at frequent intervals (weekly).
Study period: one-to-two year study (though the intention is that several will be longer-term studies).
(Peters *et al.*, 1989; Peters, 1990; Peters & Hammond, 1990; Peters, 1996b)

For non-tree products

PSPs have also been used for non-tree NWFP species (e.g palms as in box 4), usually using plots already in place –use of subplots for sampling NWFPs inside the PSP is common for focusing on seedlings and saplings, as well as for looking at fruiting and seeding of adults.

Box 4: Using permanent sampling plots (PSPs) for palms in Mexico

A study of a single palm species in Mexico used data from biannual observations over seven years. It recorded mortality at all stages, and used large numbers of replicates (50 samples) on three sites (Piñero, 1984).
Similarly, a small-scale study of growth and reproduction of a Mexican palm recorded data from biannual observations over four years on three sites (Oyama, 1990).

New developments

There is as yet few PSP systems being developed specifically for NWFPs. Users of PSPs for NWFPs should note the long experience of plant biologists, ecologists and foresters in developing effective, new systems for NWFPs. An important consideration is use of an appropriate interval for re-measurement – this should reflect the seasonality and longevity of the resource species.

Comparing harvested and non-harvested sites

Further reading: Cunningham, 2001

This method uses observations at paired sites, often using PSP style plots. The paired sites should be of similar conditions (vegetation, topography, etc.), with one site having been harvested while the other has not. Ideally, there should be several matched pairs of sites in the study. This allows statistical testing of differences between harvest and non-harvest regimes, but may not allow analysis of different levels of harvest or different types of management practice. Table 10 below gives some examples, but note that most of these have weaknesses - including insufficient replication, short-term studies and subjectively located plots. Alternative designs pair plants rather than plots and consider harvesting impacts on the resource populations.

Table 10: Productivity studies undertaken on paired study sites

Author	***Product, location***	***Sites***	***Sampling design***	***Replicates***	***Duration***
Waters *et al.*, 1997	Truffles, California	Two sites representing old growth & mature plantation	Systematic	Four plots at each site	2 years
Olmstead & Alvarez-Buylla, 1995	Palm leaves, Mexico	Four sites representing harvested and unharvested secondary forest	Subjective	No replication, one plot per site	2 years
Runk, 1998	Palm leaves and seeds, Ecuador	Three management regimes stratified by degree of inundation	Subjective	No replication, one plot per site	1 year
Konstant *et al.*, 1995 & Sullivan *et al.*, 1995	Palm, Namibia	Two sites representing high and low human and livestock densities	Systematic	Ten plots at each site	Not reported

Experimental harvests

This method allows the researcher to test different harvesting levels and thus assess the impact of different management practices.
Different harvest rates are applied to different plots. The results are compared to each other and to a control, where there has been no harvesting. This is the most direct way to assess the impact of NWFP harvesting on the population and has been used for a range of heavily exploited species. An example is shown in Case study 10.

Case study 10: A harvesting impact study

A study in Great Smoky Mountains National Park in the United States of America responded to concerns about the casual harvesting of 'ramps' (*Allium tricoccum*).

Three sites were selected according to the ease of access, abundance (at least 15 m² with 20 plants/m² and not regularly harvested). Fifteen 1x1 m plots (three replicates of five treatments) in a non-linear arrangement at each site. Maximum leaf width of largest leaf of each plant in plot measured (leaf width = bulb size). Five harvesting treatments: control, 25, 50, 75 and 100 percent harvesting. Plants harvested without bias using traditional methods. Leaf widths and flower/fruit production of remaining plants and recruits measured for 4 years post-harvest without further harvesting. Harvest technique: Three replicates of three 0.5x0.5 m plots established at one site. Plants harvested using three methods; control, complete removal and partial removal of plants. All plants too small to have been harvested removed from plots to avoid counting as regeneration in subsequent years.

(Rock, 1996)

For all harvest comparisons, standard experimental procedures should be followed and attention paid to ensuring sufficient replication and use of a control. A control is especially important as there is likely to be a high level of uncontrolled variance between plots in the first place. Protocols are typically purpose made for each resource species.

Measuring individual plants on several occasions

This method uses repeated measurements of individuals which are not inside permanent plots. Individuals are marked, and productivity measured regularly to determine growth over a relevant period (i.e. a month, season or year - depending on the species or product being measured). Case study 11 is an example. To be able to extrapolate total yield from this, it is important to have an estimate of the total size of the population.

Case study 11: Palm leaves in southern Africa

Two areas of dense palms, with a high possibility of commercial harvesting, were selected because they were easy to find and access. A number (16 and 34) of palms were marked in two sites and grouped into three size classes. Leaf lengths of each palm were measured at monthly intervals. Growth was calculated for each size class as the annual production of new leaves, defined on the basis of leaf length.
(Cunningham, 1998)

This has *advantage*s over using actual PSPs:

- adequate numbers of trees can be rapidly identified, whilst there is no guarantee of getting adequate numbers of samples in plots;
- there is no need to maintain permanently marked plots, making it low cost and straightforward; and
- can be used for animals through marking and re-capture, but is rarely used as capture is often difficult.

Key point: **It is critical that reliable methods of selecting sample individuals are used. Ideally, random selection should be used, using either stratification (for example, by size) or using nearest-neighbour methods (selecting the nearest individual to random points).**

Disadvantages include:

- a lack of detailed information about the environs of the samples (e.g. about density of competing vegetation); and
- sampling is at risk of being opportunistic and subjective, which is poor from a biometric point of view.

This method can be useful where the resource species is widely scattered and easily observed, and where interactions with other vegetation are not important. It is often used in farm-bush and savanna situations.

3.4 Determining sustainable harvest levels

The complexity of 'sustainability'

Sustainability is a complex concept with many interpretations, ranging from idealist definitions to practical guidelines.

Defining 'sustainability'

A rather idealist definition for a sustainable NWFP harvest is:
"*If the harvest has no long-term deleterious effect on the reproduction and regeneration of populations being harvested in comparison to equivalent non-harvested natural populations. Furthermore, sustainable harvest should have no discernible adverse effect on other species in the community, or on ecosystem structure and function*." (Hall & Bawa, 1993)

However, it is virtually impossible to remove anything from natural forests without creating some noticeable change. A more pragmatic approach to sustainable harvesting might require there to be "*no loss in species and no irreversible changes in ecosystem processes*" (Boot & Gullison, 1995), but even this is difficult to demonstrate.

Practical interpretations of sustainability for timber management include:

- allowable harvest levels should not exceed a level that can be harvested from the population in perpetuity without damaging its vitality; and
- annual harvest should be constant and available in perpetuity.

Sustainability and NWFPs

Further reading: Cunningham, 2001

Even for timber where growth rates are slow and there is considerable experience of sustained yield management the attainment of a relatively constant level of production is difficult. The search for sustainability for NWFPs is even more complex:

- there is often strong variability between production from year to year (e.g. good fruit crops one year, poor the next); and
- extensive, regulated management is unusual.

Working out what is a 'sustainable' harvest for many NWFPs remains problematic. Thorough understanding of their productivity must be interpreted from ecological and harvesting studies. These involve determining the rates and patterns of variation in recruitment, growth, mortality, and reproduction, and how these patterns relate to environmental and management changes.

There have been few methodological developments for determining sustainability, for several reasons:

- a common assumption is that traditional management practices are sustainable;

- available resources are often limited and seldom directed towards doing biological research on NWFPs; and
- implementing sustainable management is perceived as costly and infeasible, so developing such systems are not prioritized.

Population studies and assessing harvests

The studies that have been done to try to work out sustainable yields have used a range of approaches, including:

Looking at population dynamics – biological approaches use simple matrix models or 'rules of thumb' based on population dynamics. If sufficient data on birth, death and growth rates are available, then these approaches can identify the theoretical upper limits of sustainable extraction, i.e. the total productivity.

Matrix models predict future populations using probabilities to calculate the likelihood of individuals surviving, growing, dying or reproducing.

Establishing *appropriate harvests* – look at the impacts of harvesting on the ecosystem and economic returns from the forest. Combinations of resource-based assessments and socio-economic surveys are not uncommon, with a focus on harvesting and revenues, rather than biologically sustainable harvesting levels.

A step-by-step methodology incorporating all these approaches might be a helpful start for determining sustainable harvests. One proposal (Gould *et al.*, 1998) is to:

- delineate the current supply area;
- determine current supply;
- estimate growth and yield or target species;
- determine current demand;
- compare short-term supply and demand, and evaluate management options;
- assess secondary ecological effects;
- repeat the process for future time periods; and
- summarize results.

Some of the best examples of determinations of sustainable yield for NWFPs are again in north and eastern Europe for berries – despite harvesting rates being as yet far below available yields (Rutakauskas, 1998; Saastomoinen *et al.*, 1998).

Assessing how close a species is to overexploitation

Identifying species at risk

The 'rapid vulnerability assessment' (RVA) method collects information to identify species, resources or sites that may be at risk of overexploitation. It was developed as a quick way of collating both scientific and indigenous information about a resource species, and has been used to recommend whether or not that resource species is suitable for harvest.

Further RVA reading: Cunningham 1994, 1996a, 2001

Indigenous and scientific information must be integrated, with matched local and scientific names making the link.

The assessment is made in several stages:

- standardized field sheets are used to *collect information* for each species;
- information is evaluated according to *sustainability criteria* drawn from ecology, socio-economics, and economics – some examples are shown in Table 11; and
- each species is then assigned a management category from a selection of eight, each with a set of *management recommendations*.

Information: life-form, habit specificity, abundance and distribution, growth rate, response to harvesting, parts used, patterns of selection and use, demand, seasonal harvesting, traditional conservation practices, commercialization.

Table 11: Criteria used in rapid vulnerability assessment

Criteria	***Potential for sustainable use***	
	Low	***High***
Ecology	Low abundance	High abundance
	Slow growth	Fast growth
	Slow reproduction	Fast reproduction
	Sexual reproduction only	Vegetative reproduction
	Habitat-specific	Habitat non-specific
	High habitat diversity	Low habitat diversity
	High life form diversity	Low life form diversity
Life form	E.g use of grasses is likely to be more sustainable than trees	
Parts used	E.g the use of leaves/fruit/stem is more sustainable than of the roots (if damaging) or the whole plant.	
Method of harvesting	Potential for sustainable harvesting is higher if size/age classes are not selected – harvesting of only one particular age or size class can place pressure on the whole population.	

Table taken from Watts *et al.,* 1996

Is it biometrically reliable?

The comprehensive requirements of RVA provide a useful checklist for collating information from a wide range of sources, and provide information that is available for later updating and modification, for example during inventory. However, it does not:

- guarantee good information – much is often lacking;
- include inventory activities – it is a rapid 'first look' at a species; and
- quantify information – it is subject to interpretation.

Whilst it may seem complicated at first, experience suggests that new users of the method can usefully develop scoring systems for the criteria and simple and transparent ways of translating these into management categories. Such evaluation systems are a very informative first look at the problem and for selecting candidate species for commercialization.

Adjusting harvest levels if they appear unsustainable

A simple and attractive method has been proposed for periodically adjusting harvest levels to ensure sustainability, using minimum regeneration levels as baseline (e.g. Peters, 1994, 1996a). Box 5 gives more details of how this works, and Figure 4 illustrates basic principles of the cycle.

Box 5: Harvest adjustment method for assessing sustainable yield from trees

Regeneration survey. Network of permanent, small (5x5 or 10x10 m) regeneration subplots in PSPs for larger trees. Total number of desired seedlings and saplings of the required species less than minimum diameter for inventory tallied into four size classes and recorded. The initial data represent the *threshold values* by which sustainability is evaluated. These plots are enumerated at five-year intervals. If at a subsequent enumeration seedling or sapling density drops below the threshold value, the harvest intensity is reduced. If levels rise then harvesting levels can be increased. Successive approximations are used to try and stabilize seedling and sapling densities preferably at the original threshold level.

Harvest assessments. Visual appraisals of the behaviour and condition of adult trees conducted along with harvesting activities. During routine harvests the health, flower and seed abundance and harvesting impacts are recorded for marked trees in yield plots. Information collated and tracked for the individual trees.
If specific problems are identified, e.g. loss in vigour, increased seed predation, drop in productivity, etc. this should also initiate harvest adjustments.
(Peters, 1994, 1996a)

Care is needed with this method, due some of the assumptions made in it:

- It assumes that constant annual yields are possible and desired.
- Threshold regeneration density is determined from only one season's sampling, with the assumption that this can be the constant. Given that reproduction notoriously varies from year to year, this may be highly inaccurate.
- It gives no guidance on how to determine initial harvesting level, and seems to assume that current levels are an approximation of the sustainable yield.
- It assumes that the damaging effects of overharvesting can be observed over short time periods. However, for long-lived species dependent on natural regeneration, effects may only be apparent after years of close observation.

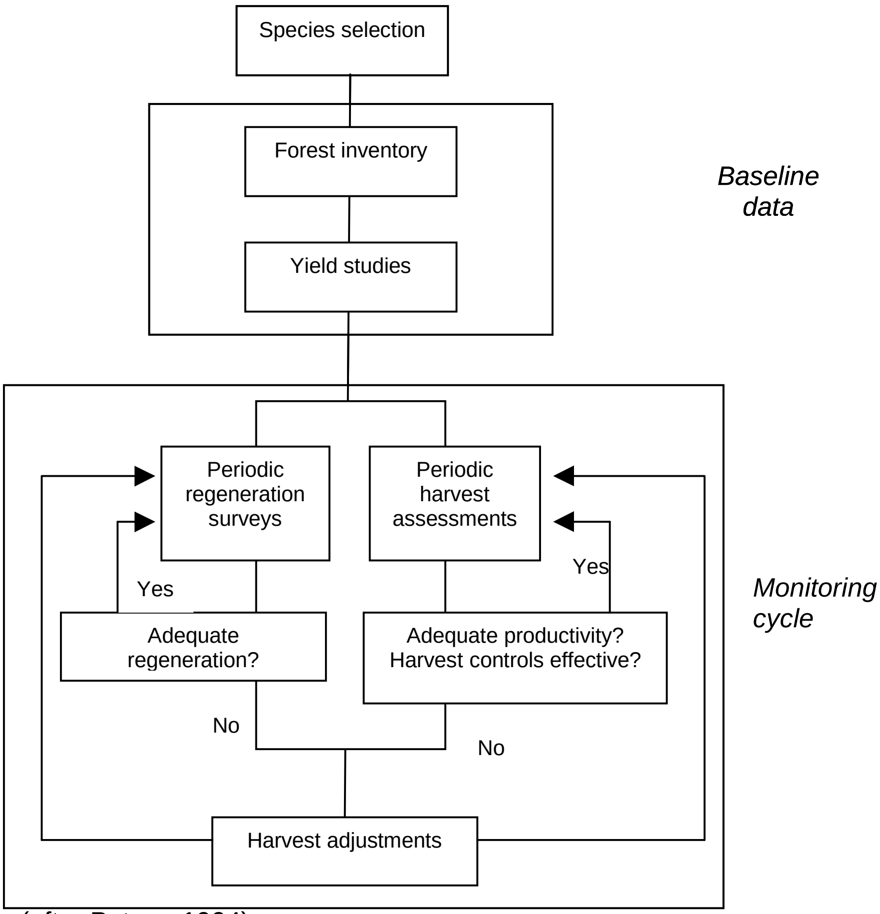
This type of method could be improved by introducing the scale and pattern of variability in productivity. This would require observations over a number of years, and could be complemented by climatic data, especially rainfall. This would provide a basis for developing yield prediction models such as those mentioned earlier for berries in northern Europe. Appropriate harvest levels could then be decided relative to:

- long-term yields, future population level, or a forecast of annual yields;

or

- current demands, with an understanding of impacts on future yields.

Figure 4: Flow chart of basic strategy for establishing sustainable harvest of NWFP plant resources



(after Peters, 1994)

Using models to predict future yields of plants

Long-term sustainability of an exploited species depends on the impacts of harvesting on its whole life cycle. Using models that represent life-cycle dynamics can contribute to developing reliable estimates of sustainable harvest levels.

What are life cycle dynamics?

Every individual goes through several life-stages from birth or germination to maturity, old age and death. For each stage, models can apply different rates of: growth; fecundity/new births; and mortality/deaths. Models use these data to predict the state of future populations under different conditions.

Using life cycle dynamics

Life cycle models are used in forestry and wildlife management, but have only recently been used for working out sustainable harvesting levels for NWFPs. The most commonly used NWFP population model is the 'matrix method' (Peters, 1996a). It predicts the number of individuals in different age or size groups (the 'size-class structure') in future populations under different harvesting regimes, based on the present population and estimates of birth, death and growth rates in each age or size class.

How does a matrix model work?

It works by jumping forward in fixed time intervals, usually one year. First, the population is divided into size (or age) classes. The structure of the current population is the number of plants in each class, determined from the field survey data. The model uses life-cycle dynamics to estimate the probabilities of each individual's chance of surviving from one life-stage to the next over given time periods. This is done for several years to predict the future population structure. Box 6 provides an example to explain such a model. The sustainability of different harvesting regimes is tested by changing the reproduction and death rates (because of harvesting) used in specific size classes in the model.

Box 6: An example matrix model to work through

Looking at a non-annual plant, the size classes might be: 1=seeds; 2=small, non-reproductive plants; 3=larger plants producing some seed; 4=fully reproductive plant.
Time steps are in intervals of one year, and year 1 is 'now'.
Example calculations:
The number of plants in size class 3 in year 2 is the proportion of those now in class 2 which survive and grow fast enough to enter class 3 in one year.
The number of seeds produced by each size class during year 1 gives the number of seeds in class 1 in year 2.
Germination rate predicts the number of seeds (size class 1) in year 1 which will be in size class 2 in year 2.
The transition matrix represents this data and calculations. The probabilities used can be altered to represent different harvesting levels and regimes.
The state matrix represents the population structure at a given time.

"State matrix"

Year 1
40
30
10
6

x

"Transition matrix"

Size Class	1	2	3	4
1			2	4
2	0.5	**0.3**		
3		0.3	**0.2**	
4			0.5	**0.5**

=

Predicted future state

Year 2
44
29
11
8

Probability that individuals will grow into the next stage

Probability of individuals remaining in given stage after one time interval

Seed production of an individual in this size class

Biometric adequacy at risk

There are several areas which reduce the usefulness of these methods.

- The models require information from PSPs, including the level of flowering, seed production and dispersal, germination and predation. This kind of information requires frequent observations, ideally over several seasons to allow for variation. As noted earlier, few PSPs for NWFPs have been studied for more than one or two years, and rarely provide biometrically reliable data, but rather a general indication of rates. This means that often the basis of life cycle models may not be reliable.
- Most of the impacts of different management methods are hypothetical, and have not been demonstrated by observations or experiments.
- They assume that mortality, growth, and regeneration rates remain constant, unless changed by management. In reality they will also vary due to other factors, such as forest fires or climate variations. An alternative approach is population viability modelling, which attempts to predict whether the species can withstand chance events over long periods. This has not yet been used in NWFP assessments.

Further reading on sampling issues for population dynamics: Bowden *et al.*, 2000); Gagnon, 1999. Also see USGS. Biodiversity monitoring programme Web site: www.mp1-pwrc.usgs.gov/powcase/index.html

Models for assessing the sustainability of hunting

Managing for a sustainable yield of animals is clearly different from doing so for trees, and different methods have been developed by wildlife managers. Population dynamics are different as survival is generally density dependent and there is a maximum carrying capacity on any area of land. Carrying capacity is the maximum number of animals that can populate an area. At this point, births are equal to deaths and the population is stable. Above it, deaths increase and the population decreases. Below it, the population is growing. If the population falls too low, breeding will not occur. There is an optimal population level which ensures maximum birth rates and survival of new individuals. This is known as the maximum sustained yield (MSY).

Further reading on MSY: Caughley and Sinclair, 1994

Direct estimation of MSY is difficult – again because of the lack of detailed data on population dynamics, and how they respond to changing animal density. With this in mind, a simplified approach has been developed and has become popular (Robinson and Redford, 1991, see Box 7 for more details):

- determining population growth rate and establishing population density, in order to
- estimate overall annual production, then
  - ➢ setting sustainable harvest at 20-40 percent of the annual production, depending on the species' longevity.

This method has limitations:

- it gives only an initial assessment of hunting impacts, and should not be used for setting quotas; and
- it assumes animals do not die before they reproduce, thus overestimating population growth. Including mortality in young animals highlights a greater level of overexploitation than previously estimated.

Models using optimal foraging theory to simulate the impacts of hunting strategies on wildlife populations may also be useful. One example (Winterhalder & Lu, 1997) simulates resources species, ranking them according to which ones hunters would prefer. This approach takes account of: differences in local preferences; availability of different resource species; and different types of hunting practices. In this way it calibrates for real,

What is optimal foraging theory? This describes hunting choices in terms of the costs and benefits in energy of a particular hunting strategy to the hunter.

multi-resource situations, but may be expensive and complex to set up with real data.

Box 7: Method for assessing sustainability

Calculate maximum production in animals km^{-2}

Model variables (actual density measured; the other parameter values estimated or taken from literature).
Actual density (*D*) – numbers per square kilometre.
Predicted density (D_2) – predicted from linear regression of $\log_{10}$ population density against $\log_{10}$ body mass by dietary categories.
Intrinsic rate of natural increase (r_{max}) – highest possible without any limitations estimated using Cole's (1954) equation:

$1 = e^{-rmax} + be^{-rmax(a)} – be^{-rmax\ W+1}$
where:
a = age of first reproduction,
w = age of last reproduction,
b = annual rate of female births.

Cole's formula assumes no mortality (error small if mortality is not significant before age of first reproduction).

Maximum finite rate of increase (λ_{max}) – exponential of the intrinsic rate of natural increase (e_{rmax}) and is the increase in population size from time *t* to time *t+1*.

Production (P) – addition to population = (birth + immigration) – (death + outmigration) + survival (to end of specified time period i.e. 1 year).

Assume:

- Predicted densities are higher than observed and that the predicted densities are close to, or at carrying capacity for the species.
- Maximum production will be achieved when the population density is at 60 percent of carrying capacity. Subtracting 0.6 D_2 maintains the population at the same density.

Production $P_{max} = (0.6\ D_2 \times \lambda_{max}) - 0.6\ D_2$

Estimate of potential harvest

It is assumed that the average life span of a species is a good index of the extent to which the harvest takes animals that would have died anyway. Thus harvest levels are set according to the longevity = age of last reproduction of the species: for very short-lived spp, < 5 years, harvest levels = 0.6 P; for short-lived species, between 5-10 years, harvest = 0.4 P; long lived spp, > 10 years, harvest = 0.2 P.

Most significant assumptions are:

- Model assumes density dependence in production, i.e. production increase with decreasing density such that it is at a maximum at 0.6 of the carrying capacity.
- The proportion of production that can be harvested without depleting the standing population. Indirect confirmation could be to compare the weight distribution of harvested and non-hunted populations, if they are the same then can argue that hunting is taking animals that would have died anyway and hunting can take a higher proportion of total production.

NEED to have the following to use this method: average body mass, food preferences (if using predictive equation), age of first reproduction, age of last reproduction, and annual birth rate of female offspring (average population density for study site – if not using predictive equation).

Model should NOT be used to generate single species harvesting schedules. It CAN provide a first assessment of the impact of hunting on wildlife populations.
(Robinson & Redford, 1991)

3.5 Monitoring the success of management actions

Why monitor?

Monitoring allows you to assess whether the interventions made have been successful and how they could be improved. It should always be part of the management process. Ideally monitoring should begin *before* any changes are made in order to provide a baseline against which to assess success of management actions.

Measuring change over time

Reliable assessments of changes due to management actions require quantitative and biometrically rigorous inventory. However, less direct approaches – for example, market surveys, harvesting records, forestry indicators – are useful for bringing attention to potential problem areas and informing management decisions.

There is no specific methodology for resource monitoring – all of the preceding methods can be used. The difference is that the inventory is repeated at intervals, often every year or five years. What is important is the ability of the inventory design to separate real trends from random errors in estimates. This is only possible if sampling errors are low each time the resource is measured. This requires large numbers of plots, which could be too expensive. The expense of rigorous monitoring means that it has not often, if ever, been used for NWFPs in the tropics. Instead, efforts have focused on developing simple and cheap indicators.

Using indicators

Whilst they are attractive, care must be taken with the choice and measurement of indicators. In particular there is a risk that they might not adequately reflect the state of the resource. Notable problems include:

- they can be difficult to measure – e.g. regeneration assessment used to monitor the state of the whole population (Peters, 1994);
- ensuring that the indicators are representative of the whole resource – e.g. use of market records, without knowledge of where the product is sourced from, may reveal nothing about local resource depletions (Milner-Gulland and Mace, 1998); and
- failure to use the indicators to refine or adjust management practices – there is little evidence of this happening, but it may be due to the lack of long-term monitoring programmes in place for NWFPs.

Further reading on indicators: Lindenmayer *et al.*, 2000

The two main approaches to monitoring the impact of NWFP extraction are:

- forest-based: monitoring the health of the forest and/or its resources remaining *after harvesting*; and
- market-based: monitoring the size and quality of *what is harvested* (e.g. Watts *et al.*, 1996).

Ideally, both should be used. Participatory monitoring at the local level is also useful to improve the sharing of understanding about the resource between regulators and harvesters.

Looking at what is left after harvesting

Further reading on harvesting impact studies: Cunningham, 2001

In forestry, PSPs have typically been used to monitor the impacts of harvesting on future yields and on other elements of the forest environment. The NWFP monitoring schemes can be similarly established, but it is important that they are done according to strict biometric principles. This will increase the likelihood of the data being representative and useful for extrapolation over larger areas. As yet there are few established protocols.

In order to allow the impact of harvesting to be properly measured, there should be a non-harvested 'baseline' that the indicators can be compared against. This is often neglected, but should take the form of a pre-exploitation survey or use comparisons between harvested and non-harvested sites. Important considerations include:

- ensuring that baseline surveys are done as early as possible and *before* management changes are made;
- verifying that they efficiently measure the relevant indicators of forest condition and productivity;
- linking social (PRA methods such as the 'walk-in-the-woods') to the more technical (quantitative, mapping) approaches; and
- limiting enumeration to resource species or indicator species rather than trying to measure everything – this is the preferred option for species harvested from outside forests i.e. in farmlands.

Benefits of local monitoring. Data collected far from the forest is the less likely to reflect what is happening in the forest. Resource based information is therefore likely to be closer to the truth than Customs and Excise records.
In addition, records measured after the product has left the village cannot link the product to its harvest location.

The PSPs for NWFPs have often been seen as high-technology, high-input methods only useful for relatively small, intensively managed areas, such as National Parks (e.g. Sheil, 1997).

Measuring what has been harvested

Records of harvests are a popular, quick and straightforward way of monitoring NWFPs. They can be quantitative (absolute weights and measures) or qualitative (relative measures – lots, few, etc.) measures of the collected product. Case study 12 gives an example of using harvest records.

Case study 12: Monitoring harvests in a Ugandan National Park

In the past, National Parks staff in Uganda have monitored harvests using records official quotas. Forest-level monitoring plots are now anticipated in areas of heavy harvests. It is planned that information for monitoring of participatory management agreements for NWFP use should be collected from three sources.

- resource users – involved with collecting information on resource harvests, illegal activities and the state of the resource;
- patrol rangers - as part of their routine activities; and
- formal ecological monitoring - PSP plots established for species indicated by the communities.

Monitoring Ensuri (Smilax kraussiana) in Rutugunda Parish, Bwindi National Park. Park staff went with collectors to traditional collection sites in the forest. Each collection site was marked with a red flag and the date and product harvested was noted. Ensuri is a liana from which ground runners are harvested. Harvesting followed traditional practices which are apparently sustainable - the collectors have reported no change in extent of any of the patches. Each bundle of collected product was uncoiled and the park staff measured the length, number of nodes and middle diameter of each vine. Records are kept against the names of individual collectors.
(Watts *et al.,* 1996)

Recording can take place at various points in the supply chain:

- at source in the forest;
- in village, local or national markets; and

- at the international trade level, as Customs and Excise or CITES import/export statistics.

Harvest records can be used for a variety of purposes:

- market-based records can put a monetary value on the product, which makes them useful to market researchers and socio-economists;
- detailed harvesting records are often used to determine hunting/collection quotas for the next season, generally supported by direct population assessments; and
- as an indicator of change in resources they can highlight the need for more detailed studies.

Harvest records are the most widespread form of NWFP resource data. However, there are important points for caution when using them:

- It can be difficult to distinguish whether the product in the market is from a wild or a domestic population. If the proportion of domestic product is overestimated, there will be an underestimate of amounts harvested from the wild population, which can make management or quota decisions inappropriate.
- Harvest records do not indicate changes in the way products are harvested. Two different harvesting methods may produce the same amount of product in the market, but one may be destructive to the resource and not be sustainable, whilst the other harvests sustainably. This is not uncommon, particularly where outsiders have been drawn into an area for valuable commercial products.
- Their use tends to assume that changes in harvest levels do actually reflect changes in the resource. This is not always the case – many factors may influence harvesting levels.
- They often do not account for changing social, market or price factors. For example, a product in high demand will remain in the market even if the resource is in decline - but the price will increase to reflect the scarcity. Thus, measuring the amount in the market can prolong overharvesting until the supply collapses. Case study 13 provides a further example. If market measures are not used in conjunction with resource assessments, it is necessary to ensure that they really are sensitive to and calibrated against actual resource availability.

Case study 13: The influence of socio-economic factors

American ginseng harvesters in Virginia, United States, must report sales every 30 days during the harvest season. Changing levels in sales are assumed to represent changing levels in the population. In reality, changing levels in the trade of ginseng is more closely related to changing patterns of employment among the harvesters – when unemployment is high, more is harvested; when people have jobs, harvests go down as they have less time and don’t need the extra money. With a predominantly rural and poor population this is not unusual.
(Bailey, pers. comm.)

Local participation in monitoring

It is important for the local people who are using the NWFP resource to understand the basis for quotas and other management prescriptions in order to make the management credible to them. Their participation in resource monitoring can be an important strategy in gaining support for management prescriptions amongst harvesters.

Local people can also adapt and improve methods through their knowledge of the resource. Using indicators of resource condition chosen by local people can increase their commitment to both the monitoring, and to consequent management adjustments.

Appropriate methods can be critical in achieving the objective of continued monitoring by local people. This accounts for the widespread interest in developing participatory monitoring techniques which are appropriate to local capabilities.

3.6 Participatory approaches

Many NWFP studies have focused strongly on local involvement for improved and sustainable livelihoods.

Involving local people

Further reading on participation: Ingles et al, 1999; Carter, 1996

Many practitioners argue that if an NWFP inventory is to contribute to improved sustainability of local livelihoods then local people should participate actively at all stages of decision-making – deciding whether do the inventory, its objectives and design, fieldwork and data analysis. The reasoning is that participation can:

- be an opportunity for a two-way learning process;
- help to generate a sense of responsibility for the environment;
- help people to understand how and why management decisions are made, making decisions more acceptable locally in the long term, and making the whole process more sustainable;
- help people see the potential economic benefit of management changes and thus ensure those management practices are adhered to;
- help to resolve conflicts between managers and harvesters of the resource by building trust and securing access (e.g. Watts *et al.*, 1996; Pilz & Molina, 1998); and
- ensure that the data collected will actually be useful for management.

Levels of involvement vary, as noted in Table 12. Establishing who will own and have the 'intellectual property rights' to the information collected is becoming increasingly important and should be decided early in the process.

Table 12: Degrees of participation - from co-option to collective action

Mode of local people's participation	***Type of participation***	***Outsider control***	***Potential for sustaining local action and ownership***	***Role of local people in research and action***
Co-option	Tokenism – representatives are chosen but have no real input of power	***********		Subjects
Co-operation	Tasks are assigned, with incentives; outsiders decide agenda and direct the process	*********		Employees/ subordinates
Consultation	Opinions asked; outsiders analyse information and decide on a course of action	*******		Clients
Collaboration	Local people work together with outsiders to determine priorities; outsiders have responsibility for directing the process	*****	***	Collaborators
Co-learning	Local people and outsiders share their knowledge to create new understanding and work together to form action plans; outsiders facilitate	***	******	Partners
Collective action	Local people set and implement their own agenda; outsiders absent		*********	Directors

(adapted from Cornwall, 1995, in Carter, 1996) ** indicate the relative strengths

Use and value of local knowledge

Key message: **Local knowledge can provide useful information about the resource, but verification of the data is usually**

Local knowledge can be useful in designing and implementing a NWFP inventory for various reasons, as highlighted in Case study 14 and noted in Table 13. Participation can improve the efficiency of the inventory and optimize local benefits. Enhanced efficiency can come from:

- local knowledge providing basic information about a resource (for example, through RVA methods described in 3.4); and this then
- helping to decide whether an inventory is actually necessary, and if so what kind of sampling design and enumeration methodology are appropriate.

Case study 14: Using local knowledge to design and implement an inventory for Pacific yew in British Columbia

An interesting North American study that contains some lessons for tropical NWFP assessment is the work that has been done in Canada on inventory for Pacific Yew (*Taxus brevifolia*, bark harvested to manufacture a breast cancer drug). As a preliminary to large-scale inventory a decision needed to be made about which of two available forest maps (an ecosystem map and a forest cover map) would provide the best stratification and whether local knowledge could be used to select which strata should be sampled for yew. A questionnaire was sent to local foresters and ecologists to elicit their knowledge about the occurrence and distribution of yew among the mapped units on each map. The questionnaire data were compiled and used to identify high and low probability strata for yew on each map. Field sampling was weighted so that 80 percent and 20 percent of samples were placed in high and low probability strata respectively. Analysis of the data showed that overall estimates of yew populations produced using either map as a basis for stratification were not statistically different, but the standard errors for the ecosystem map were much smaller indicating that it is more precise and hence a more efficient stratification. The validity of the high and low yew occurrences strata as determined by the questionnaire was not challenged or tested in the analysis of results. Presumably this is because they were confirmed as accurate. If this is the case then the local knowledge was reliable even though a diverse range of individual opinions on yew distribution were expressed by the questionnaire respondents. This study demonstrates a means of using local knowledge in the context of a biometrically sound sampling scheme that does not compromise its integrity and may offer useful lessons for the use of indigenous knowledge in tropical NWFP inventory. (Jong & Bonner, 1995)

Table 13: Examples of areas of local knowledge and their possible uses in NWFP inventory

Local knowledge	***Use in inventory***
Species identification	Local tree spotters can be useful in the field (but see section below on taxonomy)
Important economic species	Can highlight species to include in inventory (e.g. RVA)
Vegetation classification/description	Can be used for stratification
Micro-climate types and distribution	Can be used for stratification
Soil types and distribution	Can be used for stratification
Harvesting techniques and frequency	Can improve enumeration methods and frequency
History of availability	Helps to prioritize species to include according to the level of threat or change
Current estimation of availability	Helps to prioritize species to include – and influences the decision on whether inventory is necessary
Ecology and distribution of species	Helps to decide on the most appropriate sampling method
Human interaction with environment (e.g. existing management)	Influences inventory objectives and design
Forest and resource value	Influences management objectives and hence inventory objectives
Socio-economic factors affecting NWFP management	Influences decision on whether to have an inventory and its objectives and influences interpretation of inventory results

Note that this table is not comprehensive and that the above uses of local knowledge are case specific, i.e. the types of local knowledge listed cannot always be used in inventory in the manner described.

To ensure that local knowledge is helpful in NWFP inventory, care should be taken to:

- ensure the local knowledge is collected and analysed using suitable methods and that it reflects reality; and
- design the inventory to investigate areas of doubt, and to allow the flexibility for review after the data collection has started.

Combining local and scientific knowledge

Getting the name right. **Consultation with herbaria experts from national herbaria or leading botanical gardens is often needed to identify samples and apply the correct botanical name. Specimens must be prepared properly and identification can take months, even years. Whilst this can be costly and time consuming, it is the most reliable way of naming. Developing links with herbaria helps ensure competence in collecting samples.**

Further reading: Cunningham, 2001

The gap between local knowledge and scientific knowledge cannot be bridged unless local and scientific names can be matched. The NWFP surveys tend to use local names in data collection – rather than codes or Latin names – because it is easier for local staff and collaborators to record the names with which they are familiar. However there are some important problems in using local names this way.

Incomplete and inconsistent use of names by local informants – There is considerable variability in local names. For example, in central Kalimantan (Wilkie, 1998), less than a quarter of local names are applied consistently, and these are typically those which are of specific use to the informant or are especially distinctive. Switching between product name and individual species name is common.

Mis-match between local and scientific names – Analysis of experience in Uganda shows single local names being matched to several botanical names (Cunningham, 1996a). Local names often refer to scientific genera rather than to species (see Table 14).

Taxonomic difficulties – The taxonomic description and naming of species in tropical forests are notably incomplete, even for trees. This means that it is often not possible to give a taxonomic identity to a locally named NWFP species, and species identification can often only be taken as far as genera. This is the case even for rattans in most south Asian countries, where local names describe genera rather than species (Stockdale, 1995a).

However, it is essential to determine scientific names if information is to be compared between different areas – where different languages and local names may be used. This is difficult as few field guides or botanical keys are available for NWFPs and they require flowers or fruit (often inaccessible and seasonal) for identification. The most reliable way of verifying identifications is to collect samples during the inventory and have them identified by experts. Attempts to match names to samples later have been found to be unreliable. However, vouchering specimens in an inventory can be costly, time consuming and require skills which are not available.

Table 14: Correspondence of folk and scientific names

Correspondence	*Explanation*	*Correspondence**
One-to-one correspondence	Folk generic = scientific species	61%
Under differentiated (I)	Folk generic = two or more scientific species of the same genus	21%
Underdifferentiated (II)	Folk species = more than one scientific genus	14%
Overdifferentiated	More than one folk generic = scientific species	4%

* Correspondence of Tzeltal Maya names (n=471) taken from Berlin (1994) quoted in Martin, 1994

Some synergy between local and scientific knowledge develops informally through participatory or informal approaches. However, formal methodologies (e.g. Box 8) for dealing with informally collected local knowledge are important in order to gain a deeper understanding of the knowledge and its relationship with scientific investigations. Formal methodologies also have the potential for more objective verification of qualitative ecological information, and for improved storage and retrieval of knowledge.

Box 8: Formal methodology for linking and analysing formal and informal information

'Knowledge-based systems' have played a significant role in agriculture and are developing rapidly. They formally represent qualitative knowledge on computers. The processing power of the computer can then be applied to the representation, analysis and use of large and complex sets of knowledge. They have particular potential to be useful when integrated with numerical approaches to create integrated decision support systems. It keeps the links between 'units of knowledge' in a way that allows retrieval of overall concepts, rather than simple lists of the units of knowledge collected. However, this methodology may be of more use and relevance to researchers and development workers than it is for local people themselves, and may best be used in complement with informal methods.
(Sinclair & Walker, 1999)

The role of participation in NWFP inventory

Few would question the value of local people's participation in resource assessment. However, there is great debate about whether participatory inventory can or should be biometrically rigorous.

- Biometric methods typically require sophisticated techniques, which are inappropriate and/or undesirable for use by local, untrained people. Where participation and learning is more important than biometric rigour, it is argued that the latter can be sacrificed.
- However, non-biometric, social science techniques rarely collect information that is reliable enough to guide management decisions regarding sustainable harvesting levels. Sacrificing biometric rigour means denying that local people need reliable information or robust management prescriptions.

The risk of collecting poor data is that local people will be disappointed with the results and lose interest in the process. It is important to ensure that all risks involved regarding the reliability of the information should be clearly understood by local people and outsiders. Box 9 highlights a few examples of how local people can learn and change their methodologies - doing it for themselves will encourage learning and understanding of the process.

Increasingly, it is being realized that communities do need biometric data (for example, to provide the basis of a management plan for submission to government for approval), and sometimes there may be an urgent need for reliable information (for example, where a resource is severely threatened). In these circumstances, despite the learning opportunities of doing it their own way, it may be appropriate to suggest that the local people undertake a biometric inventory.

The challenge? To make biometric methods accessible to communities.

Box 9: Local people and evolving understanding – some examples

- Local communities might want to collect information only from areas they currently use – this is what they want to manage now. This might not help the researcher who wants to verify local knowledge about distribution and get figures for the whole species population, but the community might later decide they need wider information.
- Local people might decide that indirect measures, such as average walking time to the resource or harvesting statistics, are easier to assess. Whilst this might seem sufficient when the resource is abundant, if it becomes threatened they will find they need more information for management.

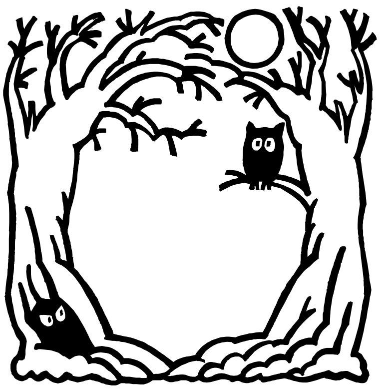
It is always important to ensure that data are simple to collect and to analyse.

This does not mean that methods and designs should be unsophisticated, but that they should be simply presented. Methods are available that allow a complicated protocol to be performed, even where literacy is low (see Box 10).

Box 10: Appropriate methods? Some examples of success

Illiteracy problems are increasingly being broken down by advances in technology – for example, the use of palm-top computers with symbols rather than words has been successful (Cunningham & Liebenburg, 1998; Cunningham, 2001), as have hand-held GPS (Stockdale & Ambrose, 1996). Use of older technology, such as mainframe computers and surveying equipment, requires much more training and may not be appropriate.

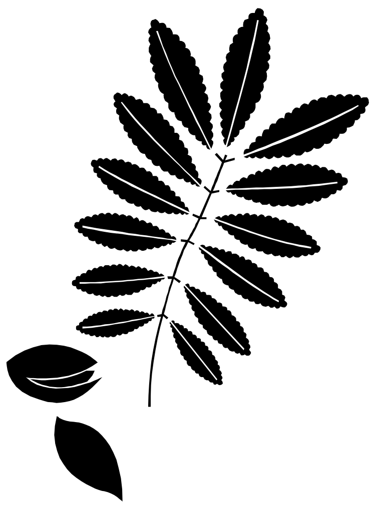
Experience and debate has shown that methods need to be adaptive to local needs whilst providing replicable, standardized data. In Nepal, the qualitative methods that have emerged from the promotion of JFM have not provided the detailed information required, and have now begun to evolve into more formal quantification of resources.



Section 4 Contributions from other approaches to NWFP resource assessment

This section looks at approaches that are typically less quantitative and assesses their biometric value and relevance for NWFP inventory. Approaches include:

- **biodiversity inventory**
- **social science techniques**
- **cultural perspectives**
- **ethnobotany and**
- **economic methods**



4.1 Biodiversity inventory

What is biodiversity inventory?
Biodiversity inventory is basically a checklist:
'a list of biological entities from a particular site or area' (Stork & Davies, 1996).

Further reading: HMSO, 1996

How is it done and used?
In general, specimens of all individuals are collected and archived in herbaria or museums - this makes the scientific names reliable. Results from biodiversity inventories are usually presented as checklists of species by family and genera for the locality. It allows comparison of data between different sites and contributes to preparation of species distribution maps.

Botanic survey is a type of biodiversity inventory that looks for landscape scale patterns. It uses many plots (fixed size or dimensionless) across the landscape, producing a list of species at various known and precise locations, though without quantification of abundance. It can help identify areas of high biodiversity and/or conservation priorities (Healey *et al.*, 1998), and data can be analysed to produce vegetation classification (e.g. Hall & Swaine, 1981), distribution maps, ecological profiles for species, and understanding of environmental and evolutionary relationships (Hawthorne, 1996).

Biometric value and relevance for NWFPs?
NWFPs are obviously a subset of all '*biological entities'*, so biodiversity inventories can provide useful information on whether any known useful taxa are present, and on their distribution. But biodiversity inventories rarely note which taxa are NWFPs, and, more importantly, only occasionally include information on abundance – i.e. how much of the resource there is present.

Recent developments tend to emphasize the importance of quantitative techniques and abundance measures for management purposes. Plot-based work can be useful if there are many replications, as this provides more quantitative data and potential for statistical analyses.

4.2 Social science techniques

What is a social science technique?
Social science techniques used in resource inventory tend to be based on participatory approaches to gain local involvement. They are more concerned with including local knowledge than providing biometrically sound information about the resource.

Social science data collection methods

As noted above, participatory approaches are useful. However, it should be stressed that social science methods are not formalized protocols, but are rather approaches to information collection and processing. As Havel (1996) puts it, each is "*… a combination of tools, held together by a guiding principle*".

Some different participatory approaches include:
- rapid rural appraisal (RRA);
- participatory rural appraisal (PRA);
- participatory learning and action (PLA);

- gender analysis;
- objectives orientated project planning (ZOPP);
- appreciation-influence-control (AIC); and
- social assessment.

Key features of these approaches are:
- involvement of multi-disciplinary researchers and methods (though rarely statisticians or inventory specialists);
- selection of tools and methods depending on the informant;
- adaptive planning throughout data collection as researchers discuss results; and
- triangulation – use of a variety of methods to cross-verify information collected in the field.

These approaches have developed over time. Earlier approaches, like RRA, tended to be extractive processes, whilst more recent approaches, like PRA, place more emphasis on local people being involved in the information analysis and problem solving elements of the process. The latter recognizes that local people are often better placed than outside researchers to analyse and seek solutions to their problems. More recently, PLA focuses less on information collection, more on local people learning from each other to promote rural development.

Further reading: Davis-Case, 1990; Nichols, 1991; Ingles et al., 1999.

There are a broad range of ways of collecting information and exploring local problems, including a range of interview types, and different activities, visual aids and games.

4.3 Looking at NWFPs from a cultural perspective

About anthropological approaches

Anthropology is the study of human origins, institutions and beliefs – i.e. ‘culture’. It includes looking at the interaction between people and their environment, including the plants they use –known as **ethnobotany**.

Internal and external approaches

There are two main approaches in anthropological methods – insider views and outsider perspectives. The two approaches are not mutually exclusive, but are rather the two ends of a continuum, and can be used together to optimize research efficiency.

External **– Looking in from outside. Categorization and organization of the environment by a non-local researcher, with definitions and rules from western science. An outsiders approach is useful when there is need for objectivity in management goals, or if some of the goals are external (e.g. specific species conservation).**

Ethnobotany is an anthropological discipline concerned with the *indigenous* knowledge of plant uses – it takes an internal approach. Other potentially useful disciplines include ecological anthropology and human behavioural ecology. These have developed methodologies for studying human use of the natural world.

The external approaches from behavioural ecology (examples are given in Table 15) are more quantitative and allow statistical analysis of hypotheses. In this way they provide a more detailed, empirical and theoretical understanding of relationships between human populations and plant resources, as well as analysing plant significance from a cultural perspective.

Table 15: Externally lead behavioural research methods

Method	***General description and purpose***	***Example methodologies***	***Uses of information***
Spatial distribution analysis	Describe and explain spatial relationships between human and resource communities	Landscape mapping and remote sensing Ground mapping Extrapolating resource production Spatial distribution of resource production and productivity	Various descriptive and analytical operations dealing with spatial relationships between human and plant communities
Human activity studies	Record the time spent at various resource-related behaviours through systematic observation techniques; compare time spent at different activities	Time and motion studies Time allocation studies	Statistical description and analysis of activity patterns of a community; necessary component of input-output studies
Resource accounting	Keep records of resource types and amounts procured or utilized by the study community during a given period	Dietary survey (weighed inventory, dietary recall, food frequency, weighted intake) Marketing survey Ethnopharmacological survey	Derive measures of the importance of different resource species and the level of exploitation pressure on these resource; necessary component of input-output studies
Input-output analysis	Cost-benefit type of analysis of different activities using time allocation and resource accounting data	Rational choice models Optimal foraging analysis Linear programme analysis	Describe or explain the interactive relationships between populations and resources

After Zent (1996)

Defining ethnobotany. **Ethnobotany has been practised since 1895, though definitions and scope have changed. Current definitions still vary greatly, but in effect, it is about the study of local people's knowledge and relationships with plants.**

Such methods, while not yet applied to NWFP inventory, are potentially useful because:

- their quantitative nature provides more biometric rigour than classical anthropological approaches; and
- methods are compatible with those in other professional fields, such as forestry, economics and commercial development.

4.4 Ethnobotany

What is ethnobotany?
Study of the interaction between people and their environment, including the plants they use.

Ethnobotanical inventory

Ethnobotanists are increasingly finding themselves as advisers in resource management. This makes it important for their recommendations to be well founded in order to avoid overharvesting of the plants in question (Cunningham, 1996b). Quantitative methods are key in the provision of best management advice. Consequently, ethnobotany is in an evolutionary state – moving from being a classical, purely descriptive method to a more quantifiable science as it acquires some of the methodologies noted above in Section 3. Table 16 highlights some of the key differences between the old and the new.

Table 16: Changing methods in ethnobotany

	Classical ethnobotanical inventory	***Quantitative ethnobotany***
Main thrust	Typically, ethnobotanical inventory has prepared lists of plant species used by different ethnic groups. Scientific naming of plants is the main priority	Transforms the traditional local knowledge into quantifiable relative use values
Advantages for NWFP inventory	The lists may provide a useful overview of the plants used by a local community	Quantification means that: • studies can be replicated – two different researchers would get the same result • it allows statistical hypothesis testing of how significant given plants are to local people
Drawbacks	There is rarely any quantitative information on level of use or abundance, with no indication of relative importance to the society Data sources may be very varied, making comparisons and verification difficult Take more time than is usually available for NWFP inventory and assessments within development projects	It is not biometrically rigorous as there are: • no formal sampling (systematic plot selection is time-consuming and expensive) • no or few replicates (often 1 plot per site) • no statistical compilation or analysis of data collected Requires familiarity with biometric sampling techniques and their theoretical bases to provide statistical rigour
Developments needed	There is limited progress with development of techniques for rapid assessments	Greater use of biometric sampling where management recommendations are required, e.g. for extractive reserves or protected/conservation areas

Quantitative ethnobotany and NWFP inventory

Despite lacking a sound biometric basis, quantitative ethnobotany has been used in NWFP resource assessment. Key methods involve relative use values – for species and for the forest as a whole.

Several *species use value* methodologies have been developed (see Table 17). This approach is promising, as it is both quantitative and focuses on the plants, but has its problems:

- Data are collected on a single day, providing a snapshot of local priorities, which might be different on another day through mood or seasonal changes. Repeating the collection on different days/seasons would help to minimize error, as would ensuring that there were adequate numbers of informants.
- It assumes that a plant with several uses (e.g. a plant used occasionally for several illnesses) is more valuable than one with a single use (e.g. a staple food), as it ignores frequency and amount collected.
- It might also miss NWFPs which are important to only a few members of the community.

Further ethnobotany reading: Alexiades, 1996; Cotton, 1996; Martin, 1994; Given & Harris, 1994.

Table 17: Methods for quantifying species use values

Method	***Data required***	***Calculations***
Subjective allocation	Several types of interview technique and/or direct observation	Relative importance of each use is subjectively assigned by the researcher on the basis of his or her assessment of the cultural significance of each plant or use
Informant consensus	Independent interviews of individual informants	Importance of each use calculated directly from the degree of consensus in informants responses
Uses totalled	Interviews, sometimes by direct observation	Number of uses summed by category of plant use, taxon or vegetation type. Not very good because, all uses given equal weights and total number of uses may be a function of research effort rather than true significance of plant, vegetation type, etc.

(after Phillips, 1996)

The basis of the determination of *forest use values* is in the use of measured plots in which the number and importance of useful species are quantified by researchers and local people. The use values for species within the plot are added together to make a total use value for the plot. Plots are usually selected to be representative, for example, of forest types (external, scientific rationale) or of local uses and perspectives (internal, local rationale). With plots of typically 1 ha, this level of work is time-consuming and costly – usually few plots are sampled. Costs can be reduced if previously established ecological PSPs are used, as this eliminates the need for collection of samples and naming efforts.

From the plots, use values are often extrapolated across a forest type, whole community lands, or even sometimes nationally. However, the small numbers of plots used often makes the validity of such extrapolation questionable.

4.5 Economic methods

What are economic methods?

- They assess the contribution of NWFPs to local and macro economies through marketing and adding value; and
- evaluate the costs and benefits of including NWFPs in management plans.

Further reading:
Godoy *et al.*, 1993;
Wollenberg, 2000.

Economic methods relate to the increasingly recognized potential of NWFPs to the development of new industries, markets and income sources, and to valuation studies. They are not designed to be biometrically sound methods – as they do not involve direct resource assessment, instead using market information (econometrics). However, they can be important in the design of NWFP inventory, as this information influences management decisions.

Further reading on market analysis and development:
Lecup & Nicholson, 2000

Market and income studies assess the income generating potential of NWFPs through:

- market research, either conventionally at the larger scale, or using participatory methods at the community-scale;
- investigating the patterns and quantities of products in the trading networks. This can estimate the amount of raw material involved in different enterprises, and is useful to highlight where there are supply problems in the chain or to improve understanding of trade relationships. In other words, it improves the picture of supply and demand, and can be used in conjunction with harvest records; and
- studying the relationship between local incomes and NWFP use, through putting together information on collection levels and price.

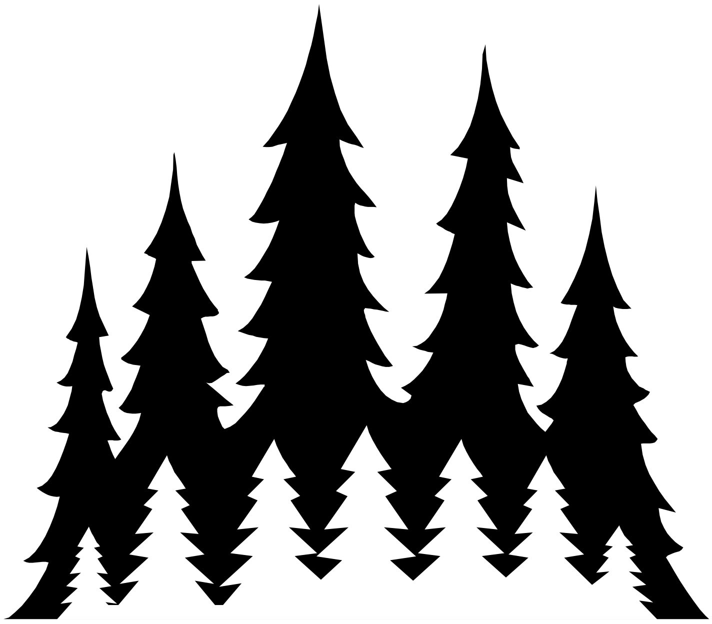
Cost-benefit and valuation studies look at the current value of the resource to different stakeholders, and can be used to compare values of different land uses – e.g. retaining forest cover *vs* conversion to agriculture. This has been used to add weight to forest conservation debates.

Clearly data on the resource base are needed along with economic studies for effective management of the resource, but economic studies can identify barriers to development of the resource that are not related to the resource itself.

Section 5 Designing a biometric inventory for NWFPs

This section helps the reader consider:

- **the relevance and application of biometrics in designing an inventory**
- **a decision-support framework as a step-by-step approach to designing a biometric inventory**
- **planning needs for data analysis and presentation and highlights some research needs**



5.1 Deciding whether biometrics is important

Do good statistics make a good assessment?
The level of biometrics required in an assessment depends on many factors, including objectives, and availability of time and resources.

Formal vs informal methods?

When it comes to data collection, there are no strict rules for the choice of method – a balance is needed between time and money and the depth and breadth of information desired – but in general:

- formal (biometric) methods work better when you want good *quantitative* data – precise, statistical answers to support findings and interpretation; and
- informal (interview-based) methods can give a rapid feel for problems when time and money are short, and this *qualitative* information is essential in providing context and understanding of local attitudes, priorities and sensitivities.

Often *both* are needed.

From a biometric point of view, there is divergence in approaches to data verification:

- formal approaches analyse data statistically after it has been collected; and
- informal approaches verify the reliability of the information during collection, through triangulation.

Participatory methods do produce statistically reliable results, if they are used appropriately. Criticism of the biometrics of informal approaches therefore relates mainly to poor use of the participatory methods. Key factors are:

- careful triangulation and cross-verification in the field;
- facilitators' skills – they must have a clear understanding of the participatory concept, a good analytical capacity and outstanding personal skills in working with people; and
- number of facilitators – one or two is rarely enough to provide a wide enough range of expertise.

Triangulation is a way of cross-checking: if more than one method gives the same answer, it is likely to be correct.

Adequate training of data collectors is vital - whatever the method of data collection used.

Selecting appropriate methods

Strategic information – planning and decision making about quotas – requires quantitative information, accurate assessments, and biometrical rigour.

Qualitative assessments – for example, information on the role of NWFP collection in forest conservation or local livelihoods – do not require biometric rigour.

The main factors determining whether statistically reliable information is required in an inventory include:

- *The objectives of the inventory.* Table 18 notes the range of objectives in studies reviewed and the corresponding need for biometric rigour. Three levels can be identified:
  - High – needed when quantitative data are required for national strategies or for management decision-making. For example, formal statistical methods such as traditional timber inventory. Typically costly.
  - Medium – e.g. mapping studies that indicate relative abundances.
  - Low – adequate for value judgements and non-quantitative issues, and for ‘quick sweeps’. For example, PRA style approaches to mapping. Typically cheaper.

Table 18: Objectives and the need for biometric rigour

Classes of objectives	Summary objectives	Need for rigour
Resource characteristics	Quantification of NWFP resources (quantity, distribution and extent)	High
	Study of population characteristics of NWFP species (biology, habitat, demographics, etc.)	High
	Investigation of relationship between forest type and quantity or diversity of useful species	High
	Status of exploited population	Medium
	Study of utilization characteristics of NWFP species (nutritional value, good ecotypes. etc.)	Medium
	Investigation of relationship between environmental variables and productivity of useful species (weather, seasonality, etc.)	Medium
	Description of habitat preferences of particular species	Medium
Resource supply and demand	Impact of harvesting on exploited populations	High
	Production potential/resource availability	High
	Determination of sustainable yield of products	High
	Assessment of ability of supply to meet demand	Low
	Quantification of forest utilization	Medium
	Accessibility of product to collectors	Low
	Assessment of extent of subsistence use (hunting)	Low
	Identification of vulnerability to overexploitation	Low
	Determination of productivity	High
	Assessment of potential ecological sustainability (using existing information)	None
Policy/strategic information	National yield estimates	High
	Provision of quantitative data for strategic planning	Medium
	Demonstration of national importance of NWFPs	Medium
	Provision of quantitative data for policy development	Medium
	Assignment of conservation priorities for rare species and ecosystems	Low
	Assess contribution of NWFP collection to forest conservation	Low
Monitoring	Provision of baseline data for future monitoring	High
	Re-current inventory	High
	Monitoring of extraction	Medium
	Statutory monitoring	High
Social aspects	Involvement of local people in protected area management	Low
	Contribution of NWFPs to socio-economic development	Medium
	Overview of land use patterns	Medium
	To secure tenure and land and rights to resources	High
	Assessment of impact of creation of protected area on local community NWFP activities and economy	Medium
	Analysis of hunters game choice	Low
	Collection of quantitative data on local food preferences	Low
Economics /valuation	Provision of data for economic valuation of forest	Medium
	Economics of sustainable extraction	High
	Valuation of resources for compensation	High
	Costs of implementing sustainable use	Medium
	Documentation of economic aspects of exploitation of particular species	Medium
Management	Provision of data as a basis for sustainable management of harvesting activities	Medium
	Impact of non-NWFP activities/forest management practices on NWFPs (logging, grazing)	Medium
	Determination of management options for NWFPs	High
	Integration of NWFP production with natural timber production management	Medium
	Impacts of alternative management schemes on NWFPs	Medium
	Predict possible population changes due to heavy exploitation	High
Methodological development	Development of NWFP enumeration protocols (plot size, use of aerial photography, etc.)	High
	Development of participatory survey/inventory/monitoring methods	High
	Development of methods to assess sustainability of NWFP extraction	High
	Development of methodology to assess feasibility of community management	Medium
	Test protocol to quantify environment/productivity relationships	High
Listing of NWFPs	Collection of indigenous botanical knowledge (medicinal/general uses)	Low
	List of products for potential commercial exploitation	Low

High rigour is not necessarily better – what is appropriate depends on the context and the objectives.

- Financial and skills resources available. More accurate assessments require higher levels of funding and skills. If funding is low and there are skill constraints, the approach required will be different to a situation where there is good funding and accuracy is a priority. It is important to use the most efficient tool available to provide the information required by the objectives. Using an expensive and complex method where accuracy may not be necessary is likely to be a waste of often scarce resources.

What goes into a 'good' design?

There are a series of elements underlying good inventory design. These include knowing:

- purpose of the inventory (for whom, for what);
- information needed to meet this purpose (distribution, density, size class distribution, etc.);
- current status of NWFP (distribution, level of threat);
- level of recorded local knowledge about NWFP;
- level of unrecorded local knowledge about NWFP;
- time and funds available for the assessment; and
- level of skills available for the assessment.

Working out how to link all these elements can be very important, but there are few developed systems to do so. Consultation and transparency are essential in the design process. Some of the approaches used to ensure the design will meet objectives are described here.

Consultative approach

This development combines semi-quantitative and participatory approaches in survey design. Several steps (see Box 11) determine: users of the information; objectives of the users; information sources; and outputs tailored to those users.

Linear decision model

This considers more than just cost-efficiency, and works by giving scores or ranks (e.g. zero for irrelevant or one for relevant, for each criteria) to a range of criteria for each different design. Table 19 describes how such approaches can work. The overall score for each design is compared – the best design is the one with the highest score, and may not always be the most complex or biometrically rigorous. This model can be adapted for different circumstances by changing criteria or scorings. Whilst the result of the process may be similar to that arrived at intuitively, it is a useful way of making standardized design decisions that are transparent.

Box 11: Formal consultative approach to the survey planning process

Step 1: Determine who the users are.

Step 2: Obtain from each user (using participatory methods, e.g. consultations and review meetings to set importance values) a clear specification of objectives; also information needed to satisfy objectives with some sort of priority rating including required limits of accuracy. Develop objectives-needs table to deal with interaction between management objectives, information needs and priorities in a quantified and consistent manner.

	Objectives		
	Prepare construction plan	Prepare environmental impact statement	
% importance	80	20	
Information needs	+		Importance index (%)
Topographic maps	70	30	62
Soil maps	25	10	22
Vegetation maps	0	25	5
Animal census	0	25	5
Air photos	5	10	6
	100	100	100

$$\text{Importance index} = \frac{(70\text{x}80) + (30\text{x}20)}{100} = \frac{5600 + 600}{100} = 62\% \text{ for topographic maps}$$

Step 3: Consider where data can come from, e.g. existing data, remote sensing, field surveys. Design field surveys to meet specific information needs at required accuracy levels.

Step 4: Develop needs-methods table to assist in the selection of survey methods to be used.

Example needs-methods table for impoundment project:

Information needs	Priority of need	Survey methods				
		A	B	C	D	B, C and D
Topographic maps	62	62	62			62
Soil maps	22	22		22		22
Vegetation maps	5	5		5		5
Animal census	5	5		5		5
Air photos	6				6	6
Effectiveness		94	62	32	6	100
Cost		2 000	1 000	500	50	1 550
Cost/effectiveness		21.3	16.1	15.6	8.3	15.5

Letters used instead of actual methods which could be field survey, air photo interpretation etc.

Step 5: Design outputs
Consider the users and plan for different types of data presentation: maps, tabulations, distribution graphs, statistical summaries, statistical expressions for relationships between variables. Offer users a choice of output formats and allow them to have a say in what these choices will be. Written guidebooks to the interpretation of available products are essential.

(Myers & Shelton, 1980)

Table 19: Decision model for assessing biometric rigour required in inventory design

Factor	***Rigour required***	
	More important	***Less important***
Number of objectives	Many	Few
Type of objectives	Broad	Narrow
User group understanding	Critical	Not critical
Scientific defensibility	Yes	No
Need for continuity	Critical	Not critical
Need for renewal, i.e. start from the beginning	Critical	not critical
Political defensibility	Yes	No

(Schreuder, 1995)

Frameworks

These work as ‘checklists’ of stages of the decision-making process required in order to reach an appropriate decision. For example, the ‘GOSSIP’ framework (Stohlgren, 1995) guides the planner through consideration of: **g**oals, **o**bjectives, **s**cale, **s**ampling design, **i**ntensity of sampling, and **p**attern of sampling. This approach is less quantitative than the others.

Trade offs when focusing on NWFPs

***The challenge*:** **How to prepare effective multi-species inventory and data analysis applicable to a range of scales from local to national.**

The context of the inventory influences how far it is possible to optimize its design for a particular product. The NWFP inventories tend to be for many different species, which makes it difficult to tailor method to tightly to any one species. Table 20 looks at some of the compromises.

‘Good’ design means different things to different people. Foresters prefer systematic plots, social scientists prefer participatory approaches, botanists rarely enumerate population numbers, and ecologists are often more concerned with processes than patterns. Whilst there is a wealth of experience amongst them all, much work is still needed to share experiences and draw out methodologies suitable for use with NWFPs.

Table 20: Integration of studies vs optimization of methods

Increasing integration of studies

Contexts
Decreasing optimization for specific product

	Spatial scale	
	Local	***Large scale, national***
Potential stakeholders initiating inventory	Communities – or their advisers	National agencies
Single species	Relatively easy to optimize sampling design	Relatively easy to optimize sampling design
Multi-species	Probably moderately difficult to optimize sampling design	Probably requires stratification for known habitats for specific species, perhaps moderately difficult to optimize design
Multi-purpose	Will generally require relatively complex protocols for sampling and analysis	Multi-institutional studies, potentially difficult to co-ordinate and probably very difficult to optimize for specific products, therefore may require an approach that endeavours to combine techniques for the peculiarities of specific NWFPs

5.2 An inventory design decision-support framework

About decision-support systems.

These help guide the user through the decision-making process in a step-by-step way, delivering advice at appropriate points. For NWFP inventory, none have yet been developed.

Ideal elements of a decision-support system for single purpose NWFP inventory are described here. Guidance is given on possible approaches, opportunities and challenges.

Narrowing down the design options

As noted already, the design of the inventory depends largely on its purpose. Where the purpose is for management planning, then methodological decisions are influenced by the resource species, its distribution, size and life-cycle. For this reason, it is useful to place target species into some kind of classification, in order to limit the number of alternative methods to assess.

***Purposes of inventory*: This publication considers only a limited set of purposes, concerned with abundance and distribution *of selected NWFP species* to inform management decisions.**

The characteristics of a species which affect inventory methodology include:

- life-form of the target species – is it a tree, fungi, rattan, bird, etc.?
- seasonality – is it only possible to find it at a certain time of year?
- product part – is the whole individual harvested, or just a part of it, such as fruit or leaves?
- destructive harvesting – does removal of the product kill the individual or not?
- mobile/sessile – does the individuals move around or remain in one place?
- distribution and dispersal – where are individuals and how far do they spread?
- visibility - are individuals easy to see?

It is also important to consider the life-stage of the resource species when it is harvested – young birds or animals may not be highly mobile, whilst adults are. Similarly, different products from the same species may need different techniques, and life-forms can be divided into the different products from them. For example, ‘shrubs’ could include: leaves, bark, fruit, sap, stems and root. Each of these might need a different methodology, depending on seasonality, visibility, accessibility, and so on.

However, similar products from different life-forms (e.g. fruit of shrubs and palms) may require similar methods/protocols. To avoid overclassification it might be sensible to apply parallel classifications for life-forms and products/parts used. In other words, use one classification approach to select a methodology to estimate, for example, liana population density and another for measuring bark yields.

Classifications of life-form and product part are especially important for deciding:

- what kind of plot layout to use – typically plants can be adequately measured in fixed area plots whilst animals may be better observed using transects for timed walks or trapping; and
- how to enumerate (measure) individuals in a sample. Some products may require measurement of size, whilst others may only require presence/absence observations.

Basic information on the species distribution is useful for deciding on what sampling design to use. For example transect sampling might be best for sparse populations, plots for dense.

What is important, is that characteristics of the target population influence design at different levels:

- sampling design requires consideration of population density and distribution;
- plot layout requires consideration of life-form and size of target species; and
- measurement protocols need to consider the product/harvested part and its form.

In other words, inventory protocols should be guided by certain characteristics of the target population. A suggested framework for doing so is shown in Table 21. Note that decisions about methods at one level do not need to influence what methods are used at another level.

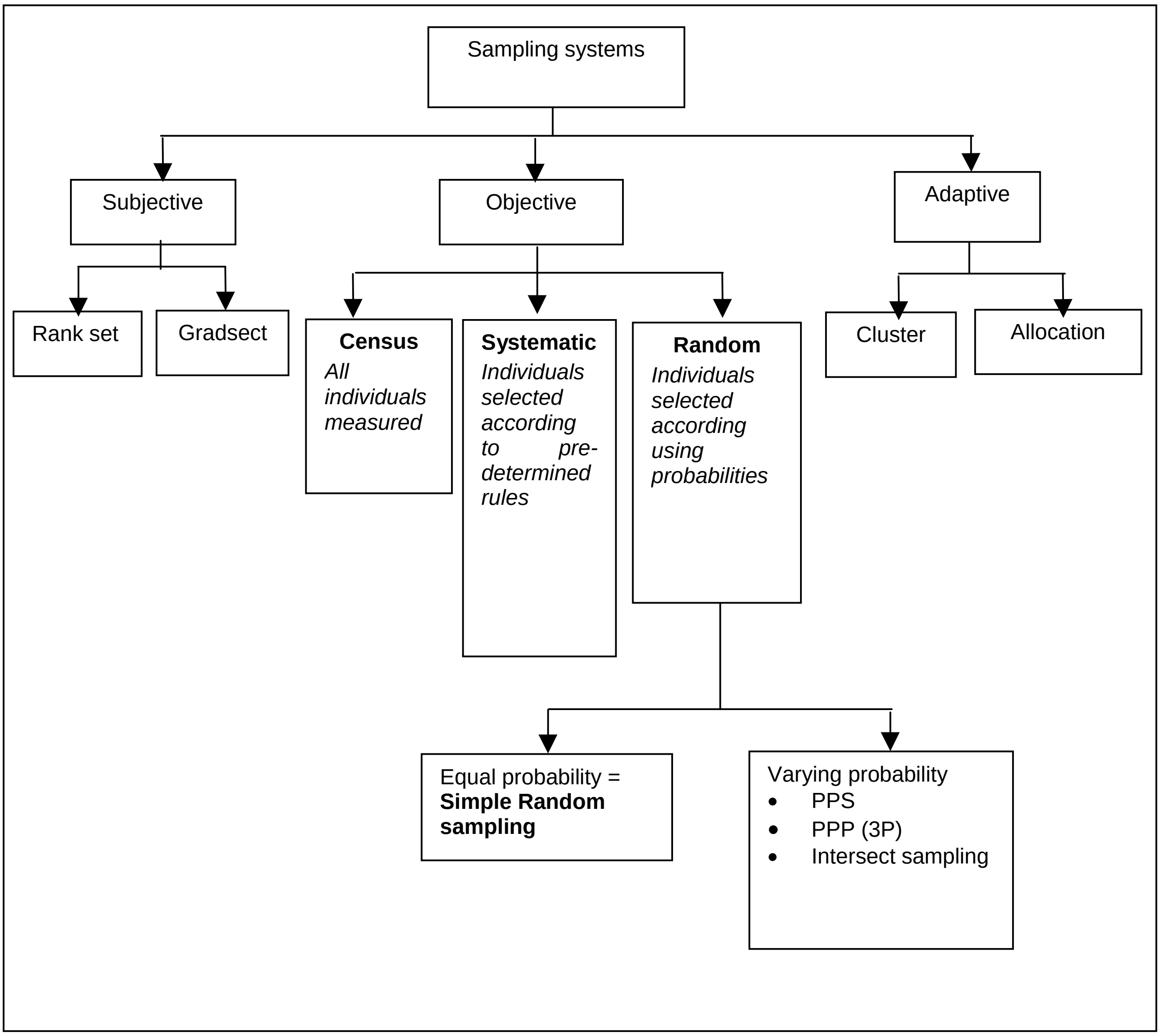
Table 21: Framework for NWFP inventory design

Inventory design element	***Protocol for:***	***Relevant target characteristic***
Sampling design	Plot number and spatial or temporal pattern	Spatial distribution of population
Plot layout	Size and shape of plot	Life form, e.g. tree, bird, fungi, etc.
Population enumeration	Means of quantifying abundance	Growth form, e.g. clonal, suckering, diffuse or discrete organism
Product quantification	Measurement of product yield	Part of organism exploited, e.g. resin, leaves, stem, meat, etc.

Choosing a sampling design

There are many different sampling designs, each with advantages and disadvantages for assessment of different products. Figure 5 provides a typology of sampling designs, and further information about the range of designs available is in Annex 4.

Figure 5: A typology of sampling designs



The main factor to consider when deciding on a sampling design is the population distribution or variability. Some designs are more appropriate for one type of population distribution than another. Table 22 shows a range of suggested designs for some common types of population distributions.

Table 22: Matching sampling design to target population characteristics

Characteristic	***Key sampling problem***	***Methods to consider***
Populations within small study area	Few	Census or 100% enumeration for trees Any other design, ensure that sample size is adequate - variation can be significant even over short distances
Abundant	Sampling needs to be efficient and cost-effective – Perform pilot study (exploratory sampling) or obtain data from previous study in order to determine optimum number of plots for required precision	Random populations – use estimate of population variance to determine optimum sample size Non-random populations – use variance/mean relationship to determine optimum sample size (e.g. using Taylor's power law)
Rare	Problem acquiring sufficient observations of target organism Many plots will be empty with conventional designs = difficulties in calculating means and errors	Adaptive cluster sampling (ACS) with initial systematic sample Sequential sampling (set target number of observations and sample until this is met) Double or two-phase sampling – stratified sampling using knowledge of species distribution obtained from initial survey to define strata - sampling may be proportional to estimated density in strata, i.e. more plots in strata containing target species Gradsect sampling (efficient means of finding populations) Sample for index of population abundance (e.g. available habitat etc.) High sampling intensity (e.g. 25% recommended for rattans)
High small-scale variability (tens of metres)	Need to sample sufficient plots close together to characterize small-scale as well as larger-scale variability	Ranked set sampling (RSS) Two-stage SRS or systematic sampling (sampling of subplots within plots) Cluster sampling
Intermediate-scale clumping (hundreds of metres)	Need to sample clumps adequately without measuring too many empty plots	ACS with initial random sampling AA (if resources limited) Cluster sampling (area covered by cluster, large and approximates scale of clumping, high sampling fraction within cluster means. Within cluster errors are small so mean for cluster is treated as if derived from a single plot measurement)
Distribution linked to landscape features (thousands of metres)	Difficult to cover large area efficiently	Transect sampling, e.g. line-intercept, strip, line-plot sampling, etc. Gradsect sampling ACS with initial strip sampling Stratified ACS with sample allocation according to observations in previous strata Systematic sampling
Uniform	Few problems	Choice of sampling design related to ease of field operations, available resources and required sampling accuracy and precision
Terrain difficulties	Cost of locating sample plots major part of overall inventory costs	Transect sampling (maximizes observations for field work effort) Systematic sampling (plots easy to locate) ACS with initial strip sampling
Dense stands of a single species	Important to characterize within- and between-stand variability	In dense stands – considerations as for abundant species In scattered stands – considerations as for small-to-intermediate scale clumping
Species which form a component of complex ecological communities	Need to account for between-species interactions and change over time (succession)	Habitat and community-based sampling Multi-resource inventory (ecosystem orientated)
Study with limited resources (either funds or time)	Insufficient funds for formal sampling	Indigenous knowledge used to select sample sites Personal judgement used to select 'representative' sample BUT reliability of assessments cannot be determined and results cannot be reliably extrapolated (so problematic for generalization)

Table based on: Cochran, 1977; Gillison & Brewer, 1985; Schreuder *et al.*, 1993; Philip, 1994; Seber & Thompson, 1994; Patil *et al.*, 1994; Myers & Patil, 1995; Greenwood, 1996; Sheil, 1998

ACS – Adaptive cluster sampling
AA – Adaptive allocation
RSS – Ranked set sampling
SRS – Simple random sampling

It is worth noting some of the new sampling techniques that are potentially useful for NWFPs (see Annex 4).

Choosing a suitable sample plot layout

The next step in the design process is to decide on an appropriate 'sampling unit' within which data will be recorded. In forest and plant inventory, the sampling unit is usually referred to as 'plots', which are fixed areas of land. However, in animal survey sampling, units over time are often used. Individuals can also be the sampling unit. In this discussion, the term 'plot' will be used to mean all possible types of sampling unit.

Appropriate plot design is typically very different for plants than it is for animals:

- for plants, **space** is most important – observations are usually made over a fixed area, at any time; and
- for animals, **time** is often more important, as they can move in and out of any area - often counted over a fixed time period, or from a point or transect line.

For plants, the form or layout of the plot must consider the life-form (including size) and growth-habit of the target species. However, as yet, little work has been done to help work out what the best size and shape of a plot might be for the range of life-forms that are harvested as NWFPs.

Further reading on plot layout:
Sunderland, 1996; Schemnitz, 1980.

Two ideas include:

- Lianas – The idea of a cylindrical plot (round and tall, up through the canopy) may be most appropriate for a climbing liana, with a circular 'slice' of it giving information on the distribution of lianas in the canopy (Parren *et al.,* 1998).
- Rattans – One suggestion is to use two 10x200m strips arranged in a cross formation, sampling at an intensity of 1-3 percent (Tandug, 1988) (see also Box 2 noted earlier).

More experience is shown in Table 23, and some thoughts on plot design choices can be found elsewhere, but more research is needed to provide reliable advice.

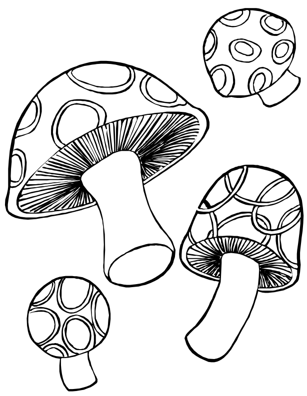


Table 23: Plot configurations that could be used for NWFPs

Class of plot	***Configuration***	***Discipline***	***Description***	***NWFP examples***
Measured fixed area	Transect	Plant and animal survey	Narrow, long strips over which all individuals of interest are sampled. Width fixed, length sometimes variable	FitzGibbon *et al.*, 1995; Lahm, 1993; Sunderland & Tchouto, 1999
	Measured fixed area plots	Forestry	Square, rectangular or circular measured areas, frame quadrats for smaller areas	Commonest type of plot, Männi, 1988; Salo, 1993; Sharma & Bhatt, 1982; Wong, 1998
	Cluster plots	Forestry	Fixed pattern of subplots which do not touch	Rai & Chauhan, 1998
	Plane-intercept	Plant survey	Count of plant stems intersecting an imaginary plane, e.g. at 1.3 m above ground surface	None - suggested by Parren *et al.*, 1999 and Shiel, 1997 for climbers
	Line-plot transects	Plant survey	Plots located along a transect line (usually distances along line are fixed in which case this is systematic sampling)	Geldenhuys & Merwe, 1988; Sullivan *et al.*, 1995
	Volumes, e.g. cylinder	Plant survey	Count/measure individuals contained within a fixed volume of space	None
Measured fixed time	Listening stations	Wildlife survey	Fixed period listening stations mainly for bird or primate calls usually at specified times of day or night	None
	Hunting trips	Wildlife survey	Data collected of all animals encountered during one day's hunting	Noss, 1998 and Noss, 1999
Variable area plots	Distance sampling	Wildlife survey	Observations made while standing at the sample point for a fixed period of time or moving at a fixed pace along a line. Distances measured from line to observed individuals/groups. Use DISTANCE programme to calculate densities	White, 1994; Bodmer *et al.* 1994; Bodmer, 1995; Silva & Strahl, 1991
Unmeasured area	Rapid botanical survey (RBS)	Botanical survey	Area within a specific landscape unit from which samples are collected – sometimes crudely measured as time taken to complete collection, i.e. fewer than one new species encountered in 30 minutes	Hawthorne & Abu-Juam, 1995
Point samples	Point quadrats	Plant ecology	Fixed area frames with array of needles used to identify points for sampling plant cover	None
	Point sample	Environmental recording	Parameter of interest recorded at a single point, e.g. a soil pit, rainfall, etc.	None
Arealess	Angle-count sampling	Forestry	Count/measure trees which subtend an angle larger than a constant angle from a fixed position – uses prisms, relascopes, etc.	None
	Line-intercept transects	Forestry & wildlife survey	Counts/measurements made of linear features, e.g. slash, animal tracks, lianas, etc., that intersect the sample line	Fragoso, 1991; Ringvall & Ståhl, 1999; Shiel, 1997
	Point-centred quarter	Plant ecology	Nearest trees to sample point in four quadrants	Schreckenberg, 1996; Lescure *et al.*, 1992
	Nearest individual	Plant survey	Fixed number of individuals closest to sample point	Singh & Dogra, 1996; Pinard, 1993; Shiel, 1997

Achieving independent observations requires care with plot distribution and configuration (distance from each other, size and shape).

Systematically located plots are theoretically not independent, as their location is fixed by a single point of origin, to which they are all related. In practice, the distance between the plots means that they can be treated as independent. The closer they are together the greater the risk of relationships between plots.

Subplots should usually not be treated as independent. Plots which touch each other should never be treated as independent, and are in fact subplots. However, many studies treat subplots and contiguous plots as independent plots - this is called 'pseudo-replication'.

Efforts to establish optimal plot shapes and sizes can also fail to consider plot independence. It is a mistake to compare different plot shapes and sizes:

- when the plots are touching each other; or
- if the plot shape or size could be influenced by underlying patterns in the population.

Deciding how to measure the product

Choice of method for measuring the size/amount and density of products depends on the life-form and growth-habit of the target species. Table 24 notes a range of ways of measuring the target species that have been used. Earlier Tables 7 and 8 are also helpful.

Table 24: Example possible enumeration protocols for NWFP resource assessment

Method	***Life form***	***Description***
Tally	Any – sessile	Counts of target individuals in plot
Presence/absence	Any	Record occurrence of target in plot (e.g. biodiversity survey, 1 ha ethnobotanical plots)
Size/age measurement	Larger plants and animals	Measure size of all individuals in plot (e.g. leaf width, stem diameter, height, life stage – juvenile/adult, etc.)
Cover	Plants	Record percentage of plot covered by target species
Relative abundance	Any	Score density of target in plot into subjective classes, e.g. low, medium, high, Braun-Blanquet or Domin scales for plants
Trapping	Mobile – animals and fruit/seeds of trees	Capture individuals for counting and measurement e.g. mist netting, Sherman traps, seed traps
Partial trapping out	Small animals (where loss from population is not critical)	Capture individuals and remove from population, repeat over a period of time and use exponential model of decreasing capture rates to extrapolate initial population
Mark-recapture	Animals (palm fruit, see Phillips, 1993)	Capture individuals, mark (toe clipping, tags, paint, etc.), release and re-capture, use numbers re-caught to estimate total population. Many variations (see Greenwood, 1996)
DISTANCE sampling	Animals	Record distance from observation point to target and use Fourier analysis to estimate target population
Response to playback	Birds	Play recording of bird calls and count number of responses
Indirect/Index methods	Any	Record hair, dung, nests or other easily observable signs and use regression methods to estimate size of target population

Methods for animals are well researched, and relate closely to the type of plot chosen. Obviously, methods for measuring trees are also well established through experience in forestry-based inventories. Application of both of these potentially useful bodies of experience to NWFPs needs more work.

In contrast, there has been little work on protocols for tropical non-tree plants. This is usually because of difficulties that relate to:

- large size of many tropical plant species – makes the use of point- and quadrat-based methods developed for temperate plant ecology generally impractical; and
- difficulty in finding some individuals – for example, mushrooms or canopy orchids, which are hidden from view, or animals which actively avoid observers.

There are no set rules. General guidelines include:

- Measure the part of the plant or animal that is usually harvested. Using local hunters or pickers can help ensure that the harvested part is that which is measured. Be aware that harvesters may not collect low quality products, and thus that measurements may not represent overall biological productivity.

- Consider what proportion of the biological production can be harvested - accessibility has a strong influence on harvest levels. This can be done by weighting the contribution of collection areas according to their accessibility (e.g. distance from road or village). This will help estimate the amount actually available to harvesters.

Deciding how many plots are needed

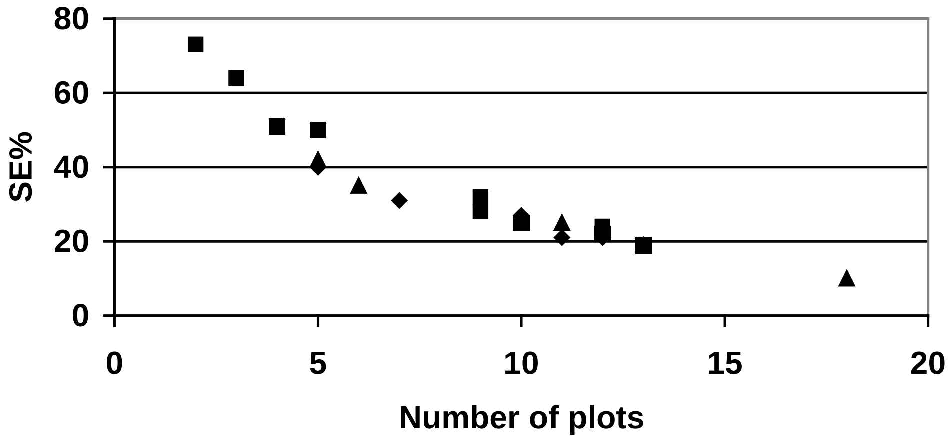
> *Further reading on plot numbers*: Bowden *et al.*, 2000; Cochran, 1977; Philip, 1994; Shiver & Borders, 1996

The number of plots used is critical for the management of sampling errors; the greater the number of plots the smaller the sampling error and therefore the more precise and potentially accurate the results will be. However, in the interests of efficiency there is no need to have more plots than can be expected to deliver an acceptable sampling error. There is no scientific way of deciding what sampling error is acceptable - this is a management, pragmatic or even a political, decision. It depends on how much risk the manager is prepared to take. Generally, for forest inventory the target error is taken as 10-20 percent of the mean.

There is a non-linear relationship between the number of plots and sampling error such that there are diminishing returns as numbers increase (see Box 12) . This relationship can be used to estimate the number of plots required to achieve a specified sampling error. However, in order to do this a measure of the expected variance of the sample is required. Ideally, this can be estimated from a pilot study but figures can also be obtained from secondary sources, e.g. similar studies elsewhere, experience or local knowledge.

Box 12: Relationship between sampling error and the number of plots used

There is a relationship between the sampling error and the number of plots used as indicated in the following diagram. (These data are derived from sampling a fictional forest for species laid out to mimic distributions common in tropical forests.) The diagram clearly shows that as the number of plots increases, the sampling error decreases in a non-linear manner. These relationships form the basis for determining how many plots are required to achieve a target sampling error and hence precision.



The cost of enumerating a plot is also needed if cost-efficiency is a concern.

There are a number of methods for calculating how many plots are required from these figures, Box 13 gives one of the more straightforward.

Box 13: An example of a method for calculating the optimum number of plots

The number of plots required to meet a predetermined allowable error can be calculated using the equation:

$$n = \frac{4(CV)^2}{(AE)^2}$$

where:
n = estimated number of plots required
4 = approximation of the t value at the 95 percent probability level squared
CV = coefficient of variation among sampling units (%). This is standard deviation divided by the mean expressed as a percentage.
AE = desired allowable error (%).
Note that this example is only valid for random sampling - it is not appropriate for systematic layouts.
(Shiver & Borders, 1996)

Data handling, analysis, interpretation and presentation

Futher reading:
Dytham, 2000;
Zar, 1999.
Advanced reading:
Patil & Rao, 1994;
McCullagh & Nelder, 1983

An essential, but often overlooked, element of the design of a data-collection exercise is planning for the eventual data handling and analysis. Other and forthcoming FAO publications provide useful 'how to' manuals to implementing inventory, and what is provided here is only a brief introduction to the key considerations.

It is important to have at least some idea of how the data are to be collated, analysed and presented to those interested in the results at the beginning of the study. The methods used do not need to be sophisticated, though in practice it is difficult to do much more than straightforward analysis without access to a calculator or computer. If complex designs are to be implemented it is advisable to consult a statistician before designing the study. This will help to collect the necessary data efficiently and to plan appropriate data analysis. However, straightforward presentations of mean densities and gross amounts of product are often all that is required. Errors should always be calculated to give an indication of the reliability of the results.

Careful planning of analyses is most important when the study is intended to test a quantifiable hypothesis. Planning ensures that the data collected can be used in the intended manner. If data are being coded (for example, for entry onto a computer) it is often worth thinking about what other analyses are possible so that appropriate codes can be entered. There are a large number of statistical tests that can be used to test hypothesis and care is needed to ensure that the most appropriate one is used.

Interpretation of the results of an inventory requires skill and experience, and there is little formal guidance that can be given. Generally, the first stage is a straightforward direct answer to the original question, but since the question itself often requires interpretation, even this can require some careful thinking. For example, the straightforward question 'how much of product x is available from y forest?' gets the answer something like '17.6 kg per hectare with a 18 percent sampling error'. But how was *availability* assessed? What would the answer be if some of the assumptions (e.g. villagers only harvest within 2 km of road) change?

Often there is considerable scope for further interpretation of collected data (e.g. if we map density, does this tell us anything useful about the ecology of the species?). How much, and what is possible or appropriate, depends on the skill of the people undertaking or guiding the analyses.

Further reading:
Myers & Shelton, 1980,
Shanley *et al.*, 1996

Presentation of the results is a key consideration. Even if the inventory is well designed and analysed, if the results are not conveyed in an appropriate, timely and considered manner to those who need to act on the results, it will be of limited use. The design of data presentation should be part of the planning stages of the inventory so that results can be processed and disseminated without delay. Annex 3 gives an example of a rather formal presentation style that has been used for reporting a national NWFP inventory.

Role of pilot studies

Many text books advocate the use of pilot studies, but it seems that very few of the studies reviewed for this publication made use of such preliminary studies. There is also little advice on what to do with the data and experience gained from execution of a pilot study. Even when they are done, they do not often result in radical change to the sampling design used after the pilot study.

Pilot studies are most useful in the execution of large-scale inventories, where small changes in the number or size of plots required can lead to significant savings. Pilot studies should include sufficient plots to be able to make meaningful calculations of the sample variance (as a guide: more than 30 plots). The data from pilot studies can be useful to test and verify the following:

- number of plots required to achieve the required sampling error (calculated from variance of the pilot study plots);
- optimal size for the plots;
- practicality of the field protocols;
- efficiency of data capture and handling procedures;
- accessibility of the style of presentation chosen for the results; and
- preliminary results which may inform the sampling design (i.e. the species may turn out to be rarer than anticipated).

5.3 Research issues

Are existing methods adequate but inappropriately applied, or do we need further research to develop better methods?

The FRP project (ZF0077) from which this publication has been derived was commissioned to identify researchable constraints to the application of sound biometric methods to NWFP resource assessment. The initial identification of priority research issues was made from a purely academic perspective, in a background literature review (Wong, 2000). These topics were then discussed and modified by the workshop *'Developing needs-based inventory methods for non-timber forest products - Application and development of current research to identify practical solutions for developing countries',* held in Rome in May 2000. The focus on needs-based methods prioritized the research to provide practitioners with better tools for immediate problems, rather than focusing attention on the most challenging and esoteric academic questions.

The workshop considered the needs for biometrically rigourous resource assessment from three basic perspectives (see Table 25):

- species or product level;
- from the perspective of a community seeking to quantify local resources; and
- assessment by macro or national level regulators such as Forestry Departments.

At the species/product level (where attention is focused on particular resources) technical problems, such as better designs for clumped distributions, dominate. At the community and national levels these issues are obscured by context-related issues. At the community level all quantification should be capable of being undertaken in a participatory manner and be sensitive to local knowledge, skill levels and yet provide data suitable for formal management planning. At the national level the issues change to those of designing multi-purpose, multi-resource inventories on a large scale. The specific priority research activities proposed by the workshop are given in the workshop report (Baker, 2001 available in the enclosed CD-ROM).

There were also a number of general issues which are relevant to all levels. Some of these require research while others are more direct issues concerned with effective dissemination of better advice and promotion of good practice among fieldworkers.

Table 25: Summary of identified research topics

Level	***Issue***	***Specific ideas***
National	Relationship between NWFPs and forest type	Use of the geographical information system (GIS)/remote sensing Use of adaptive sampling Difficulty of using single design for products that are collected from both forest and non-forest lands
	Multi-purpose resource inventory	Integration with existing surveys - case study approach Integration between inventories at local and national scale
	Product specific inventory (>1 spp.)	Gum/bamboo/rattan/bark Classification in terms of inventory need
	Links with market information	Assessment of best market statistic for use as an indicator of the distribution and abundance of a species
	Certification data needs	What is required?
Community	Matching local knowledge with information needs	Development of participatory methods acceptable to community and regulatory stakeholders
Species/ Product	Measurement	Multi-disciplinary screening for suitable protocols Develop, test and adapt protocols Evaluation of user-based methods
	Monitoring	Collation and evaluation of forest monitoring systems Examine linkages between methods for growth and yield and those for extraction Investigate linkage between assumed indicators and resource condition Decision-support system for design of monitoring protocols
	Sampling	Evaluation of relative efficiency of new designs Evaluate potential utility of rank set sampling as a means of using local or prior knowledge Investigate use of local knowledge for generating sampling designs
	Analysis	Forecasting yields of seasonal products Determination of harvest levels
	Linkages between scientific and local knowledge	Linking local and scientific names

Dissemination of biometric advice

Advice on sampling designs suitable for use for specific products and suitable for use by communities is in strong demand from fieldworkers. Other interests, such as national Forestry Departments also need advice on the development of suitable protocols for multi-purpose resource inventory including NWFPs. This could be addressed through the provision of:

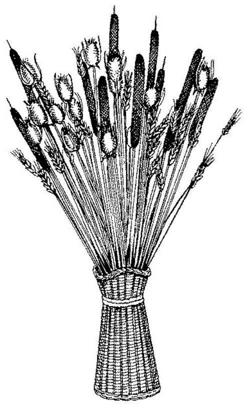
- practical training workshops;
- a biometrics hotline to offer one-to-one advice to fieldworkers; and
- a manual based on a decision-support approach to inventory design.

The development of a manual and the provision of small-scale practical training is being undertaken through the FAO EU-funded project GCP/RAF/354/EC 'Sustainable forest management in African ACP countries'. This initiative is specifically for Africa and there is a need to consider the provision of similar initiatives for other areas.

Development of novel methods

Much can be learnt from other disciplines such as horticulture and autoecology. This needs to be collated into a resource that will be useful for those designing NWFP inventories. However, the general consensus is that the problem with increasing the use of biometric methods in NWFP assessment requires more than the application of existing methods. There are specific features of NWFPs that mean that new methods for inventory, monitoring and yield determination are required. These are:

- *Rarity* - many NWFPs are rare which means that only a few plots of a conventional systematic or random design will contain the species of interest - this means that these designs may be very inefficient, can give results with large sampling errors and the calculation of errors cannot be done using conventional estimators.
- *Imperfect detectability* - many NWFPs are difficult to find (i.e. fleeing animals, underground fungal bodies, plants growing in the canopy) which means techniques for estimating the fraction of the population represented by observations are needed.
- *Seasonality* - many products are seasonal and such products will often exhibit large variation in yields from year to year - these all cause problems for conventional, forestry-based designs.
- *Mobility* - animals occupy a home range, which may extend beyond the extent of the inventory area.
- *Determination of yield for non-destructive harvesting* - most existing methods are based on methods where the whole organism is harvested, the few methods developed for non-destructive harvesting need further development.
- *Development of a theoretical basis* for sustainable NWFP harvesting.

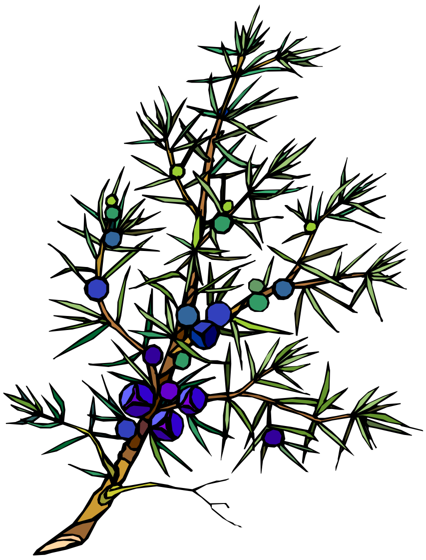


Use of local knowledge

It is generally accepted that where there is a body of local knowledge of a species or product this can potentially form the basis for sound inventory, monitoring and management of the resources. At all scales (national as well as local) and in all areas of resource assessment it is important to collate, validate and use such knowledge in a participatory manner. Before it is possible to start to combine local and biometrically derived knowledge it is first necessary to be able to link scientific and local names. Once this has been established, local knowledge can form the basis of more formal sampling designs and measurement techniques. Objectivity and respect for complexity is perhaps the key to both the handling of local knowledge and the biometric design of participatory inventory.

Section 6 **Literature resources**

This final section provides the reader with details of references cited and provides some useful information on relevant literature for further reading.



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6.2 Further reading

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6.3 Supplementary literature

The CD-ROM included with this publication contains the following additional resources:

- Wong, J.L.G. 2000. The biometrics of non-timber forest product resource assessment: A review of current methodology. Background paper prepared for ZF0077;
- Sampling designs used by reviewed studies (searchable database and summary table in PDF);
- Complete reference list used in the review (searchable database);

- Baker, N. 2001. Report of the workshop “Developing needs-based inventory methods for non-timber forest products” held in FAO Rome, 4-5 May 2000. DFID-ETFRN;
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Section 7 **Annexes**

Annexes include:

1. **Classification of NWFPs – examples of approaches used**
2. **Understanding plots and subplots**
3. **Example of NWFP inventory outputs**
4. **Some currently used and emerging sampling methods**
5. **Useful institutions and Web sites**

Annex 1. Classification of NWFPs - examples of approaches used

Approaches

International trade reporting: for example Customs and Excise, tend to group resources according to:

- *product type* (e.g. 'live plants', 'prepared beverages', 'animal fats', 'prepared bark products'); or
- *end use* (e.g. 'chewing sponge or stick', 'cloth', 'edible leaves', 'wine', 'resin').

Biodiversity inventories usually group animals and plants according to scientific names of family and genera.

Ethnobotanic studies classify according to local end uses (e.g. construction, edible, fuel, medicinal, poisons).

Foresters and forest-based assessments use groupings according plant form and parts used (e.g. non-wood tree parts, tree fruit, herbs, climbers, shrubs, etc.)

Wildlife ecologists usually group according to the scientific family and size (e.g. insectivores, primates, reptiles, rodents, ungulates).

Land/resource managers sometimes group according to management characteristics (e.g. ease of propagation or cultivation, accessibility, who collects it, for regular household consumption, occasional use, for sale in local markets).

Examples

A. Typology for national NWFP accounting (after Chandrasekharan, 1995)

A. Live plants and parts of plants
Live plants
Parts of plants (fresh, cut, dried or crushed), collected for specific uses
Specific parts of plants with multiple uses, not included under the previous group
Vegetable materials not elsewhere classified
Raw exudates and similar natural products

B. Animal and animal products
Live animals
Animal products

C. Prepared/manufactured products
Prepared (provisionally preserved) edible products
Prepared beverages
Prepared animal feed/fodder
Vegetable oils/fats
Animal fats/oils
Prepared waxes of animal or vegetable origin
Dying and colouring extracts of plant or animal origin
Phytopharmaceutical/medical extracts, galenicals, medicaments
Essential oils and their concentrates
Rosin and rosin derivatives
Processed gums and latex
Fuels and alcohols
Other basic organic/phytochemicals
Prepared bark products
Plaited products
Products of natural fibre
Tanned leather, fur and products of taxidermy
Miscellaneous products, manufactured from non-wood forest raw materials
Other non-wood plant and animal products n.e.c.

D. Services
Forest-based services

B. End use classification (after Wyatt, 1991)

Category
Sponges, chewing sticks, tooth cleaners
- Bathing sponge
- Chewing sponge & sticks
- Tooth cleaners
- Aphrodisiac

Fibres, bast fibres, jute, cloth
- Basketry (fish traps, furniture, ornaments)
- Jute fibre
- Wool
- Cloth
- Pestles

Foodstuffs
- Wild fruit
- Sweeteners
- Neutralisers
- Vegetables and mushrooms
- Edible leaves

Water, beverages wine
- Water
- Beverages
- Wine
- Intoxicants

Medicinal plants
- Medicinals plants

Latex, rubbers, gums and resins
- Latex
- Adulterants
- Bird lime
- Coagulants
- Gum
- Resin
- Gum copal
- Gutta percha

Decorative beads
- Decorative seeds

C. Plant use classification as used by ethnobotanists

Prance *et al.*, 1987	Edwards, 1991	Boom, 1989	Valkenberg, 1997	Salick *et al.,* 1995
Edible	No use	Food	Timber	Aesthetic
Construction material	General purpose	Fuel	Special purpose wood	Construction
Technology	Timber	Construction	Bark/leaves	Edible
Miscellaneous	NTFPs not in trade	Medicinal	Edible fat	Firewood
Remedies	NTFPs in trade	Poisonous	Fruit	Hunting
Religion		Commercial	Exudate	Animal habitat
		Miscellaneous	Medicinal	Intoxicant
			No use (including firewood)	Medicinal
				Oils
				Poison
				Resins, etc.
				Shade
				Timber
				Utility
				Non-timber wood
				Other

Malhotra *et al.,* 1991
Raw materials for commercial sale or processing
Subsistence food or drinks
Animal fodder
Fuel
Timber and fibres for tools and construction purposes
Medicinals

D. Grouping of NWFPs according to feasibility criteria for forest inventory

NWFP group	Group description	Examples	Comments
1	Non-wood tree parts	Fruits, leaves, twigs	Can be related to tree dimensions
2	Products from 'tree like' plants	Bamboo, rattan	Relatively easy measurable dimensions
3	Herbs and other plants	Medicinal and aromatic herbs	Some specific properties to be taken into consideration when incorporating into standard forest inventories

(after Kleinn *et al.*, 1996)

E. NTFP classification based on life form and plant parts (McCormack, 1998)

<table>
<tr><td>Animals</td><td colspan="4">No sub-division</td></tr>
<tr><td rowspan="10">Plants</td><td rowspan="8">Perennial species and products</td><td rowspan="2">Trees</td><td colspan="2">Wood</td></tr>
<tr><td colspan="2">Bark</td></tr>
<tr><td rowspan="6">Non-trees</td><td rowspan="2">Climbers</td><td>Lianas</td></tr>
<tr><td>Rattans</td></tr>
<tr><td rowspan="4">Non-climbers</td><td>Palms</td></tr>
<tr><td>Bamboo</td></tr>
<tr><td>Epiphytes</td></tr>
<tr><td>Shrubs</td></tr>
<tr><td>Ephemeral products from perennial species</td><td colspan="3">E.g. Fruit, fluff from seed cases, nuts/seeds, oil seeds, apical buds, leaves</td></tr>
<tr><td>Ephemeral species</td><td colspan="3">E.g. Herbs, mushrooms, wild honey</td></tr>
</table>

F. Life-form classification as used in multi-species resource assessments

Wong, 1998	Dunn *et al.,* 1994	FitzGibbon *et al.,* 1995	Lahm, 1993	Gadsby & Jenkins, 1992
Non-timber trees	Climbers	Primates	Reptiles	Insectivores
Herbs	Shrubs	Duikers	Pangolin	Bats
Climbers	Palms/bamboo	Elephant shrews	Rodents	Primates
Rattans	Marantacae	Squirrels	Primates	Rodents
	Non-timber trees		Carnivores	Carnivores
	Rattan		Ungulates	

G. Provisional categorization of NTFPs according to management characteristics (Wiersum, 1999)

Supply characteristics
1. Production characteristics - Degree of ecological sustainability of extraction - Ease of vegetative or regenerative propagation - Ease of cultivation under different environmental conditions - Ease of stimulating production by technological means 2. Organization of production - Access to NTFP resources - Gender division of production responsibilities
Demand characteristics
1. Opportunistically collected products for subsistence consumption not related to main household needs (e.g. snack foods) 2. Occassionally collected products purposively collected in times of emergency (e.g. medicinal products, emergency foods during droughts) - Products for regular household consumption - Easy to substitute with products of other species (e.g. various food products, fodder, fuelwood) 3. Difficult to substitute with products of other species (e.g. preferred forest foods) 4. Products for sale at various market types (local, regional/national, international) - High degree of competition with substitutes - Low degree of competition with substitutes 5. Products demanded in manufactured form, and which can be locally produced giving them added value (e.g. palm sugar, liquors)

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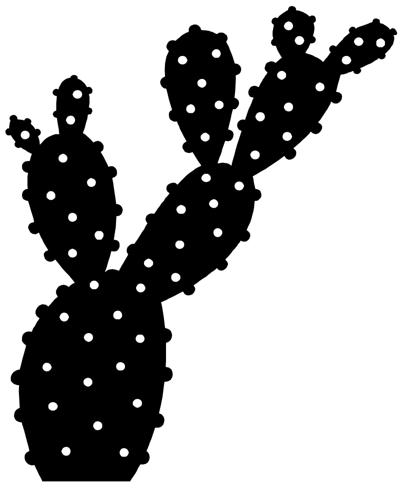
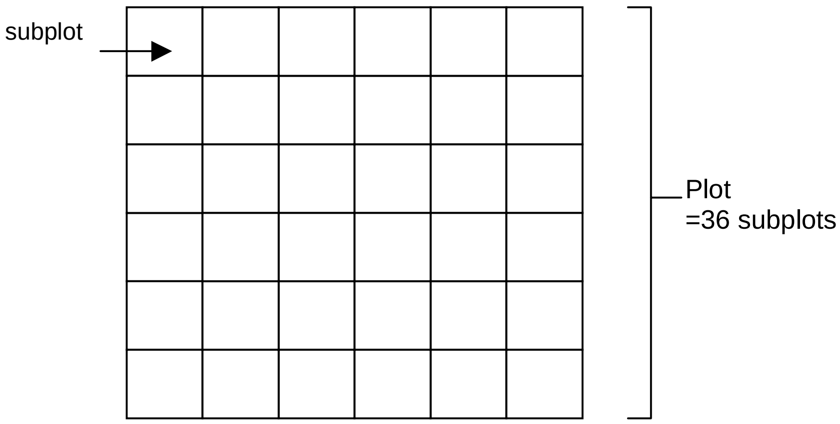


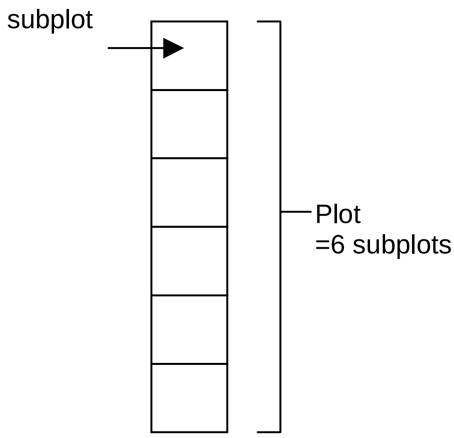
Annex 2. Understanding plots and subplots

Plots and subplots

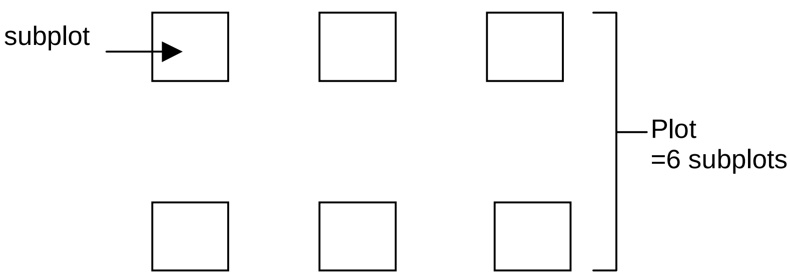
Square plot



Transect



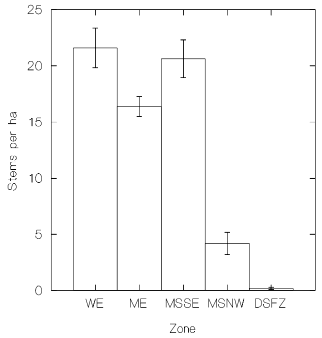
Cluster



Annex 3. Example of NWFP inventory outputs

From Case study 3 - Ghana national inventory. Climbers - Hunhun - Fruit - *Manniophyton fulvum* (L5)

1. Vegetation zone preferences

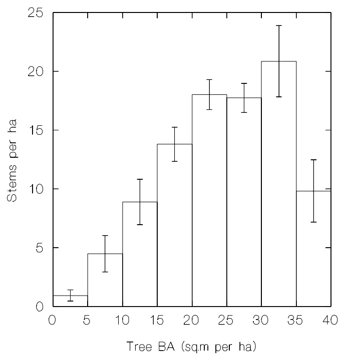


TUKEY HSD MULTIPLE COMPARISONS.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	WE	ME	MSSE	MSNW	DS
WE	1.000				
ME	0.000	1.000			
MSSE	0.545	0.000	1.000		
MSNW	0.000	0.043	0.000	1.000	
DS	0.000	0.071	0.000	0.992	1.000

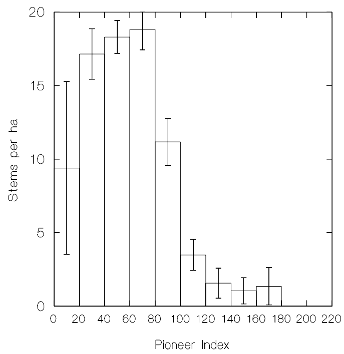
WE & MSSE not different
MSNW & DS not different

2. Tree basal area



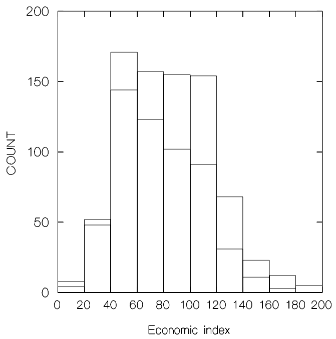
Mean BA = 23.218 SE = 0.260

3. Tree pioneer index

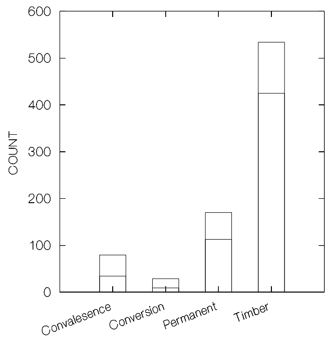


Mean PI = 59.787 SE = 22.284

4. Economic index for trees > 30 cm d



5. Management zones



6. Relative abundance

Zone	WE & MSSE	ME	MSNW & DS
Occupancy (%)	78.9	58.9	27.4
Mean density (stems ha^{-1}) *	26.531	18.692	9.271
Standard error	20.939	16.142	13.131
Maximum density (stems ha^{-1})	118	95	59
Area to search to find 10 (ha)	0.5	0.9	3.9

*Density in area occupied by species

Annex 4. Some currently used and emerging sampling methods

a) Sampling designs possible for NWFP inventory.

Subjective sampling

Generally not statistically acceptable but often used in 'cruise' or rapid assessments to ensure complete range of environments are sampled. Also used in PSP location to ensure that all types of forest are represented. Take care that a design does not inadvertently become subjective. Watch for bias e.g. leaving out areas where access is difficult.

Gradsects – used in ecological surveys to ensure that all vegetation types along major environmental gradients are sampled.

Objective sampling

The most commonly used types of designs for natural resource inventory.

Complete census - Measuring and recording every individual. Only practical for small areas. Generally used for stock survey of forest compartments due to be logged.

Simple random - Samples drawn using random numbers from a pre-determined sampling frame. E.g. set up a grid of 1x1 km numbered squares, select squares for sampling using random number tables.

Systematic – Samples selected according to pre-determined rules, i.e. plots placed at the intersections of a 1x1 km grid, every fifth tree measured, etc. There has been some argument about whether this is statistically acceptable. However, it is generally considered that such designs are acceptable as long as care has been taken to reduce the risk of the sampling grid coinciding with some regular feature of the landscape. Note: the sampling error can be calculated using the formula for a simple random sample with the assumption that the underlying population is random (i.e. that the placement of trees is itself random). If it is not safe to assume this, then calculation of the sampling error can be problematic. Note that the systematic grid can be considered a single plot, replication of the grid could therefore be used to estimate errors.

Probability sampling

Samples where the probability of selecting an individual is proportional to its size. Note: all other methods discussed sample with constant probability of selection which can mean that rarer, large individuals are undersampled given that they contribute disproportionately to the total quantities present.

List sampling – make a list of all individuals and their size. Calculate cumulative size i.e. the sum of sizes of all smaller individuals should be tabulated for all individuals. Assign numbers for selecting individual according to cumulative size (see example). Probability of selection given by cumulative size/sum of sizes.

Individual	*Size*	*Cumulative size*	*Numbers*
1	2	2	1-2
2	5	7	3-7
3	10	17	8-17
4	15	32	18-32

If random number drawn is 5 then individual 2 is selected, if it is 20 then individual 4 is selected. The larger individuals have a higher probability of being chosen because they have more number assigned to them.

3P sampling – developed for estimating volume of timber in a timber sale. Do a visual assessment of tree, select sample with *probability proportional* to the *predicted* size of the tree. Use of selection rules to determine which trees to be sampled. It requires that every tree in the tract is visited. Estimate the maximum tree volume in the stand.

At each tree:
If the tree is bigger than the maximum estimated size then estimate its volume and measure it.
Otherwise use a random number table to determine if tree is sampled.
  If random number is less than estimated size measure the tree
  Or move onto next tree.

Use data to estimate total volume on the stand.

Line intersect sampling – sample individuals that touch or intersect a line – the bigger they are the higher the chance that they will touch the line. Originally developed to estimate the amount of material e.g. slash or fuelwood lying on the ground. Has also been suggested for sampling lianas and used for wildlife tracks and signs.

Besides these basic designs it is also possible to use more or less any of them within a larger plan which can be used to achieve sampling efficiencies or to ensure that all subpopulations are adequately sampled. These plans are:

Stratified sampling - Dividing the population into sub-populations.

- Pre-stratification - Dividing the population into sections which are generally less variable and therefore can lead to savings in terms of the overall number of plots required. Also help to ensure that small subpopulations are adequately sampled. Generally stratification is beneficial and can reduce errors by 5 to 20 percent compared with an independent measurement of the total stand.
- Post-stratification – uses characters of the plots to group similar plots to improve precision of overall estimates (not strictly statistically correct unless sampling is random).

Note that more or less any design can be stratified hence: stratified random, stratified systematic etc. Strata may be decided by mapping or be systematic, e.g. dividing an area into 10x10 km blocks.

Multi-stage sampling

Sampling a series of nested plots, generally smaller plots located within larger ones. For example 1x1 km areas may be selected for land use mapping, within this a 1 ha plot may be randomly selected, every fifth tree in the 1 ha plot may have 10 percent of its branches sampled for fruit.

- Often used in extensive inventory as a simple layout would give too many plots.
- Sampling design at each level can be different and the highest level often uses remote sensing.
- If the subplots are selected systematically then these designs effectively become cluster plots.
- Better to use a multi-stage design than to undertake a low intensity sample of whole area as you at least have good data within the largest sampling units.

Double sampling

Independent selection of two different samples selected from the same population of individuals with the objective of measuring different characteristics in each sample. Often there is at least one character in common which can be used in regression-type models to predict a character that is more difficult to measure from a simpler one. E.g. using an independent, small sample of trees for which fruit yield is measured, this information used to interpolate fruit yields from a larger sample of trees for which only diameter is measured. Choose designs most efficient for each type/scale of sampling. The two inventories are related using ratio or regression estimators.

b) Emerging sampling designs

Adaptive sampling

General class of methods in which the number of plots sampled responds to the occurrence and number of individuals encountered during sampling.
Features:
+ Efficient (precise and cost-effective) and unbiased sampling strategy for rare, clustered or spatially uneven populations;

+ Increases numbers of observations for a given sampling effort than SRS[2];
+ Locates and incorporates local hot spots;
- Cannot know number/cost of sampling at start of exercise;
- Special calculations of mean and variance required.

Adaptive cluster sampling - Method for locating and recording the size and composition of clumps in heterogeneous populations. Start with a low intensity sample and when the item of interest is located, add additional samples until you run out of individuals to sample. This forms a cluster of plots.
It is especially useful where density is clumped across large areas, allowing maximum number of individuals to be sampled for minimum sampling effort. A drawback is that additional plots may get disturbed through the sampling of the first. The principle is that the plot data are aggregated so the whole clump becomes the sample unit, so it does not matter if the plots touch. A problem is that you do not know how long or how expensive the inventory will be until you have finished.

Variants which may suit different situations are:

Initial simple random sample. Add plots (usually adjacent to 'filled' plot in a fixed pattern, recommended in a cross configuration) whenever a plot contains more than a threshold number of individuals (adding rule) stop adding when all new plots do not satisfy the adding rule.	+Forms clusters of sample plots that grow towards local maxima and completely include aggregations of individuals
Initial strip samples (plot clusters grow sideways from strip once species is discovered)	+Good for covering large areas
Initial systematic sample (with random starting point)	+Very efficient for rare, clustered populations
Order statistics adding rule (adding rule uses rank order of samples i.e. if new plot has density > 4th highest then add new plots)	+Population of unknown density for which an a priori adding rule cannot be determined - Computations more involved
Stratified: (1) Clusters not allowed to cross strata boundaries (2) Clusters allowed to cross strata boundaries	+Permits use of prior information (1) Strata independence maintained (2) More efficient but requires special calculation of mean
Adjusted for imperfect detectability: (1) Constant detectability (2) Variable detectability	+Good for motile or cryptic organisms -Uses non standard mean and variance calculations

Adaptive allocation - Two stage adaptive designs. Take initial sample in a conventional manner. Allocate next set of plots according to the density of target trees in first set of plots. This permits the final number of plots to be known in advance. Approaches include:

Sample sizes based on initial observations in each stratum: Stage 1: Area divided into strata and SRS (or other allocation system) used in each strata Stage 2: More plots added using SRS (in proportion to number of plots per strata that qualify on adding rule or to minimize estimated final variance)	+Maximizes the value of pilot studies +Permits collection of additional data in areas discovered to have high population density without compromising design +Costs easier to control -Requires two passes over study area -Small negative bias in estimates for total pooled sample

[2] SRS – simple random sampling

Sample size based on observations from previous strata (sequential SRS of strata; allocation of plots to subsequent strata based on adding rule and observations in previous strata)	+Only requires one pass +Good for sampling across large scale environmental gradients, e.g. mountain slopes where target species may be confined to certain altitude zones +Traditional stratified SRS calculations apply

Subjective - **Rank set sampling**. Novel technique that is actually unbiased and efficient. It ranks plots laid out in groups at different locations according to average value (e.g. size) of the measured characteristic. For example, three plots could be laid out in each of three sample locations. At each location the three plots are ranked (high, medium, low) according to density of the resource species. At the first location, the high density plot is measured, at the second the medium, and at the third the low density plot is measured. The mean of the three measured plots is used for calculating overall estimates about the population. It is useful where there is a lot of local variation, avoids bias and can potentially use local knowledge. This needs further development for use on NWFPs.

Features:
+ Gives unbiased estimates and better precision than SRS of same sample size
+ Works best for populations with high local variability and can be tailored to match the level of local variability
+ Permits the incorporation of subjective knowledge
- Requires visual comparison of plot sets for ranking so they must be close together
- Cost of locating plots for ranking needs to be small compared to cost of enumeration

Guided transect sampling. A two-stage unbiased design for transect survey utilizing high resolution prior information.
Stage 1: Wide strips laid out as primary units and divided into grid-cells of suitable dimensions for which prior information, i.e. remote sensing is available.
Stage 2: One survey line for subsampling per strip is randomly selected. The grid-cells that will form the route of the survey line are selected with probabilities proportional to their covariate values. The strategy for selecting cells can be varied.
Along selected lines the inventory is performed using some transect based method such as line transect sampling, strip surveying, line intersect sampling, etc.

Features:
+ Can use high resolution a priori data, i.e. classified pixels from remote sensing interpretation
+ Better alternative to gradsect sampling, etc., as line selection is based on probability rather than subjectivity
+ Good for sparse populations
- Requires large amounts of detailed prior information

Further reading

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Annex 5. Useful institutions and Web sites

Material from a range of resource institutions informed the original review. These are available to further your knowledge in this area, some of which have useful Web sites.

Institution	***Web site***
AERDD, University of Reading	http://www.rdg.ac.uk/AERDD/
Afrirattan	www.africanrattanresearch.fsnet.co.uk
Birdlife International	http://www.wing-wbsj.or.jp/birdlife
Bushmeat Crisis Taskforce	www.africanrattanresearch.fsnet.co.uk
CABI Online Publishing	http://www.cabi.org/Bookshop/Readingroom/
CARPE – Central African Regional Programme	http://carpe.umd.edu/
Centro Agronomic Tropical de Investigación y Enseñanza (CATIE)	http://www.catie.ac.cr/research/research.asp
Centre for International Forestry Research (CIFOR) -*Criteria and Indicators*	www.cifor.cgiar.org/ *www.cifor.cgiar.org/acm/methods/candi.html*
Conservation International	www.conservation.org/
Department for International Development (DFID), United Kingdom	http://www.dfid.gov.uk/
Department of Forestry, University of Aberdeen	http://www.abdn.ac.uk/~for257/forestry.hti
European Forest Institute - *Certification information service*	www.efi.fi www.efi.fi/cis
European Tropical Forest Research Network (ETFRN) – *NWFP workshop report*	www.tropenbos.nl *www.etfrn.org/workshops/index.html*
Falls Brook Centre, Canada (Certification of NTFPs)	http://www.fallsbrookcentre.ca/programs/International/certmark/certmark.html#ntfp
FAO	www.fao.org
Institute for Culture and Ecology - NTFP programme	www.ifcae.org/ntfp
Institute of Ecology and Resource Management, University of Edinburgh	http://www.ierm.ed.ac.uk/ierm/research/index.htm
Instituto Nacional de Biodiversidad (INBio) - *inventory*	www.inbio.ac.cr/en *www.inbio.ac.cr/en/inv/invent.html*
International Institute for Environment and Development (IIED), London	www.iied.org
International Union of Forest Research Organisations (IUFRO)	http://iufro.boku.ac.at/
IUCN, Sustainable Use Initiative	www.iucn.org/themes/sui/
Natural Resources Institute (NRI)	http://www.nri.org/Themes/forest.htm
New York Botanical Garden - *herbaria information*	www.nybg.org *www.nybg.org/bsci/ih/*
Overseas Development Institute (ODI)	www.odi.org.uk/fpeg/rdfn
Oxford Forestry Institute (OFI)	www.plants.ox.ac.uk/ofi
ProFound: Advisers in Development - NTFP information	www.thisisprofound.com/ www.ntfp.org
Royal Botanic Gardens, Kew Royal Botanic Gardens, Edinburgh	www.rbgkew.org.uk/ www.rbge.org.uk/
School of Agriculture and Forest Sciences, University of Wales	http://www.safs.bangor.ac.uk
Statistical Advisory Centre, University of Reading	www.rdg.ac.uk/ssc
Tropenbos, NTFP Programme, University of Wageningen, the Netherlands	www.tropenbos.nl/tropenbos/thementfp.html
Tropical Forest Forum (United Kingdom)	www.nri.org/TFF/forumfra.htm
University of St. Andrews, RUWPA	www.ruwpa.st-and.ac.uk

Downloadable DISTANCE software	www.ruwpa.st-and.ac.uk
USGS Biodiversity monitoring program *Downloadable MONITOR software*	www/mp1-pwrc.usgs.gov/powcase/index.html
UNEP World Conservation Monitoring Centre	www.unep-wcmc.org
UNESCO, People and Plants Initiative	www.rbgkew.org.uk/peopleplants
Wildlife Conservation Society	www.wcs.org

This publication is intended as reference material for practitioners considering inventory of non-wood forest product (NWFP) resources. Through review and analysis of experience it provides an overview of biometric issues in the design of NWFP inventory in the following areas: a description of the range of approaches used and developed to date and their biometric adequacy; and a suggested method for selecting appropriate biometric methods for resource quantification in different situations and for different products.

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