Working Paper
Document de Travail
FOPW/03/6

FORESTRY DEPARTMENT
DEPARTEMENT DES FORETS

NON-WOOD FOREST PRODUCTS PROGRAMME
PROGRAMME PRODUITS FORESTIERS NON LIGNEUX

SUMMARY OF SIX CASE STUDY REPORTS AS A CONTRIBUTION TO DEVELOPMENT OF PRACTICAL TECHNIQUES TO ASSESS NON-WOOD FOREST PRODUCT RESOURCES

RESUME DE SIX ETUDES DE CAS CONTRIBUTION A L'ELABORATION DES GUIDES PRATIQUES D'EVALUATION DES PRODUITS FORESTIERS NON LIGNEUX

May / *Mai* 2003

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EUROPEAN COMMISSION - FAO PARTNERSHIP PROGRAMME
TO SUSTAIN FOREST MANAGEMENT IN AFRICAN ACP COUNTRIES

PROGRAMME DE PARTENATIAT COMMISSION EUROPEENNE - FAO
DE GESTION DURABLE DES FORÊTS DANS LES PAYS ACP
D'AFRIQUE

Edited by
Jenny Wong, François Ndeckere-Ziangba and Daniel Pouakouyou

May / *Mai* 2003

Acknowledgements - Remerciements

This report would not have been possible without the contributions and support from the case study authors especially the forbearance of Gerald Meke, Fabien Malambo, Saloman Belinga and Ben Chikamai. The FAO staff involved with this project were Michel Lavadiere, Paul Vantomme Sven Walter, Tina Etherington and Laura Russo. Major contributions to the evolution of the case studies came from Kevin Mawdlesley, Daniel Pouakouyou and Nell Baker.

The following people who assisted with the field studies deserve special thanks:

Benin - Nos sincères remerciements à tous ceux et celles qui nous ont apporté leur soutien dans la réalisation de cette étude, et plus particulièrment Madame Christine OUINSAVI, Ingénieur Agronome Forestier Aristide ADOMOU, Botaniste.

République Centrafricaine - Que tous ceux et celles qui ont d'une manière ou d'une autre nous ont apporté assistance pour réaliser les travaux de cette étude soient sincèrement remerciés, notamment les collègues du Projet Ecofac ainsi que ceux du Ministère des Eaux, Forêts, Chasses, Pêches , Environnement et Tourisme.

Cameroon - Nous ne saurons oublier le personnel d'appui sans lequel les travaux de terrain n'auront pas été réalisés et qui s'est manifesté par son endurance, sa patience et son abnégation au travail. Pour ce, nous adressons notre profonde gratitude à un remerciement particulier à l'endroit de Madame Tchamda Anne pour son application dans la saisie de ce rapport Monsieur OM Bilong, Conservateur de la réserve de Lokoundjé-Nyong pour les facilités qui nous ont permis de réaliser notre étude.

Kenya - We are greatly indebted to the farmers who allowed the data for this research to be collected in their fields at no costs and the staff of KEFRI in Kibwezi Field Station for their generous support and facilitating the fieldwork. Messrs Muchiri and Musya deserve special mention for taking most of the measurements and Messrs Mwambaka and Muumo for climbing the trees without any reservations despite the many myths associated with the Baobab by the local people.

Malawi – The villagers, mushroom collectors and traders who gave of their time and knowledge.

Zambia – The students of Copperbelt University and the long and short term inhabitants of Mwekera forest.

Finally, special thanks are due to Tina Etherington of the FAO NWFP Branch who wholeheartedly supported this work and without whom it would not have been possible.

Abbreviations

ACP	Africa – Caribbean – Pacific
DFID	Department for International Development
ETFRN	European Tropical Forestry Research Network
FAO	Food and Agriculture Organization of the United Nations
FRIM	Forest Research Institute of Malawi
FRP	Forest Research Programme
GPS	Geographical positioning system
KEFRI	Kenya Forestry Research Institute
ICRAF	International Centre for Research in Agro forestry
MINEF	Ministère de l'Environnement et des Forêts
NWFP	Non-Wood Forest Products
ONADEF	Office National de Développement et des Forêts
PFNL	Produits Forestiers Non Ligneux

d	Diameter at breast height
UR	Relascope unit
SD	Standard deviation

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1 Introduction

NWFPs are an important component of food and livelihood security in ACP countries. The development and sustainability of these resources depends upon judicious management which stay within the limits of production. Many NWFPs are wild species where production levels are determined by ecological processes rather than cultivation. Management of such resources depends upon the determination of harvesting practices and levels which do not compromise the ecological processes on which continued production depends. In many societies close to their forests, traditional knowledge and practices are often ecologically sustainable and can provide a basis for management. However, for many resources there may be no appropriate traditional knowledge, commercial demand may have outstripped traditional subsistence levels or there is a need for scientific justification for harvesting levels. In these circumstances it is important to employ scientific approaches to the collection of information of the species abundance and ecology to provide a basis for rationale management planning. Science is not a panacea but can at least provide an objective and replicable framework for data collection. It is this objectivity, along with quantifiable precision which are the cornerstones of a scientific or biometric approach to information acquisition.

An expert workshop held in Rome in May 2000 (Baker, 2001) confirmed that there are few biometric protocols available or used in NWFP management plans. This is partially because existing forest inventory techniques are not suitable for use with NWFPs and also because there has been little cross-over from other disciplines. Amongst the conclusions of the workshop were the following points:

- a need to increase awareness of the desirability of sound assessment of NWFP populations and dynamics when considering the utilisation of these resources,
- a clear expressed need from field workers for NWFP inventory methods that are simple and easy to use but at the same time are adequate for the determination of harvest levels,
- further work by inventory specialists on the development of inventory methods and protocols for NWFPs is required, drawing on methods that currently exist in a variety of disciplines,
- there is an urgent need to provide advice on existing NWFP inventory and analysis methods to field workers.

In response to these requests the FAO undertook to develop guidelines for NWFP inventory in the ACP region focussing on Africa under component 4 'Development of techniques to assess non-wood forest products' of the FAO/EU partnership programme 'Sustainable forest management in African ACP countries' (GCP/RAF/354/EC). These guidelines, when complete, will help to meet the need for advice. Two expert meetings were convened, one in Lusaka on the 15-17 October 2001 and the other in Yaoundé on the 11-14th February 2002. Subsequent to these meetings six case studies in NWFP biometrics were commissioned. The problems to be addressed in the case studies and suggestions for methods to try where agreed at the meetings and were as indicated in Table 1-1. For each case study a novel method or approach to the problem was used some more successfully than others. Each case study is reported along with example analyses to indicate the usefulness of such data.

Table 1-1 Case studies in NWFP assessment

Country	Species	Topic	Problem
Benin	Kinkeliba	Leaf yield per shrub	Shrubs which form a continuous canopy are difficult to count – how could leaf biomass on a shrub canopy be measured?
Cameroon	Johimbe	Bark mass per tree	Normally, only the bark on tree boles is measured, but it would be useful to be able to estimate branch bark volumes – how might this be done?
Central African Republic	Poto (eru)	Plant density per ha	These lianas are difficult to locate and are loosely clumped in the forest – how can they be sampled efficiently?
Kenya	Baobab	Fruit numbers per tree	Counting fruit on large trees is time consuming and difficult – is it possible to efficiently sample within a tree crown?
Malawi	Edible mushrooms	Seasonal cap yield per ha	Objectively chosen sites do not seem to reflect the abundance or variety of mushrooms in the market – could the use of local knowledge improve on the representiveness of field monitoring data?
Zambia	Tree fruit and bulbous herbs	Plant density per ha	What are the costs and benefits of optimising sampling for specific species over using a standardised design for all species?

This document reports on the findings of these case studies, draws out the lessons learnt and makes some recommendations for further development of the guidelines. It will be of interest to those needing to tackle similar inventory problems to those investigated in the case studies as well as those seeking inspiration for diversifying their approaches to NWFP inventory.

The case studies and lessons presented in this document represent a field testing stage in the development of FAO Guidelines for NWFP assessment. This document is in development and will draw heavily on the case studies as examples and as sources of sample data. The generic lessons related more to the delivery mechanism for the Guidelines and suggest that a comprehensive training and support programme will be needed to complement any literary based manual.

2 Quantifying leaf resources of *Combretum micranthum* populations in Benin *

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2.1 The product

Combretum micranthum D. Don (Combretaceae), locally known as Kinkeliba, is a small tree or a shrub, 2 to 4 m tall, but can also attain 20 m. Its natural distribution range stretches from Senegal and Mauritania to Nigeria and Niger where it occurs naturally in the sahelo-sudanian and sudanian savannas. *Combretum micranthum* is a multi-purpose species extensively used in the sahelian regions such as Mali, Niger and Senegal where leaves are specially used not only as tea, but also for medicinal purposes. The notes condensed below describe the methodology used in the assessment of the species abundance in savanna woodlands of Northern Benin and an attempt to quantify leaf yield from areas where it has been located.

2.2 Sampling design

A preliminary survey of the study site was conducted in five line transects laid out at 5 km interval in the Atacora Division, northern Benin. A number of plots of unspecified sizes were established along the transects for a rapid appraisal of the main habitats and the distribution patterns of *Combretum micranthum* in this part of Benin. The information generated from this rapid reconnaissance work indicated that the species was rare in the study area and occurred in patches in five main habitat types: on hill slopes, lateritic slabs, anthills, dense dry forest and gallery forest along rivers. Based on these findings, the author ruled out any random or systematic approach, on the ground that either sampling design would result in no or very few individuals of *Combretum micranthum* being captured in the sample plots.

The Braun-Blanquet method of vegetation classification which is somewhat subjective was adopted. Sampled quadrats of variable sizes and shapes were purposely laid out in areas where individuals of *Combretum micranthum* were found. The size of the quadrats, rectangular or square in shape, varied from 20 m^2 to 25,000 m^2 and was determined using the "minimum area" concept. In total, 26 quadrats distributed within 44 transects (0.5 to 5 km long and 100 to 150 m wide) were established.

2.3 Data collection

The inventory consisted in a complete enumeration of all plant species present in each quadrat. A coefficient of abundance-dominance and the presence was attributed to each species in relation to its degree of cover and its frequency in the quadrat. The cover and the frequency scale were defined as follows:

Cover scale	Frequency scale coefficients
+ less than 1% cover	I (frequency < 20%)
1 (1-5% cover)	II (20-40% frequency)
2 (5-25% cover)	III (40-60% frequency)
3 (25-50% cover)	IV (60-80% frequency)
4 (50-75% cover)	V (80-100% frequency)
5 (75-100% cover)	

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* "Original report done in French." For more details please contact FOPW webpage.

The diameter and the height of all individuals of *Combretum micranthum* $\geq$ 2 cm at 10 cm above ground level were measured in each quadrat. Individuals with a diameter < 2 cm, considered as recruits, were all counted within the quadrat.

The quantification of leaf production consisted in a random selection of one to three clumps of *Combretum micranthum* in each quadrat. A stem of average height was then selected from the sampled clump and the number of leaves on the stem counted. Sampled of leaves were taken and dried in an oven for 48 hours in order to determine the dry weight.

2.4 Data summarisation and analysis

Data on the species presence or absence from a quadrat were subjected to a multivariate Detendred Canonical Analysis. This allowed the identification of the different plant associations of which *Combretum micranthum* was part.

The species diversity was studied for each plant association on the basis of the species richness and the Shannon diversity index.

The species richness is the total number of species in the association under consideration.
The Shannon diversity index is obtained through the formula: $ISH = - \Sigma\ N_i/N.\log_2 (N_i/N)$ where N_i is the total number of individuals of species $_i$ and N is the total number of the species present in the association under consideration. A high value of ISH implies that environmental conditions in the site are favourable for plant growth, a situation that results in a high number of species and a reduced number of individuals within a species. Conversely, a low value of ISH suggests unfavourable environmental conditions that induce a high level specialisation characterised by a reduced number of species and a high number of individuals for a species.

Pielou equitability index was also calculated as $EQ = ISH/\log_2 N$. This is the ratio of the Shannon index obtained to the maximum diversity possible. It fluctuates from 0 for a species with high cover on very selective sites to 1 when all the species display the same importance.

The population dynamic was studied through the density of the regeneration and the population structure.

Leaf yield was estimated as the product of the mean density of *Combretum micranthum* stems per quadrat and the weight of the leaves produced. These data were sorted into the different plant association in order to ascertain the impact of some ecological variables such as climate and soil types on leaf production.

2.5 Discussion and conclusions

This study discovered that *Combretum micranthum* was relatively rare in the study area so that conventional inventory designs (random and systematic plots) where not likely to produce reliable results. It was therefore decided to modify a phytosociological sample design. Such designs are intended to characterise the species composition of vegetation communities. Consequently plots are subjectively placed to 'represent' communities and are made large enough to capture the majority of species at the site and are of variable size. In this case study these plots where deliberately placed in *Combretum micranthum* patches. Such plots are consequently highly biased and although they provide a useful impression of the composition of the communities within which *Combretum micranthum* is found it is not a good basis for quantifying resource availability. This is because the figures are the density of *Combretum micranthum* where it is found so in order to bulk up to the quantity in the area it is necessary to map the vegetation community which is usually problematic and costly. Furthermore, replicate plots in each vegetation type would be required. It is therefore not ideal to base inventory on phytosociological sampling strategies without considering these issues.

3 Techniques de quantification des Ecorces du *Pausinystalia yohimba* Pierre ex Beille (Johimbé) dans la forêt de Lokoundjé-Nyong au Cameroun *

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3.1 Objectifs

L'Union Européenne et la FAO ont lancé un programme de partenariat pour assister les Pays ACP d'Afrique dans le cadre de la gestion durable des forêts du continent à travers le Projet GCP/RAF/354/EC. Le volet N ° 4 de ce projet vise le développement des techniques d'évaluation des ressources de produits forestiers non ligneux (PFNL). Cette idée a émané du constat de l'insuffisance des méthodes biométriques devant présider à la quantification de ces produits. Dans l'exécution des activités de ce volet, la réunion d'experts des Pays ACP Francophones d'Afrique tenue du 12 au 15 février 2002 à Yaoundé a retenu le *Pausinystalia johimbe* (Johimbé) comme espèce suscitant une attention quant'à la méthode de quantification de la production d'écorce. La forêt de Lokoundjé-Nyong a été choisie comme site devant abriter cette étude de cas avec les objectifs spécifiques suivants :

Développer les techniques appropriées de quantification de l'écorce du Johimbé au niveau du fût et des branches;
Tester ces techniques sur le terrain et mettre en place un outil statistique d'analyse des données;
Déterminer la quantité d'écorce au niveau du fût et des branches.

3.2 Présentation de la zone d'étude

La zone d'étude est le massif forestier de Lokoundjé-Nyong. Ce massif est situé dans la partie méridionale du Cameroun (entre les latitudes 3°07' et 3°36' Nord et les longitudes 10°04' et 10°33' Est), à cheval entre les Départements de l'Océan, du Nyong et Nkellé et de la Sanaga Maritime. Dénommé 'Forêt Pilote Lokoundjé-Nyong', ce massif qui couvre une superficie de 163.958 ha incluant la zone agroforestière, est une réserve forestière classée comme forêt de production dans le domaine privé de l'Etat (Décret N° 97/073/PM du 5 février 1997). Il est de ce fait considéré comme Unité Technique Opérationnelle (UTO) de première catégorie.

La classification phytogéographique de Letouzey place ce massif forestier dans le domaine de la forêt dense humide toujours verte *(simpervirente)* guinéo-congolaise, dans le secteur forestier toujours vert nigéro-camerouno-gabonais et dans deux districts: le district atlantique biafréen avec sa forêt typique à Caesalpiniaceae et dans une moindre mesure le district atlantique littoral.

Le climat est en général du type équatorial guinéen à 4 saisons et plus particulièrement de la variante équatoriale maritime du fait de la proximité de la mer. Les moyennes pluviométriques annuelles sont de 2 252 mm/an à Eséka, 2 597mm/an à Edéa et 2 971 mm/an à Kribi. Les températures sont élevées et de faible amplitude. Les moyennes annuelles sont de 25,0°C à Eséka, 26,2°C à Kribi et 26,5°C à Edéa. La majorité de la zone est située à une attitude en dessous de 200 mètres avec cependant quelques pics culminant entre 488 m et 670 m. la zone est formée en majorité de matériaux précambriens d'origine métamorphique (micachistes, gneiss, quartzites et granites) et dans les basses altitudes, des matériaux d'origine sédimentaire (Sandstones, silts et limestones). Ce matériaux ont donné naissance en majorité aux sols ferralitiques fortement désaturés, appauvris, jaunes sur roches acides

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* "Original report done in French." For more details please contact FOPW

(oxisols) et parfois entrecoupés des sols hydromorphes ou des sols peu évolués (Entisols) dans les marécages, les abords des vallées et les pentes très raides érodées.

Sur le plan socio-économique, 31 villages se trouvent dans la zone d'étude. La population totale est de 7812 (recensement de 1987) personnes pour une moyenne de 252 personnes par village. On dénombre un total de 1603 ménages pour une moyenne d'environ 5 personnes par ménage. L'agriculture est l'activité principale pratiquée dans tous les villages. La chasse, la pêche, le petit élevage, la cueillette, la récolte du vin de palme et dans quelques rares cas l'artisanat sont des activités qui, selon les saisons et à des dégrés divers viennent compléter l'agriculture. Les villageois utilisent de nombreux produits forestiers non-ligneux que ce soit pour l'alimentation, la pharmacopée, la construction ou l'artisanat. La plupart sont exploités pour un usage strictement domestique tandis que certains le sont dans un but commercial.

3.3 Connaissance de la ressource

Le Johimbé ou Johimbo, de nom scientifique *Pausinystalia yohimba* Pierre ex Beille est de la famille des Rubiaceae. Il est remarquable par son fût très cylindrique, droit, élancé et légèrement empatté à la base (voir photos de couverture). C'est un grand arbre à feuillage sempervirent atteignant 35 m de haut et 145 cm de diamètre. Sa cime est hémisphérique, compacte, à branches plus ou moins horizontales et verticillées. L' écorce grise, avec des taches vert-noirâtres, a un goût très amer. Elle est lisse chez les jeunes sujets puis devient rugueuse chez les grandes tiges. Elle est légèrement écailleuse et se desquame en plaques plus ou moins allongées laissant des cicatrices rouge vif. La tranche épaisse de 1 à 2 cm, rose-violet à brun, parfois à couche interne jaune est fibreuse et assez dure. L'odeur de l'écorce est faible et elle a un goût très amer typique. Les feuilles simples et entières sont opposées-décussées. Leurs pétioles sont longs de 1,5 à 2,5 cm et très épais. Les scipules sont caduques. Les fleurs, petites et blanches, ou parfois jaunâtres sont de longues panicules terminales et axilaires. Les fruits sont des capsules de 1 à 1,5 cm de long contenant plusieurs graines ailées d'environ 5 mm de long. Le bois est jaune-or, dur et lourd.

L'analyse chimique de ces écorces revèle qu'elles sont riches en alcaloïdes (5 à 12 %) dont le principal est la Johimbine (Betz et Al 1995, Pousset 1992 ,Tyler 1995). La Johimbine est vasodilateur et hypotenseur. La vasodilatation est surtout marquée au niveau du bassin et des organes génitaux (Pousset, 1992). La Johimbine est connue depuis plus de 70 ans dans le traitement des difficultés sexuelles aussi bien chez l'homme que chez la femme (Riley, 1994). Aux Etat-Unis, l'écorce du Johimbé a recemment été identifiée comme une alternative aux stéroïdes anabolisants dans l'augmentation de la performance des atlètes (Betz *et al*, 1995). La concentration en Johimbine est plus élevée dans le matériel végétal (7 089 ppm) que dans de nombreux produits fabriqués à partir de cet alcaloïde que l'on rencontre sur le marché (0,1 à 489 ppm) (Betz *et al*, 1995). L'écorce est peu toxique mais une dose élevée peut provoquer des troubles tels que l'hypotension (Pousset, 1992).

3.4 Métodologie de l'étude

3.4.1 Dispositif d'échantillonnage de l'inventaire de 1995

Un sondage systématique a été réalisé à un taux de 0.5%. Les layons étaient équidistants de 4 km et supportaient les parcelles-échantillons contigües de 0,5 ha chacune (250 m x 20 m). Au total, il y avait 31 layons orientés suivants 4 directions magnétiques. Ces layons, distribués dans 3 UC (Tableau 3-1), étaient perpendiculaires à la direction générale des cours d'eau de façon à rencontrer le maximum de formations végétales. La matérialisation de ce dispositif est présentée sur la carte dénommée "plan de sondage".

Tableau 3-1: Description du plan de sondage de l'inventaire d'aménagement de 95 (ONADEF, 1995)

UC1 (65.266 ha)				**UC2 (51.910 ha)**				**UC3 (46.783 ha)**			
N° layon	Azimut (°)	N Parc	Distance (m)	N° layon	Azimut (°)	N Parc	Distance (m)	N° layon	Azimut (°)	N Parc	Distance (m)
1	75	35	8 750	13	112	34	8 500	20	112	79	19 750
2	75	44	11 000	14	112	53	13 250	21	292	15	3 750
3	75	126	31 500	15	112	107	26 750	22	112	90	22 500
4	75	69	17 250	16	112	92	23 000	23	112	15	3 750
5	75	53	13 250	17	292	54	13 500	24	112	75	18 750
6	75	31	7 750	18	112	136	34 000	25	292	8	2 000
7	75	24	6 000	19	292	35	8 750	26	112	16	4 000
8	75	34	8 500					27	112	10	2 500
9	75	28	7 000					28	112	50	12 500
10	255	39	9 750					29	112	8	2 000
11	75	8	2 000					30	112	78	19 500
12	255	18	4 500					31	112	36	9 000
Total		509	127 250	**Total**		511	127 750	**Total**		480	120 000

3.4.2 Unité d'échantillonnage

L'unité d'échantillonnage était la parcelle de 0,5 ha (250 m de longueur et 20 m de large). Dans l'inventaire d'aménagement de 1995, 1500 parcelles de 0,5 ha étaient implantées (Tableau 1). Au début de chaque parcelle, dans les premiers cinq mètres sur la longueur, était délimitée une sous-parcelle de 0,01 ha. Parmi les 1500 parcelles, 509 seulement réparties dans les 29 layons contiennent le Johimbé.

3.4.3 Méthode d'étude de la distribution des tiges

Pour étudier la distribution des tiges, nous avions repris les résultats de l'inventaire d'aménagement de 1995 (ONADEF, 1995), compte tenu des moyens et du temps disponibles. Au cours de ces travaux, les sujets de DHP inférieur à 20 cm étaient dénombrés dans des sous parcelles de 0.01 ha et ceux de DHP supérieur ou égal à 20 cm dans les parcelles de 0.5 ha (250 m x 20 m). Les résultats de ces travaux (Tableau 3-2,

Tableau 3-3 et

Tableau 3-4) ne tiennent pas compte de l'accroissement annuel en diamètre des tiges du fait de l'absence des données y relatives.

Tableau 3-2 : Effectif des tiges de Johimbé par UC, par layon et par classe de diamètres (ONADEF, 1995)

UC	Layon	Diam	Tiges	UC	Layon	Diam	Tiges	UC	Layon	Diam	Tiges
01	01	0	1	01	12	3	1	03	20	4	3
01	01	1	14	01	12	5	1	03	20	5	1
01	01	2	9	02	13	1	10	03	21	1	4
01	01	3	8	02	13	2	12	03	22	0	2
01	02	1	15	02	13	3	4	03	22	1	15
01	02	2	11	02	13	4	2	03	22	2	17
01	02	3	7	02	14	1	14	03	22	3	8
01	02	4	4	02	14	2	11	03	22	4	2
01	02	5	1	02	14	3	2	03	23	1	3
01	03	1	51	02	14	4	3	03	23	2	2
01	03	2	37	02	15	0	1	03	24	1	30
01	03	3	13	02	15	1	30	03	24	2	12
01	03	4	4	02	15	2	12	03	24	3	3
01	03	5	1	02	15	3	6	03	24	4	2
01	03	6	1	02	15	4	2	03	25	1	6
01	04	0	1	02	15	7	1	03	25	2	1
01	04	1	41	02	15	9	1	03	25	4	1
01	04	2	24	02	15	13	1	03	26	1	4
01	04	3	7	02	16	0	2	03	26	2	1
01	04	4	6	02	16	1	28	03	27	1	2
01	04	5	1	02	16	2	25	03	27	2	1
01	05	1	4	02	16	3	8	03	28	1	13
01	05	2	6	02	16	4	6	03	28	2	11
01	05	3	2	02	16	8	1	03	28	3	2
01	05	6	1	02	17	0	1	03	28	4	3
01	06	2	1	02	17	1	3	03	29	1	9
01	06	3	1	02	17	2	3	03	29	2	4
01	06	5	1	02	17	3	1	03	29	3	1
01	07	2	1	02	18	0	1	03	29	4	1
01	07	3	2	02	18	1	37	03	30	0	4
01	07	5	1	02	18	2	20	03	30	1	63
01	08	1	1	02	18	3	6	03	30	2	28
01	08	2	1	02	19	1	9	03	30	3	10
01	10	0	3	02	19	2	6	03	30	4	4
01	10	1	29	02	19	3	4	03	30	5	2
01	10	2	25	02	19	4	1	03	31	0	1
01	10	3	14	03	20	0	1	03	31	1	20
01	10	4	9	03	20	1	31	03	31	2	8
01	12	1	9	03	20	2	15	03	31	3	4
01	12	2	4	03	20	3	11				
Total											**1 014**

Il ressort du tableau 2a que 1014 tiges de Johimbé étaient repertoriées lors de l'inventaire de 1995. La répartition des tiges par classes de diamètre est consignée dans le Tableau 3-3. Il est évident de constater qu'aucun sujet n'était recruté dans les classes 110-119, 120-129 et 130-139.

Tableau 3-3 : Répartition des effectifs par classe de diamètres (ONADEF, 1995)

Classes de diamètre	Code de Classe de diamètre	Effectifs
0 à 10	0	18
10 à 29	1	495
30 à 39	2	308
40 à 49	3	125
50 à 59	4	53
60 à 69	5	9
70 à 79	6	2
80 à 89	7	1
90 à 99	8	1
100 à 109	9	1
140 à 149	13	1
Total		**1 014**

La répartition des effectifs par type de strate est consignée dans le Tableau 3-4.

Tableau 3-4: Distribution des tiges de Johimbé en fonction des strates (ONADEF, 1995)

Strates	Significations des symboles des strates	Nombre de tiges
DHSb	Forêt dense humide simpervirente densité forte du couvert	274
DHSbcp	Forêt dense humide simpervirente densité forte du couvert et coupe partielle du bois	99
DHSdcp	Forêt dense humide simpervirente densité faible avec coupe partielle du bois	39
MIT	Forêt marécageuse inondée temporairement	223
Sab	Forêt secondaire adulte densité forte du couvert	277
Sabcp	Forêt secondaire adulte densité forte du couvert avec coupe partielle du bois	12
Sadcp	Forêt secondaire adulte densité faible du couvert et coupe partielle du bois	52
Sjb	Forêt secondaire jeune avec densité forte du sous-bois	37
CU	Culture vivrière	1
Total		1 014

3.4.4 Quantification des écorces du fût

Pour quantifier les écorces des tiges de Johimbé dans la forêt de Lokoundjé-Nyong, on a fait les études de 110 arbres-échantillons tirés des 1014 tiges dénombrées lors de l'inventaire de 1995. La distribution et les caractéristiques de ces sujets sont consignées au Tableau 3-5.

Tableau 3-5: Distribution et caractéristiques des arbres-échantillons

No UC	No Layon	Distance (m)	#parcelles	Classes de diamètre						Strates forestières
				00-20	20-30	30-40	40-50	50-60	60-70	
1	1	1600	7	3	13	13	4	1	0	DHSb
	3	1200	5	4	10	10	4	1	1	MIT/Sab
2	18	1150	5	4	11	8	0	1	0	SJb/DHSb/MIT
	19	950	4	1	15	5	0	1	0	Sab
Total		4900	21	12	49	36	8	4	1	

Pour les études des écorces du fût, les mesures de diamètres à différents points, les hauteurs à ces points et la distance à partir du point d'observation ont été prises.

A l'aide du relascope de Bitterlich, les diamètres ont été mesurés à différents points:

- Au d confondu au diamètre d'abattage (Da);
- Aux trois points équidistants P1, P2, P3 entre le point (Pa) situé au DHP et le point (Pu) localisé à la première grosse branche. Ces diamètres étaient dénommés respectivement D1, D2, D3.

Pour avoir la position des points P1, P2, et P3, les calculs suivants ont été effectués en considérant E comme équidistance: $E = (Pu-Pa)/4$; $P1 = Pa + E$; $P2 = P1 + E$; $P3 = P2 + E$. Les valeurs P1, P2, P3 et Pa sont mesurés en pourcentage (%) et peuvent être positives ou négatives. Les diamètres Da, D1, D2, D3 et Du sont donnés en Unités Relascope (UR) et sont convertis en cm en applicant la formule :

$d = 2.n.D$ où
d = diamètre en cm; n = nombre de grandes bandes;
D = distance d'observation ou de lecture.

Avec le Relascope de Bitterlich, on a pris les hauteurs en (%) aux 7 points: Ps au sol, Pa au niveau du DHP, P1, P2, P3, Pu et Pt à la hauteur totale. La hauteur à partir du DHP jusqu'à la première grosse branche (Hu) au point Pu est obtenue à partir de la formule:

$Hu = (Pu - Pa).dh/100$ où dh = distance entre l'opérateur et le centre de l'arbre (en m).

La hauteur totale (Ht) au point Pt est calculée avec la formule :
$Ht = (Pt - Ps).dh/100$.

L'épaisseur de l'écorce prise au d a été mesurée avec la règle millimètrée en (mm) après prélèvement d'une tranche d'écorce.

3.4.5 Quantification des écorces des branches

Pour l'étude des écorces des branches, 73 branches ont fait l'objet des mesures. Les branches prises en compte sont celles de diamètre ≥ 5 cm et les écorces ont été prélevées au milieu des branches. Les longueurs des branches et les diamètres au niveau des points de mesure ont été enregistrées.

Pour atteindre les branches à étudier, compte tenu de la longueur totale moyenne des tiges (24,95m), 10 tiges ont été abattues avec l'autorisation de l'Administration forestière et 8 tiges cassées par la chute des arbres abattues par l'exploitation forestière en cours dans le site ont été choisies. Ces tiges de Johimbé appartenaient aux différentes classes de diamètres et layons (Tableau 3-6).

Tableau 3-6: Distribution et caractéristiques des branches étudiées (les chiffres entre parenthèses refèrent au nombre total de branches par layon)

No layon	# total tiges
01	7 (17)
03	5 (28)
19	6 (28)
Total	18

Classes de diamètre	# tiges/classes	# branches de diamètre ≥ 5 cm
0 à20	1	1
20 à 30	4	11
30 à 40	4	15
40 à 50	5	20
50 à 60	3	18
60 à 70	1	8
Total	18	73

3.5 *Traitement des données*

3.5.1 Nombre de tiges de Johimbé

Pour déterminer le nombre de tiges de Johimbé dans un certain seuil de probabilité, nous avons calculé la variance, l'erreur d'échantillonnage et l'intervalle de confiance. Dans ces calculs, les symboles suivants ont été utilisés.

- $f = s/S$
- f intensité de sondage (taux de sondage);
- s superficie échantillonnée en hectare;
- S superficie totale en hectare;
- i indice d'une unité (parcelle de l'échantillon);
- n nombre d'unités (parcelles) dans l'échantillon;
- X_i nombre de tiges dans la parcelle i (paramètre à étudier);
- $\hat{\mu}_j = \bar{X}$ estimation de la moyenne du nombre de tiges / ha dans l'échantillon j;
- $V(\mu_j) \hat{=} V(\bar{X})$ estimation de la variance du nombre de tiges/ha dans l'échantilon j;
- σ_x écart type;
- cv coefficient de variation;
- $e_u(\mu)$ erreur d'échantillonnage ou précision commise sur l'estimation de $\bar{X}$ au seuil μ de probabilité en (%).

$$\bar{X} = \left(\sum_{i=1}^{n} X_i\right) / n$$

$$V(\bar{X}) = \sigma^2 = \left(\sum_{i=1}^{n} (X_i - \bar{X})^2 (1-f) / n(n-1)\right.$$

$$\sigma_x = V(X)$$

$$Cv = \sigma_x / X$$

$$e_u(\hat{\mu}) = \pm t_u \, x \sqrt{\sigma^2 / n}$$

Il est entendu que (1-f) tend vers 1 lorsque f < 5%

3.5.2 Calcul des volumes

Calcul du volume des écorces du fût utilisable. Soit :

V_f	volume du fût utilisable avec écorce (m^3);
V_{fse}	volume du fût utilisable sans écorce (m^3);
V_{ef}	volume des écorces du fût (m^3);
e	épaisseur de l'écorce mesurée au DHP (mm);
d_a, d_1, d_2, d_3, d_u	diamètres à différents niveaux (di = 2ndh, n = Nbre d'Unité Relascope
D^h	distance en (m) entre l'appareil et l'arbre;

$$V_f = {}^{Dh}\pi / 8 \; x \; [(P_1 - P_a)(d_1^2 + d_2^2) + (P_2 - P_1)(d_2^2 + d_1^2) + (P_3 - P_2)(d_3^2 + d_2^2) + (P_u - P_3)(d_u^2 + d_3^2)]$$

$$\begin{aligned} V_{fse} = \pi / 8 \; x \; x \; \{ & [(P_1 - P_a)(d_1 - 2e)^2 + (d_a - 2e)^2] \\ & + [(P_2 - P_1)(d_2 - 2e)^2 + (d_1 - 2e)^2] \\ & + [(P_3 - P_2)(d_3 - 2e)^2 + (d_2 - 2e)^2] \\ & + [(P_u - P_3)(d_u - 2e)^2 + (d_3 - 2e)^2] \} \end{aligned}$$

Le volume des écorces du fût est donné par la relation : $V_{ef} = V_f - V_{fse}$

Calcul du volume des écorces des branches
Soit :

V_{eb}	Volume des écorces des branches (m^3);
e	épaisseur de l'écorce des branches (m);
L	Longueur de la branche (m);
V_{eb}	Volume des branches avec écorce (m^3);
V_{bse}	Volume des branches sans écorce (m^3);
d	diamètre de la branche (m);

$V_b = (\pi d^2 \text{ x } L) / 4$ et $V_{bse} = [\pi (d - 2e)^2 \text{ x } L] / 4$.

Le volume des écorces issues des branches est donné par la re lation: $V_{eb} = V_b - V_{bse}$

3.6 *Resultats*

3.6.1 Nombre de tiges à l'hectare

La densité des tiges de Johimbé de 0,34/ha dans la forêt de Lokoundje-Nyong. La variance totale est de 0,01 pour un coefficient de variation de l'ordre de 0.32. L'erreur d'échantillonnage quant'à elle s'élève à 2.8% au seuil de 95%. Ce nombre moyen de tiges à l'hectare est compris dans l'intervalle de confiance [0,33 –0,35]. La généralisation de ces données à l'ensemble du massif donne un effectif total de 55.418 tiges de Johimbé. Si l'on s'en tient à la superficie définitive de cette réserve (129.188 ha - hors mises les zones agroforestières), cet effectif est reduit à 43.666 tiges.

3.6.2 Hauteur des tiges

La hauteur totale moyenne est de 25 m. La hauteur du DHP à la première fourche ou première grosse branche atteint 17,06 mètres (Tableau 3-7).

Tableau 3-7: Hauteurs totales moyennes et hauteurs utilisables des fûts en fonction des classes de diamètre

Classe de diamètre	Hauteur totale moyenne (m)	Hauteur utilisable moyenne (m)
10 à 20	23,44	15,00
20à30	23,74	15,91
30 à 40	23,73	15,70
40 à 50	24,49	17,30
50 à 60	26,32	17,29
60 à 70	28,01	21,25
Moyenne	24,96	17,06

3.6.3 Epaisseur d'écorces et variations

L'épaisseur des écorces du fût varie de 3 mm à 9 mm. Elle est de l'ordre de 6,8 mm en moyenne (Annexe 3). Au niveau des branches, l'épaisseur moyenne est de 4.3 mm et varie entre 3.8 et 4.75 mm (Annexe 4). Dans l'un et l'autre cas, la variation de l'épaisseur en fonction des classes de diamètre n'est pas linéaire (Figure 1).

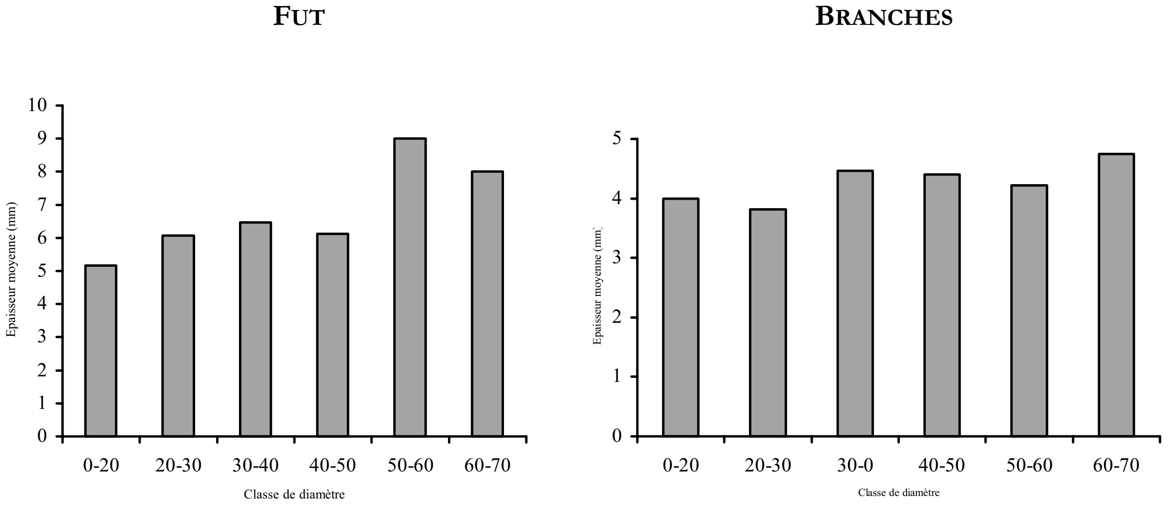

Figure 3-1: **Variation de l'épaisseur d'écorce du fût et des branches en fonction des classes de diamètre.**

3.6.4 Volume des écorces

Le volume moyen des fûts avec l'écorce et sans écorce en fonction des classes de diamètre est donné au Tableau 3-8.

Tableau 3-8: Volume moyen d'écorce en fonction des classes de diamètre

Classe de diamètre	Volume avec écorce (m^3)	Volume sans écorce (m^3)
0 à 10	0,26	0,20
10 à 20	25,13	21.48
20 à30	306,79	269,60
30 à 40	565,08	514,82
40 à 50	214,53	199,80
50 à 60	174,54	160,93
60 à 70	98,78	92,85
Total	1385,11	1259,68

Il ressort du Tableau 3-8 que le volume moyen du fût à partir de 1.30 m du sol, jusqu'à la première branche de la tige est de 12,59 m^3 (1385,11 m^3 / 110 arbres), soit 4,26 m^3/ha. Considéré sans écorce, ce volume est de 11,4516 m^3 (1259,6802 m^3 / 110 arbres), soit 3,87 m^3/ha. Les détails sur les volumes avec ou sans écorce sont consignés en Annexe 5 et 6.

3.6.4.1 Volume de l'écorce du fût

Le Tableau 3-9 donne le volume des écorces du fût à partir de 1.30 m au dessus du sol jusqu'à la première branche en fonction des classes de diamètre des tiges.

Tableau 3-9: Volume des écorces du fût par classe de diamètre

Classe de diamètre	Volume écorce (m^3)
0 à 10	0,06
10 à 20	3,65
20 à30	37,18
30 à 40	50,26
40 à 50	14,74
50 à 60	13,61
60 à 70	5,94
Total	125,43

Il ressort du Tableau 3-9, que le volume moyen de l'écorce d'une tige du DHP à la première branche est de 1,14 m^3 (125,43 m^3/110 tiges), soit 0,39 m^3/ha. Sur l'ensemble du massif inventorié, le volume total de l'écorce est donc de 63193,31 m^3, soit un volume effectif de 49789,05 m^3 en tenant compte de la superficie de la reserve (129 188 ha).

3.6.4.2 Volume des écorces des branches

Les volumes des branches avec écorce, les volumes des branches sans écorce et les volumes des écorces de cette partie de l'arbre sont donnés au Tableau 3-10.

Tableau 3-10: Volume des branches avec écorce, sans écorce et volume des écorces par classe de diamètre

Classe diamètre	Vol avec écorce	Vol sans écorce	Vol de l'écorce m^3
10 à 20	0,20	0,16	0,05
20 à30	0,64	0,55	0,09
30 à 40	0,12	0,11	0,01
Total	0,96	0,82	0,15

Il ressort du Tableau 3-10 qu'une branche a un volume d'écorce de 0,0020 m^3, soit 0,0027 m^3/ha. Considéré sur l'ensemble du massif inventorié (163 959 ha), le volume total de l'écorce des branches est de 442,7 m^3, soit 348,8 m^3 pour la superficie effective de la réserve.

3.6.4.3 Rapport volume de l'écorce du fût et volume de l'écorce des branches

Le rapport volume des écorces des branches et celui du fût (0,0020 m^3 x 4 /1,1403 m^3) est de 0,007 m^3. En d'autre terme, le volume des écorces des branches représente 0,7 % de celui du fût.

3.6.4.4 Relation volume des écorces avec les diamètres des fûts et des branches

Ces relations sont données respectivement par les Figure 3-2 et Figure 3-3.

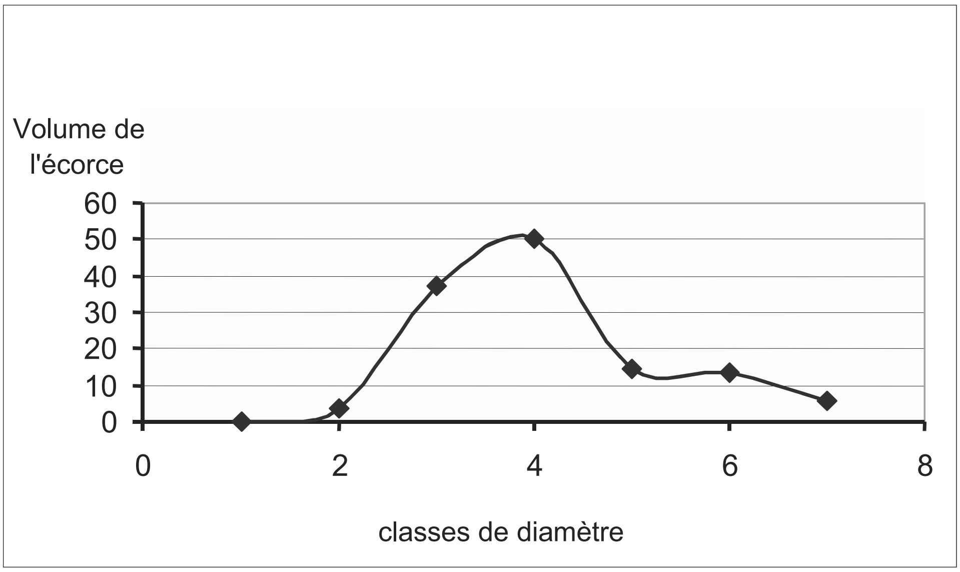

Figure 3-2: Volume de l'écorce du fût en fonction des classes de diamètre

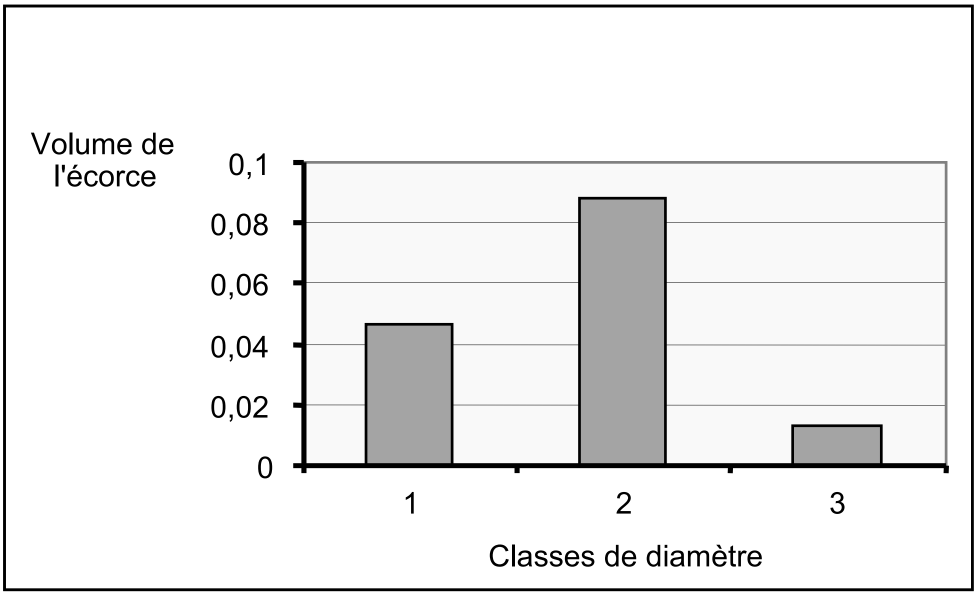

Figure 3-3: Distribution du volume de l'écorce par classes de diamètre des branches.

3.7 Conclusions et recommandations

Au terme de l'étude sur les techniques de quantification des écorces de Johimbé, nous pouvons retenir que les techniques utilisées en se référant aux clés dichotomiques développées lors de l'atélier de Yaoundé, étaient les suivantes:

1. Compte tenu de la superficie grande de la zone d'étude (163959ha), de l'accessibilité plus ou moins facile du site d'une part, de la distribution uniforme et du nombre d'individus attendus se chiffrant à des milliers d'autre part, le dispositif d'échantillonnage systématique a été adopté.C'est celui qu'avait appliqué l'ONADEF en 1995 dans la même forêt à un taux de 0,5%. Ceci est lié aux faibles moyens prévus par la FAO pour l'étude de cas.

2. La ressource (Johimbé) étant un grand arbre des forêts denses, pour la recencer, l'unité d'échantillonnage retenue était la parcelle de surface fixée à 0,5 ha (250m de long et 20 m de large) installée le long des layons. Quatre layons sur 29 de l'inventaire de 1995 qui contenaient le Johimbé ont choisis et réouverts sur 4900 m au total.

3. L'énumération de la ressource a consisté à identifier et à dénombrer les tiges dont le DHP était supérieur ou égal à 20 cm dans les parcelles de 0,5 ha et les tiges de diamètre inférieur à 20 cm dans les sous-parcelles de 0,01 ha installées au début de chaque parcelle de 0,5 ha. Vingt et une parcelles ont été sondées sur 509 renfermant le Johimbé .Ces tiges étaient regroupées en classes de 10 cm d'amplitude.

4. Compte tenu du manque de connaissances sur les accroissements annuels en diamètre devant permettre de maîtriser le passage d'une classe à une autre, la variabilité du diamètre entre 1995 et 2002 a été supposée faible et donc négligeable.

5. Les écorces sont les seuls produits récoltés actuellement sur le Johimbé. Pour la quantifier, on a procédé aux études d'arbres sur un échantillon de 110 arbres répartis dans les différentes classes de diamètres sur une population évaluée à 1014 sujets par l'inventaire de 1995.

Pour quantifier les écorces au niveau de chaque partie, la démarche était la suivante:

Au niveau du fût

On a pris les mesures des diamètres à cinq endroits (au niveau du DHP, à la première grosse branche ainsi qu'à trois points équidistants situés entre les deux premiers), les différentes hauteurs correspondantes et la hauteur totale. Les épaisseurs étaient aussi relevées au niveau du DHP.

Au niveau des branches

Compte tenu de la hauteur des tiges (24,96 m) et de l'inaccessibilité des branches, l'abatttage de dix (10) arbres et l'exploitation de huit (8) tiges trouvées cassées ont été les seuls moyens pour l'étude des branches. Ainsi soixante treize (73) branches de diamètre $\geq$ 5 cm ont fait l'objet des mesures d'épaisseur et de lonngueur.

Les données ont été analysées dans le logiciel informatique EXCEL. Les différents résultats sur les moyennes, la variance, l'erreur d'échantillonnage et les volumes ont été obtenus sur la base des formules préétablies. Une courbe liant le diamètre du fût au volume de l'écorce du Johimbé a été établie. Un histogramme a été établi en ce qui concerne les relations au niveau des branches.

Il ressort de ces opérations que:

- L'erreur d'échantillonnage commise pour le dénombrement des tiges en 1995 était faible, de l'ordre de 2,8% au seuil de probabilité de 95%;
- La variabilité du nombre de tige dans l'échantillon était également faible, avec un coefficient de variation de l'ordre de 0.32;
- Le volume moyen de l'écorce d'une tige de Johimbé est de 1,14 m^3

- Le nombre de tige de Johimbé à l 'hectare est de 0,34. On rencontre beaucoup plus de tiges dans les classes de diamètre 20-30 et 30-40. Le Johimbé atteint les gros diamètres jusqu'à150 cm contrairement aux données de la littérature;
- Le volume de l'écorce du fût croît de façon exponentielle avec le diamètre jusqu'à 60 cm tandis qu'au niveau des branches, il évolue à l'allure logarithmique avec le diamètre;
- Les écorces du fût sont plus épaisses (6.80 mm) que celles des branches (4,30mm);
- En importance relative , le volume de l'écorce des branches représente 0,7% de celui du fût.

Au regard des résultats obtenus par cette étude de cas, les recommendations suitvantes sont formulées:

A. Sur les techniques de quantification

1. Afin de minimiser la variabilité de l'accroissement en diamètre des tiges, il est souhaitable que les études d'arbres visant à estimer la production d'écorce se déroulent au même moment que le dénombrement des tiges.

2. L' étude de l'écorce des branches devrait être faite au cours du déroulement des activités d'exploitation, car ceci éviterait l'abattage inutile des tiges. L'alternative consisterait à une estimation visuelle des diamètres des branches.

3. Les inventaires forestiers en zone de forêt dense s'effectuant pendant les saisons précises de l'année et nécessitent une main-d'œuvre abondante du fait de l'ouverture des layons. Il est nécessaire que les financements tiennent compte de ces particularités et soient débloqués à temps et en quantité suffisante pour garantir la qualité des résultats et minimiser les coûts.

B. Sur la gestion durable de la ressource

4. Compte tenu du pourcentage du volume des écorces des branches par rapport au volume du fût (0,7%), du nombre faible des branches exploitables (4 branches de diamètre ≥ 5 cm de diamètre), de la longueur du fût (17,06 m) et des difficultés d'accés à ces branches, l'abattage des tiges (méthode destructive) en vue de l'évaluation des écorces ou de leur exploitation doit être proscrit sauf autorisation de l'Administration forestière. Dans ce cas, celle-ci procédera au préalable à un marquage des tiges concernées;

5. Dans le cadre de l'exploitation durable des écorces du Johimbé, il est nécessaire de procéder à une exploitation par quotas alloués dans des concessions ayant fait préalablement l'objet d'un inventaire d'aménagement à un taux relativement faible et d'élaboration d'un plan simple de gestion; et ce dans une approche participative;

6. En ce qui concerne le prélèvement de l'écorce (écorçage), à l'instar de l'exploitation des écorces du *Prunus africana* (Hook f.) Kalkman, l'écorçage des tiges doit se faire sur une ou deux bandes opposées à partir de 1,30 m du sol jusqu'à la première grosse branche. Seuls les arbres qui ont atteint 30 cm de diamètre à hauteur de poitrine mesurés à 1,30 cm du sol (DHP) doitvent être écorcés. Ces arbres doivent être numérotés et marqués. Les numéros et les dates d'écorçage doivent obligatoirement être portés dans un carnet délivré par l'administration forestière. Avant l'adoption des techniques d'écorçage, il faudrait faire des essais pour connaître la capacité régénératrice des écorces. C'est ainsi qu'on définira le temps de passage en écorçage sur une même bande de la tige (rotation). En adoptant un Diamètre Minimum d'Exploitabilité(Dme) à 30 cm, les volumes sont donnés au Tableau 3-11 suivant.

Tableau 3-11: Volume des écorces en fonction du Dme

Classe de diamètre	Vol < Dme	Vol ≥ Dme	Volume écorce
0 à 10	0,0588	0,0000	0,0588
10 à 20	3,6480	0,0000	3,6480
20 à30	37,1816	0,0000	37,1816
30 à 40	0,0000	50,2605	50,2605
40 à 50	0,0000	14,7380	14,7380
50 à 60	0,0000	13,6090	13,6090
60 à 70	0,0000	5,9353	5,9353
Total	40,8884	84,5428	125,4312

7. Une étude du marché des écorces du Johimbé incluant la maîtrise des circuits de commercialisation, les prix du kilogramme et les acheteurs devrait être menée pour une meilleure valorisation économique de ce produit.

8. Des études chimiques devraient par ailleurs être menées pour étudier la concentration du principe actif (Johimbine) en fonction des provenances et des parties de l'arbre pour pourvoir adopter les techniques de récolte.

9. Les différents résultats qui proviendraient de la Recherche (temps de rotation, techniques appropriées de récolte, etc.) devront être diffusés auprès des opérateurs économiques et des populations.

4 Quantification of *Gnetum buchholzianum* in the Ngotto forest, Central African Republic *

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4.1 Objectives

Many NWFPs derived from natural high forest are derived from single species which can be rare, difficult to locate and clumped. These features often mean that conventional forest inventory designs are not able to count sufficient plants to obtain reliable estimates of stocking density. Adaptive cluster sampling (ACS) (Thompson 1991) is a sampling design that can be used to locate clusters of plants, concentrate measurements on them while providing an unbiased estimator of stocking density. A trial of ACS on populations of *Prunus africana* on Mount Cameroon (Underwood and Burns 2000) demonstrated that it can provide more efficient data capture and more useful secondary data than conventional strip transects. This case study was intended to test if ACS would also provide advantages for the inventory of a liana in dense forest.

4.2 Product

The product selected for the case study is *Gnetum buchholzianum* Engl. (Gnetaceae), locally called Poto. The plant, together with the closest species *Gnetum africanum,* is a deciduous understorey liana, although in some cases individuals have been found to scramble into the crowns of emergent trees. The product is the oval, leathery leaves which are used as a vegetable. Both species have significant value to many forest-based communities and are distributed in the humid tropical forests from Nigeria through Cameroon, Central Africa Republic, Gabon, Democratic Republic of Congo and Angola. It is a popular nutritious green vegetable across Central Africa and is subjected to considerable cross-border trade that has increased dramatically in recent years, leaving the resource base seriously threatened by unsustainable harvesting methods and the gradual disappearance of the forests in which it thrives.

4.3 Location and site selection

The study was conducted in the Ngotto forest within the area of thr ECOFAC project as shown in

.

Two sites were selected for the present study:

Area 1 - An experimental site covering 31,142 ha created in 1999 at Kindo camp, 6 km north of Ngotto. This site is situated in the middle of the forest and has been subjected to a scientific experimentation and monitoring for four years. The sample sites were located in vicinity of Toandio and Mbam villages.

Area 2 – An area of 38,977.5 ha of natural forest located close to the villages of Baboundji and Grima west of Ngotto.

Within each area there was a mix of forest types though not including swamps or savanna as indicated in Table 4-1. Most of the area contains valuable forest currently being exploited by the concessionaire.

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* "Original report done in French." For more details please contact FOPW webpage.

Table 4-1 Forest types in the selected study areas

Strata	Area 1	Area 2
FD1	6748	12035
FD2	15071	12357
FD3	6639	12768
Mature secondary	-	-
Immature secondary	-	-
Recruit	718.5	516
Degraded forest	761	712.5
Flooded forest	304.5	589
Total high forest	**31142**	**38977.5**

Source : ECOFAC Forest Management Plan

4.4 Methodology

4.4.1 Plot layout

Three or four sample sites were selected at each village to represent vegetation differences. At each site, a 100 m long, variable width 'plot' was laid out. The location, orientation and forest type for each plot is given in Table 4-2. At each site a randomly located 100 m long, variable width 'plot' was laid out. The plot was made up of a 10 x 10 m grid and the number of Gnetum in each grid cell was counted.

Table 4-2 Location of the sample sites

Study area	Village	Transect	Direction	Latitude (decimal degrees)	Longitude (decimal degrees)	Forest type
1	Toandio	PE	220°	03.9782900	017.3712622	Experimental site
		TT1	220°	03.9779145	017.3711333	Young, secondary forest
	Mbam	MT2	240°	03.9485980	017.3942272	Mature, unexploited forest
2	Baboundji	BT1	180°	04.0241397	017.1964466	Forest degraded by fire
		BT2	180°	04.0235282	017.1975569	Forest degraded by fire
		BT3	260°	04.0240860	017.2238920	Regenerating forest Recrû forestier/Jachère ??
		BT4	260°	04.0246653	017.2236925	Forest-savanna boundary ?? Contact forêt-savane/Lisière
	Grima	GT1	0°	04.0168333	017.0456366	Burnt forest
		GT2	130°	04.0246653	017.0956653	Mature, unexploited forest
		GT3	190°	04.0240270	017.0956653	Mature, unexploited forest

The intention was to test ACS which would have required that the transects were much longer (> 1 km) and laid out as a row of 10 x 10 m cells. Side cells should have been added adjacent to cells on the centre line which contained Gnetum. If any of these contained Gnetum further cells are added until no further Gnetum is encountered. In this way the entire clump of plants would be included in the sample. In this case study the central transect was short and the addition of side cells did not continue until no further Gnetum were found. In a sense this was fortuitous as the data reveal high densities of Gnetum and using full ACS may have ended up including impractically large areas of forest.

The design that was used is most properly described as random variable area plots and have been analysed accordingly.

4.4.2 Measurements

The following parameters were measured for all Gnetum encountered:

- The number of stems in the cell
- The number of leaves on a stem

- The number of internodes on a stem
- Length of the stem
- The distance between internodes

In each plot severeal cells were randomly selected and all stems harvested to allow the leaves and the stem residues to be weighed.

4.5 Results

The results which are of most use in assessing the main objective of the case study is the pattern and number of stems counted in each plot as shown in Figure 4-1. Summary data for each plot as used to derived the estimates of total stocking and mean stem density are given in Table 4-3.

Figure 4-1 Distribution of Gnetum stems in sample plots

AREA 1

PE

	3	5	7	4
	3	7	6	6
	4	3	4	7
	4	4	4	5
	6	4	4	6
	4	4	4	4
	4	2	5	5
	2	5	3	5
	8	7	6	6
	13	9	10	6

TT1

			1	5	2	5	3
	4	6		10	6	6	1
	2	4	4				4
		3	3			1	
				1			
				2	3	4	
		12	5	5	1	2	
		4		5	2	2	
	4		4		3		
		3	6	5	5		

MT1

				4	15	7	7	5	
				3	3	8			
	2				3	5	6	5	4
2	4	4		5			2	2	2
6	4	5			7	4	6	2	3
3	2	5	13	1	1	5			
4			2	2	6	5	5	3	2
	3		5	1	5	5	6	3	4
1	10	4	5	5	4	2		3	3
			7	18			4	2	3

AREA 2

BT1

		4			
		8			
			5		
	4				
21				4	11
		1	1		

BT2

8						
	2			3		
		4		4		
			1			
						11
	4					
	7	3	8			
	4		9		7	
3		4	7	9	3	

BT3

		14		
24	7			
9	9		2	6
8		2	5	
9	8			
10			6	
7			4	
2				
	3			
5		2		

BT4

	8	7			
	39				
	14	20			
		9			
		14			
	3	8			
		3			
			5	12	3
	5	4	25	12	9

GT1

				4		3	3	2
		3	14			4	4	5
			4	3	3	5	8	
	8	2	2			3		
	2	5					8	
		16	3	4	2	8		
			5	9			3	
					3			
					9			
					2			

GT2

7	5	7		5	10	4			
		4	3	4	3		3		
	3			2	3	2		2	11
3	7	5	1	5	2	4	4	2	
	5	10		9	4	3			
		13	5	6	2	3	3		
7	9	6	10	6	2		4	5	
	5	4		3	3			4	6
			4		2		2		
3	2	3	5	3			2		

GT3

3	4	3		
4	3	6	4	4
	6			
3	2	2		
	3	4	3	4
2	3			
	7		2	4
2				
4		3		

Table 4-3 Summary plot data

Zone	Vegetation type	Transect	Number of subplots	Plot area (ha)	Number of occupied subplots	Number of stems per plot	Mean stems ha^{-1}
1	Culture/Parcelle expérimentale	PE	50	0.050	40	208	4,160
1	Forêt secondaire jeune	TT1	80	0.080	38	148	1,850
1	Forêt non exploitée adulte	MT1	100	0.100	66	297	2,970
2	Passage du feu/Forêt dégradée	BT1	60	0.060	9	59	983
2	Passage du feu/ Forêt dégradée	BT2	70	0.070	19	101	1,443
2	Recrû forestier/Jachère	BT3	50	0.050	20	142	2,840
2	Contact forêt-savane/Lisière	BT4	60	0.060	18	200	3,333
2	Passage du feu	GT1	90	0.090	32	159	1,767
2	Forêt non exploitée adulte	GT2	100	0.100	60	274	2,740
2	Forêt non exploitée adulte	GT3	26	0.026	24	85	3,269

The data contained in Table 4-3 is best described as a stratified random sample with unequal sized plots. The first step in the analysis it therefore to calculate the mean and variance for unequal sized plots for each strata and then to calculate the stratified mean and variance for both areas together. Since the plots are different sizes the probability of encountering a Gnetum stem is proportional to the size of the plot – it is therefore possible to use the Hansen-Hurwitz estimators for unequal probability sampling as given below:

An unbiased estimator of the population total is $\hat{\tau} = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{p_i}$

with variance $\mathrm{var}(\hat{\tau}) = \frac{1}{n(n\quad 1)}\sum_{i=1}^{n}\frac{y_i}{p_i}\qquad^{2}$

An unbiased estimator of the population mean is $\hat{\mu} = \frac{1}{nN}\sum_{i=1}^{n}\frac{y_i}{p_i}$

with variance $\mathrm{var}(\hat{\mu}) = \frac{1}{N^2}\mathrm{var}(\hat{\tau})$

Where:

N total number of possible sample plots at site
n number of sample plots measured
y_i measure of interest, in this case the number of stems
p_i probability of inclusion for plots n/N where N was estimated as the area of the site
divided by the mean area of a plot

The standard error is $SE(\hat{\mu}) = \sqrt{\frac{\mathrm{var}(\hat{\mu})}{n}}$

and the sampling error as a percent of the mean $SE\% = \frac{SE(\hat{\mu})t100}{\hat{\mu}}$

The stratifed (both areas together) total is given as $\widehat{Y}_{st} = \sum_{h=1}^{L} N_h \bar{y}_h$

with the mean given by $\bar{y}_{st} = \dfrac{\sum_{h=1}^{L} N_h \bar{y}_h}{N}$

and the standard errors as $SE(\bar{y}_{st}) = \sqrt{\dfrac{1}{N^2}\sum_{h=1}^{L}\left[\dfrac{N_h^2 s_h^2}{n_h}\left(1-\dfrac{n_h}{N_h}\right)\right]}$

The results of these calculations are given in Table 4-4. The stratifed total figures are based on the formula given above are the weighted sum of the variance of each strata. The pooled total figures dispense with the strata and treat all ten plots as if they represent a single sample.

Table 4-4 Total and mean stocking of Gnetum using variable sized plots

Statistic	Area 1	Area 2	Stratified total	Pooled total
Area	31,142	38,977.5	70,119.5	70,119.5
Number of plots (n)	3	7	10	10
t value	3.182	2.365	2.228	2.228
Total	93,218,390	91,181,850	184,400,200	177,790,900
Mean ha^{-1}	2993.33	2339.35	2.602.80	2,535.54
SE%	40.93	13.48	21.36	17.34

The stem number data given in Figure 4-1 is the most relevant for the analysis of alterntive sampling designs. The other data are therefore not considered in this report though a summary of the other findings is given in

Table 4-5. The quantity of Gnetum obtained from the 10 transcts was 43 kg from an area of 3.26 ha.

Table 4-5 Quantities of Gnetum in the sample plots

Plot	Superficie	Number of leaves	Biomass of leaves (gms)
BT1	0.09	4,406	2329
BT2	0.19	4,869	2574
BT3	0.20	7,903	4178
BT4	0.18	10,076	5327
GT1	0.32	10,205	5395
GT2	0.60	14,712	7778
GT3	0.24	3,398	1788
PE	0.40	2,487	1314
TT1	0.38	9,808	5185
MT1	0.66	13,493	7133
Total	3,26	81,357	43001

4.6 Evaluation of objectives

The objective of this study was to consider if ACS was a suitable sampling design for Gnetum in Ngotto forest. The distribution patterns of Gnetum stems within the sample plots (see Figure 4-1) shows that these data cannot be analysed using ACS estimators as they do not wholly contain clusters of plants which is a prerequisite for ACS. However, the distributions do suggest that Gnetum clumps must be more than 1 ha in size and probably extend over several hectares. The fact that all plots apparently contained Gnetum also suggests that either the plant is ubiquitous (as suggested by the extremely high densities and totals in Table 4-4) and therefore that ACS wouldn't be needed or else that the plot locations where not as random as reported and they had been selectively placed within Gnetum rich areas or else the whole forest has dense

Gnetum as there are no empty plots. The latter may well be the case as the numbers of the plots in Area 1 are rather low given the ascertion that three to four plots where laid out at each village. These results suggest that further investigtations of whether Gnetum does form clusters and on what scale is required before ruling ACS out completely.

The data collected also permit some investigation of other features of a sampling design suitable for Gnetum, such as the use of stratification and the number and size of plots required.

Stratification is usually employed to improve the overall precision of the mean by splitting the population into homogeneous areas. In this case the strata where administrative units which had different numbers of sample plots which confounds the interpretation of the results. The sampling error (SE%) of Area 1 is higher than that for Area 2 which suggests it is more heterogeneous but it also has only three plots which is really too low for interpretation of this type. The effect of the small sample size for Area 1 is apparent in the higher SE% for the stratified total than for the pooled total where the contribution of the three extra plots is masked. In this case study it would appear that stratification has not improved the precision of the estimates and that the areas should be treated as a single strata. Consideration of the vegetation types of the sample plots from Table 4-3 suggests that a better basis for stratification might be the vegetation types themselves, the data suggests that all of the burnt plots have low Gnetum densities while the unexploited mature forest whether on the savanna boundary or not have high densities. The highest density of all is the experimental plot which has a uniform density of stems suggesting Gnetum has been cultivated at this site. The difficulty with vegetation zone strata is that although they give rise to precise estimates of mean density, bulking up the figures to give totals can be difficult if no maps or area estimates for the strata are available. However, the figures in Table 4-1 show that such a stratification would be possible in Ngotto forest.

The layout of the cells within the plots (see Figure 4-1) meant that it was possible to simulate different sized plots to investigate the relationship between plot size and the estimated means and SE%. One column of cells was selected randomly (using random number tables) from each plot to represent a 10 x 100 m plot. Adjacent columns of cells were added to this to simulate plots of 20, 30 and 40 x 100 m. The means and SE% where then calculated over all ten plots for each plot size as shown in Table 4-6.

The next step in determining the optimal sampling design is to estimate the number of plots required to achieve a target sampling error. The conventional target for forest inventory is 20%.

The plots to achieve a 20% sampling error is given by $n = \frac{4(CV)^2}{(20)^2}$

where CV is the coefficient of variation (standard deviation expressed as a percentage of the mean). The numbers of plots to achieve a 20% sampling error for each plot size is given in Table 4-6. These result mirror plot size; as the size of the plot increases so the number of them required decreases. It is clear that as the plot size increases the estimate of the mean decreases slightly, the precision of the estimate increases (i.e. the SE% gets smaller) and the fewer plots are required. A pragamatic choice of a combination of size and number should be made. In this case it appears that there are few gains to be made for plot sizes greater than 0.3 ha. If this were a pilot study the conculsion would be to use a minimum of 25 plots of 0.3 ha in each sample strata.

Table 4-6 Optimising plot size and number

Plot dimensions	10 x 100	20 x 100	30 x 100	40 x 100	50 x 100
Plot area	0.1 ha	0.2 ha	0.3 ha	0.4 ha	0.5 ha
Mean ha^{-1}	346	288	293	292	267
SE%	58	48	42	42	37
Plots required	48	32	25	25	20

4.7 Conclusions and recommendations

This case study was not able to provide data suitable for ACS analysis, possibility because of the difficulties of undertaking such a design without field demonstration as the design is rather more demanding of field crews than conventional designs. However, the data provided was able to demonstrate that Gnetum clumps must be larger than one hectare in size. Further investigations are required to determine (a) whether Gnetum clumps within suitable habiats and (b) the size of such clumps before judging the merits of ACS for this species.

The sample data was stratified but sample sizes were really too small to be able to draw conclusions but it appears that stratification by administrative area did not confer many advantages. The available information suggested that stratification by vegetation zone may be more efficient.

The data also enabled some analyses for the optimal plot size and number for conventional random sampling design utilising a fixed area plot. The optimal design was suggested as being 25 plots of 0.3 ha located randomly.

5 Testing Techniques to Assess Fruit Yield: The Case of Baobab (*Adansonia digitata*) from the Drylands of Kenya *

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5.1 Objectives

Fruit collected from native trees is a very significant non-wood forest product. Fruits are eaten, processed in edible and non-edible products and used in the manufacture of craft items. As with other products collected from wild populations there is a need to determine sustainable harvesting levels for fruit. The basic data required to underpin sustainable harvesting are reliable estimates of yields. However, quantifying fruit yield is problematic for the following reasons;

Seasonality – need to measure at a particular time of year,

Perishability – may need to measure frequently throughout season as fruit may come and go throughout the season,

Annual variability – yields can vary dramatically between years,

Access/visibility – trees may be large and fruit hidden in foliage.

Perhaps the most basic difficultly in undertaking the inventories and monitoring programmes that could address these issues is the lack of a reliable methodology for quantifying tree fruit yield for large trees. Fruit fall traps can be used for species which drop their fruit, while counts of visible or harvestable fruits can be done on small trees. However, there are no standardised methods for assessing yield of retained fruit from large trees where it is impractical to count all fruit and climbing is required.

The purpose of this study was to develop a simple and reliable method for estimating the numbers of fruit in the canopy of a single tree.

The species chosen for the exercise was Baobab which is large and retains its fruit. A secondary objective was to determine the fruit yield potential of the baobab trees in Kibwezi Division to facilitate development and marketing of baobab products.

5.2 Product

Kenya's dry lands constitute about 80 % of the country's total land area and support 25 % of the population. The majority of the people in the dry lands are pastoralists who rely heavily on the indigenous tree products as a source of firewood, construction material, food, medicine, fodder and income (Arum 1989). Baobab *(Adansonia digitata*) is one of the commonly found and extensively used tree species in the dry lands of Kenya. It has a variety of subsistence, economic, traditional and mystical values across Sub-Saharan Africa (Owen 1999). The species is typically found in the thorny savannah woodlands characterised by attitudes below 1500 metres above sea level, annual rainfall of 200-1500 mm and extended dry periods. One area with such characteristics in Kenya is Kibwezi Division in Eastern province where Baobab is widely distributed and is among the top ten wild fruit tree species that are commonly used by the local communities (Muok *et al* 2000).

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* "Original report done in English." For more details please contact FOPW webpage.

The baobab tree is an imposing large tree (see Fronstpiece) with mean height of 18 m, maximum diameter at breast height of 9 m and can live for 3 000 years (Owen 1999). The fruit is a hard-shelled yellow-brown capsule, typically ovoid and 12-24 cm in length. It hangs on a long stalk and is covered with yellowish-grey velvety hairs. The fruit releases the seed by decay rather than splitting open. Inside the woody shell are many seeds embedded within a white-pink, dry, edible pulp. The baobab fruit shells can be used as a dish for food or liquid when hollowed out. They make good rat-traps and recently, a British company has been using them to make musical shakers. They can also be used as fuel, fertilizer, making soap, smoked as tobacco substitute or added to snuff to increase its pungency. The baobab pulp is very nutritious, with particularly high values of carbohydrates, energy, calcium, potassium, thiamine, nicotinic acid and vitamin C. The vitamin C content ranges from 170-500 mg/100g and is about six times higher than that in the commercial fruit such as citrus (Muok and Ondanchi 2001). The seeds are very nutritious with high values of protein, fat, fibre and minerals (ICRAF 1992 and Owen 1999). The local communities in Kibwezi Division use the fruit to prepare a beverage and chew the pulp leisurely. Sometimes, they dye the white pulp for sale in large supermarkets.

5.3 Location

The study was carried out in the dry thorny savannah woodlands of eastern Kenya at longitude 38°0′ E, latitude 2°30′ S (Figure 2) at an altitude of 880 m above sea level. Mean annual rainfall varies from 500 mm to 1000 mm and is bimodal. The first rainy season is mid March to April while the other season, which is more reliable, is mid October to early December. The dry seasons are January to mid March and August to mid October. Soils are loams and generally ideal for agriculture as they are rich in nutrients and have a free drainage system. The area is sparsely populated and subsistence agriculture is the main form of living.

The selection of the study sites was based on the criteria that they contained populations of fruiting baobab trees. To ensure the sample plots were representative of the structure of the baobab population (high, medium and low densities), study sites were selected by interviewing the local people and confirmed by rapid reconnaissance of the recommended areas. The sites were distributed in a stretch measuring about 60 km × 20 km (1200 km^2) along the Nairobi-Mombasa highway in Kibwezi Division, Makueni District (Figure 5-1). The actual locations of the sample plots were subjective to ensure they contained fruiting baobab trees and were easily accessible. The locations (determined by GPS) of the selected 22 study sites are as shown in (Table 1).

Figure 5-1. A map of the study area.

Table 5-1. Geographical location of the study sites.

Division	Site	Plot	GPS readings*		Altitude (m)
			Eastings	Northings	
Kibwezi	Thange	1	3800343	229433	919
Kibwezi	Machinery	2	3801395	231079	948
Kibwezi	DWA	3	3758555	224354	909
Kibwezi	Ndauni	4	3803126	227569	847
Kibwezi	Mwaini	5	3804370	225566	819
Mtito Andei	Kambu	6	3804116	235451	880
Kibwezi	Usalama	7	3758278	228078	978
Kibwezi	Usalama	8	3759015	227329	950
Kibwezi	Kwa Kisivo	9	3808145	239341	814
Kibwezi	Silanga	10	3805517	236427	830
Kibwezi	DWA	11	3759008	227283	956
Kibwezi	Usalama	12	3757491	225535	955
Kibwezi	Kalamba	13	3758505	223236	893
Kibwezi	Kalamba	14	3759115	222242	875
Kibwezi	Syembeni	15	3759291	221488	910
Kibwezi	Kalulini	16	3759336	220475	888
Kibwezi	Mwembeni	17	3759138	220159	890
Kibwezi	Kivuti	18	3759310	218581	885
Kibwezi	Ukuno A	19	3801321	218011	826
Kibwezi	Tarda farm	20	3804572	222027	765
Kibwezi	Katilamuni	21	3804207	220186	785
Kibwezi	Ukuno B	22	3801457	218426	825

* UTM co-ordinates

5.4 Sampling design and field measurements

The sampling design was a modification of methods used by various researchers (Jessen 1955, Peters and Hammond 1990; Phillips 1993; Gregoire et al 1995; California Agricultural statistics series 2001; and Wong 2001b) with modifications to take into account the architecture of the baobab tree.

5.4.1 Site selection

Study sites were subjectively selected to ensure that a range of tree densities and size where included to reflect the structure of the baobab population. However, the other site characteristics were similar and did not vary much between plots. Because of a lack of information on the structure and ecology of the baobab populations and the characteristically low density of the studied stands, the sample plots were circular and of varying sizes. The plots were located with their centres one metre from a fruiting baobab tree with a radius measured to the middle of the furthest tree less than 100 m from the centre. Thus, the area of the sample plot was an area of a circle with a radius equal to the distance from the centre of the plot to the middle of the trunk of the furthest tree.

5.4.2 Logistics

Sampling was done in July 2002 to ensure that the fruit were ripe and had not fallen off. The field crew comprised of two scientists, two technicians, two professional tree climbers and a driver. The fieldwork (including preparation and reconnaissance) was accomplished in four weeks and 139 trees were assessed in 22 sample plots. Notable difficulties in the field included climbing the trees and counting the fruits during hot sunny days.

5.4.3 Tree measurements

All the sample trees were assessed for the following variables/parameters: bearing and distance (correcting for the slope) from the centre of the plot, diameter at breast height (1.3 m above ground level), total height, crown width and depth. In 19 sites one fruiting tree was randomly selected for fruit counts. In the remaining three sites, two trees were assessed to include some smaller trees and to ensure that the number of cases to be analysed was statistically significant.

The most accurate means of determining yields is to climb the tree and count the fruit directly. However, for large trees this is often difficult even if the tree can easily be climbed or the fruit are visible from the ground. It is obvious that it would be easier in these circumstances to sample the fruit on the tree rather than attempt to count them all. As with all sampling designs, the ideal is have a protocol which is simple to understand, unbiased and gives results within a acceptable margin of error. Randomised branch sampling (Jessen 1955) is a means for randomly selecting a sample branch from a tree crown which should give an unbiased estimate of total fruit in the crown by multiplying the fruit on the branch by its probability of selection. This sampling method is in widespread use for cultivated orchard crops in the United States of America (e.g. California Agricultural Statistics Service 2001). This case study undertook to test randomised branch sampling for use with baobab. To be able to do this it was first necessary to count all fruit on all branches of the test trees to be able to determine the accuracy of the different branch selection methods. Counts of fruit on randomly selected primary and secondary branches were made. The branches to be sampled were selected by numbering the branches arising at a node and then using a random number table to select one for sampling. Primary branches are those which arise directly from the main trunk of the tree while secondary branches arise from primary branches (see Figure 5-2).

Figure 5-2. Diagram of typical branch arrangements on a baobab tree

Fruit counts on the sample trees were made using five branch selection methods as listed in. Although the fallen fruits were counted, they were excluded from the analysis because it was not possible to tell which fruit had fallen from which branch and they were not in any pattern or restricted to certain sample plots.

5.5 Data analysis

The density (number of trees ha^{-1}) of the stands was determined using the data collected in the 22 sample plots using the equation:

$$D = N\frac{10000}{\pi r^2}$$

where;

D	Density (trees per ha)
N	Number of trees in a plot
r	Distance from plot centre to middle of the trunk of the farthest tree (m)

The cross-section area of the tree trunk at breast height and at the base of the branch were calculated from the over bark diameter measurements.

To obtain the total fruit yield of a tree, the following equation was applied:

$$X = \frac{x}{P}$$

where:

X	estimated number of fruits on the tree,
x	actual number of fruits on the selected branch and
P	probability of selecting the branch.

The probability of selecting primary and secondary branches are given by:

Probability of selecting a primary branch $p_p = \frac{1}{n_p}$

Probability of selecting of a secondary branch $p_e = p_p \frac{1}{n_s}$

n_p – number of primary branches
n_s – number of secondary branches on selected primary

5.6 Results

Table 5-2 presents a range of simple statistics for the trees which were sampled from Kibwezi Division. The diameter range was from 65 cm to 503 cm, height from 7.8 m to 25.6 m, crown diameter from 4 m to 30 m and the number of fruit per tree from 12 to 2 675. The coefficient of variation (CV%) is the standard deviation divided by the mean expressed as a percentage and is a good measure of the variability. A low CV% means that variation was small as in the case of height and diameter. However, the number of fruit per tree has a CV% of 144% which indicates that it is extremely variable and probably has a non linear relationship with the standard measures of tree size (if the relationship was linear the CV% would be more similar).

Table 5-2. Mean, S.D. and range of individual tree variables in the study material

Variable	Number of trees	Minimum	Maximum	Mean	Std deviation	CV%
Diameter (cm)	139[1]	65	503	95.9	62.7	32
Height (m)	139	8	26	17.6	3.6	20
Crown diameter (m)	139	4	30	14.9	4.9	33
Number of fruit per tree	25[2]	12	2675	360.0	520.0	144
Diameter (cm)	25[2]	74	300	174.6	51.0	29

[1] Total number of trees in the sample plots

[2] Total number of trees assessed for fruit yield

5.6.1 Baobab population structure

The mean tree size and densities also varied from one site (sample plot) to another (Table 5-3). Mean diameter varied from 141.5cm to 245.8 cm, mean total height from 14.4 m to 20.7 m and mean crown diameter from 10.3 m to 18.8 m. Density varied from one tree ha^{-1} to 14 trees ha^{-1} and mean percentage crown cover from 3.0 % to 26.5 %. The structure of the baobab population was rather interesting. The shape of the curve for the number of trees ha^{-1} by diameter class was a normal curve, as opposed to the expected inverted J-shaped curve (Figure 5-3). There is therefore a need to carry out studies to enhance the survival and growth of the baobab regeneration.

Table 5-3. Average characteristics of 139 Baobab trees in 22 sites in Kibwezi Division, Kenya.

Site	Plot No	No of trees	Mean diameter (cm)	Mean height (m)	Mean crown diameter (m)	No of trees ha^{-1}	Mean crown area (m ha^{-1})	% crown cover (ha^{-1})
Thange	1	7	227.4	17.2	14.9	3	477	4.9
Machinery	2	8	192.7	17.9	16.2	6	1 327	13.4
DWA	3	5	212.0	14.4	15.3	7	1 245	12.5
Ndauni	4	6	244.8	20.2	16.5	12	2 647	26.0
Mwaini	5	5	162.4	17.1	7	6	999	10.1
Kambu	6	10	192.4	18.2	8	4	601	6.0
Usalama	7	7	191.5	17.4	5	2	366	3.8
Usalama	8	6	211.2	19.8	4	6	1 428	14.4
Kwa Kisivo	9	7	241.2	17.3	5	1	302	3.1
Silanga	10	6	141.5	18.0	10	3	312	3.0
DWA	11	5	160.3	16.6	6	6	454	4.6
Usalama	12	8	166.7	16.6	6	14	1 567	15.9
Kalamba	13	5	245.8	20.7	7	3	701	7.1
kalamba	14	4	204.5	19.0	6	3	612	6.1
Syembeni	15	7	180.3	15.6	5	8	1 061	10.0
Kalulini	16	5	154.5	16.9	8	3	462	4.7
Mwembeni	17	9	201.8	15.1	5	4	686	7.0
Kivuti	18	4	157.5	16.1	4	7	929	9.3
Ukuno A	19	6	206.5	18.8	7	3	530	5.4
Tarda farm	20	6	206.3	17.3	5	4	907	9.2
Katilamuni	21	6	192.0	18.3	9	4	907	9.2
Ukuno B	22	7	197.5	20.7	4	5	597	6.1

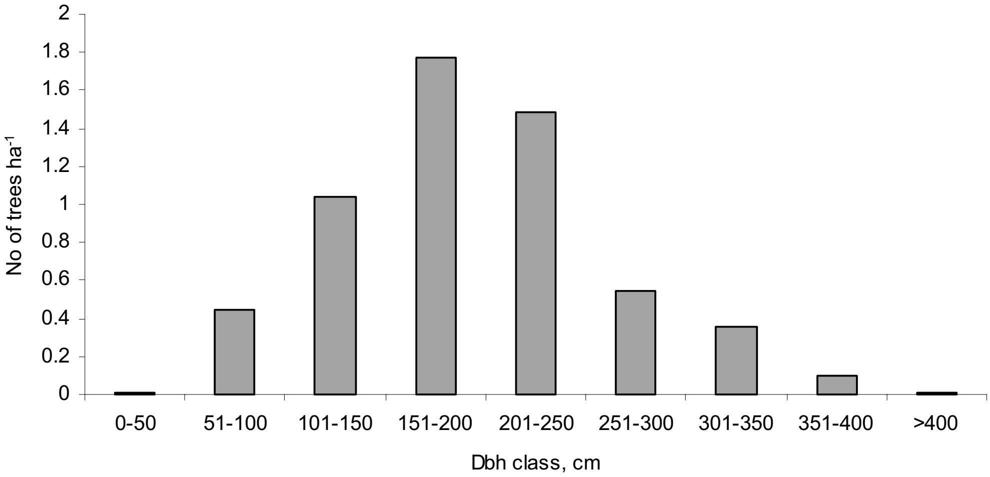

Figure 5-3. Density by diameter class of the baobab population in Kibwezi division.

The diameter for the 25 trees sampled for fruits yield ranged from 74 cm to 300 cm, total height from 12.6 m to 22.6 m, and crown diameter from 8 m to 19 m (

Table 5-2). Large trees (with diameter of more than 250 cm) had exceptionally high numbers of fruits (Figure 5-6). The differences among trees may have been due to variations in study sites in terms of soil characteristics (depth, fertility and moisture), type of landscape and the total basal area of the competitor trees (Peters 1996). High densities were observed on flat terrain with reddish-grey clay soil and lower densities on hilly sites with whitish sands. Trees were mostly imposing, independent and showing no inter-tree competition. However, in a few situations, suppressed trees were found intimately growing together with dominant trees.

5.6.2 Predicting fruit yield

The relationships between fruit count and each of the three variables measured in the field (diameter at breast height, height and crown diameter) were investigated to determine the best predictor of fruit yield.

It appears that there is a rather weak relationship between fruit numbers (Figure 5-4) and tree height and between fruit numbers and crown area (Figure 5-5). Although there appear to be discernable relationships these are very weak as expressed by r^2 values of 0.2 for height and 0.3 for crown area. It is obvious that there is a single tree with a very large number of fruit which looks like an outlier, distorting the relationships. However, this tree has an exceptional diameter (300 cm) and it rather appears that there are external limits to tree height and area which restrict the maximum sizes attainable. We therefore should expect that we could predict fruit yield from height and projected crown area up to the maximum sizes possible after which the relationships would break down.

Tree diameter exhibited the strongest relationship with fruit numbers per tree (Figure 5-6) with a r^2 of 0.57 which is respectable although it leaves about half the variation in yield unaccounted. The relationship indicated in Figure 5-6 could be used to estimate mean fruit yield for trees up to 200 cm diameter in Kibwezi Division. More sampling would be required to extend the relationship to larger trees, to other areas of Kenya and to other years. Californian experience suggests that it takes around ten years of data to build predictive models for fruit yield which can account for annual variability.

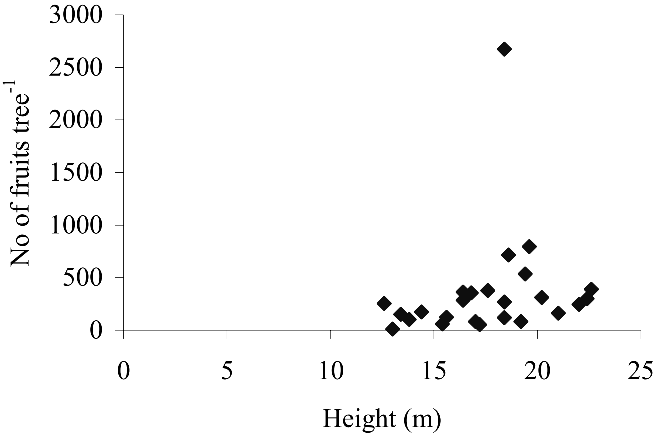

Figure 5-4. Number of fruits per tree by height.

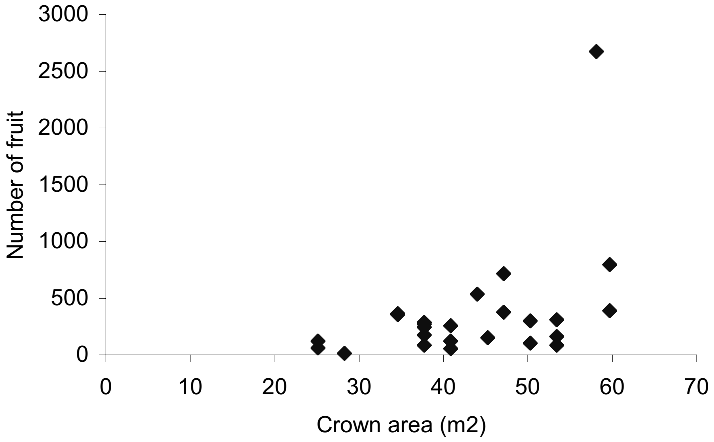

Figure 5-5. Number of fruits per tree by crown area.

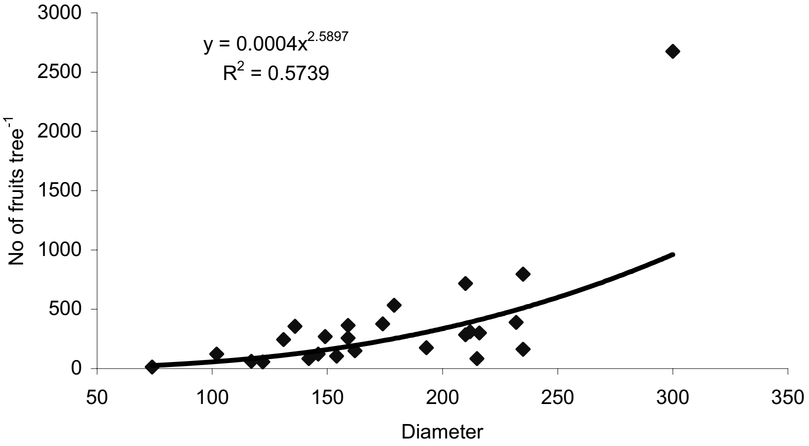

Figure 5-6. Number of fruits per tree by diameter

5.7 Evaluation of objectives

The objective of this study was to establish whether randomised branch sampling is a useful method for estimating fruit yield in Baobab trees. Table 5-4 gives the total counts and estimated based on random sampling of primary and secondary branches. The 'Discrepancy' figures are the amount of under or over estimate expressed as a percentage of the total count. The better the estimate, the smaller the discrepancy figures. It is clear that the discrepancies for primary branch selection are generally smaller than those for secondary branches, though both are in many cases more than 100% in either direction. The mean discrepancy for primary branches of 98% suggests that in general selecting a primary branch would give fruit yield estimates twice that of a full count. Although this is less than ideal the mean discrepancy for secondary branches is twice as bad at 190%. Although the mean discrepancy is high, the fruit yield for half of the trees was within 50% of the total count which is probably acceptable given the time and cost savings involved.

Table 5-4. Estimates of individual tree fruit yield using randomised branch sampling

Site	Plot number	Diameter (cm)	Height (m)	Crown diameter (m)	Total count	Primary branch		Secondary branch	
						Estimate	Discrepancy (%)	Estimate	Discrepancy (%)
Thange	1	300	18.4	18.5	2675	1232	-54	1342	-50
Machinery	2	174	17.6	15.0	377	680	80	1104	193
DWA	3	162	13.4	14.4	151	410	172	480	218
Ndauni	4	142	17.0	12.0	135	120	-11	130	-4
Mwaini	5	122	17.2	13.0	73	136	86	312	327
Kambu	6	215	19.2	17.0	84	72	-14	44	-48
Usalama	7	154	13.8	16.0	103	148	44	144	40
Usalama	8	136	16.8	11.0	356	518	46	966	171
Kwa Kisivo	9	149	18.4	12.0	270	220	-19	288	7
Silanga	10	210	18.6	15.0	716	705	-2	530	-26
Silanga	10	102	18.4	8.0	60	470	683	1394	2223
DWA	11	193	14.4	12.0	175	470	169	570	226
Usalama	12	179	19.4	14.0	535	348	-35	752	41
Kalamba	13	232	22.6	19.0	390	855	119	1095	181
Kalamba	14	210	16.4	12.0	286	592	107	1008	252
Kalamba	14	212	20.2	17.0	311	498	60	588	89
Syembeni	15	235	19.6	19.0	795	870	9	984	24
Kalulini	16	146	15.6	13.0	122	651	434	10	-92
Kalulini	16	74	13.0	9.0	12	15	25	45	275
Mwembeni	17	216	22.4	16.0	300	624	108	528	76
Kivuti	18	117	15.4	8.0	51	112	120	144	182
Ukuno A	19	235	21.0	17.0	163	270	66	480	194
Tarda farm	20	159	12.6	13.0	256	534	109	360	41
katilamuni	21	159	16.4	11.0	364	216	-41	288	-21
Ukuno B	22	131	22.0	12.0	245	330	35	192	-22
						Mean	98		190

Figure 5-7 and 8 illustrate the relationship between the total counts and the estimates based on branch sampling omitting the outlying single very large tree. The regression line in the figures is a measure of the strength of the relationship, if the branch sampling gave perfect results the line would be a diagonal with a slope of 1 and a r^2 of 1. As it is, both have slopes of close to 1 (0.83 and 0.89 respectively) but primary branch sampling has a higher r^2 of 0.45. This suggests that of the two methods, primary branch sampling was more accurate and precise. The poorer performance of secondary branch sampling is probably a result of the fact that a smaller proportion of the tree crown is sampled. It would be interesting to compare taking two secondary branches with taking a single primary branch in terms of statistical and cost efficiency.

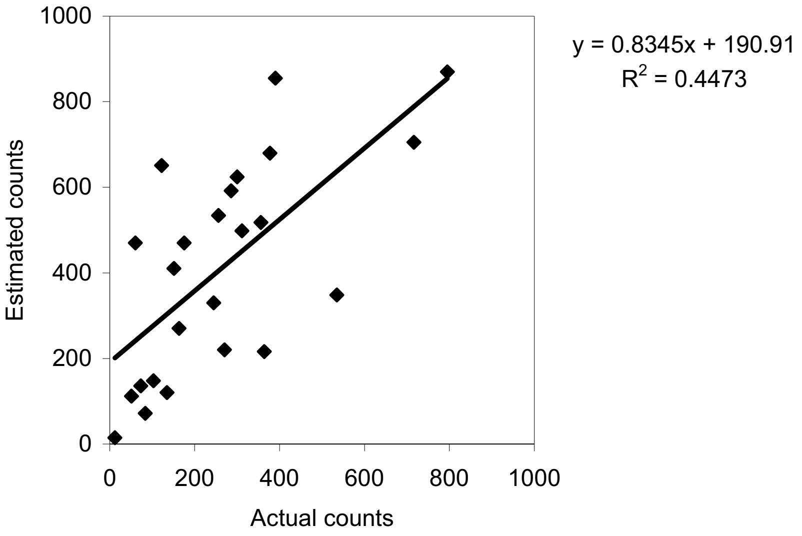

Figure 5-7. Estimates based on random selection of primary branch

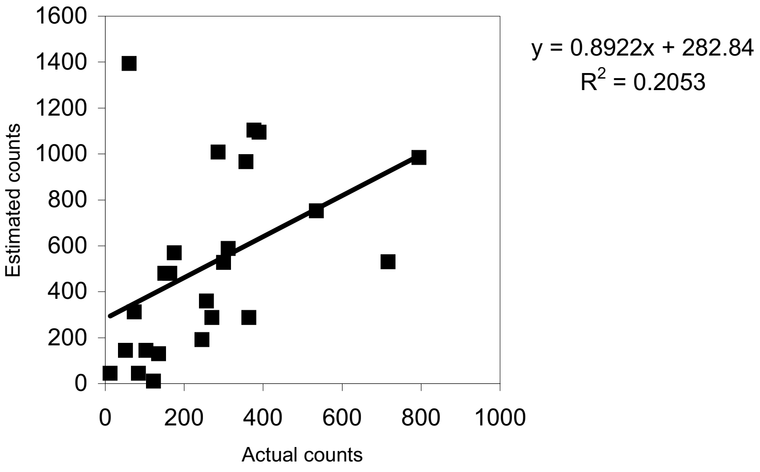

Figure 5-8. Estimates based on random selection of secondary branch

5.8 Conclusions

The trials indicate that simple randomised branch sampling can be used to estimate fruit yield for Baobab with fairly large errors. Although the discrepancies are large, the time saving are great as Baobab can be a very large tree with several thousand fruit. The fact that branch sampling worked at all is encouraging as the Baobab trees are often very misshapen (see Figure 5-2). Using a selection method based on branch size or increasing the number of branches sampled may improve on the quality of the estimates and should be examined in further tests.

Analysis of tree allometry using the data for the 22 sample trees indicates that the best basis for Baobab fruit yield tables is bole diameter at breast height. Tree height and crown area were unrelated to fruit yield.

The method developed in this study was closely modelled on that used by California Agricultural Statistics Service (2001). However, it is preliminary in nature because it is based on the data from 25 trees in 22 sample plots in one locality and covers only one fruiting season. A realistic estimate of fruit yield potential of the baobab trees will require data collected for a period of at least five years and cover entire ecological range to take into account variations due to seasons and site factors of the major regions where baobab is found.

5.9 Baobab fruit project data sheets

Date----------------------------- Name of the recorder---------------------------------

Division ------------------------ Crew
Name Position
1.----------------------- -------------

Site -------------------------- 2.--
--------------------- -------------

GPS readings at the plot centre 3.------------
------------ -------------

-------------------------- 4---
---------------------- -------------

---------------------------- 5------------
------------ -------------

Recruits ------------------------ 6.-------------
----------- -------------

Regeneration ---------------- 7.------------
------------ -------------

8.--------------------- -------------

1. Abundance/distribution **4. Uses both local and Commercial**

For the area:
Fruit:

For the division:
Tree:

Geographical limits and reasons: 5. **Marketing**

Frequency of sale:

2. Regeneration

Local knowledge:
Price:

If planted and reason for not planting: **6. Other information:**

Effect of tree on crops:
Felling and reason for not felling:

3. Fruiting

Seasonally, reasons and trends for 5 yrs:
Between tree variations, quantity and quality:
Sites: Red site, white sand, clay

Baobab fruit recording sheet

Tree No	Distance from plot centre m	Bearing from plot centre	Fruiting/Not fruiting	DBH, cm	Height, m	Crown size		FRUIT COUNT									Cause of fruit damage	Diseaes (tree and fruit)
						Width m	Depth m	Primary branch			Secondary branch			Total crown				
								No	Diam, cm	No of Fruit	No	Diam, cm	No of Fruit	No fallen	No on the tree	Total No		

6 Using local knowledge as a basis for stratification of inventory sites: wild mushroom inventory in Liwonde Forest Reserve, Malawi. *

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6.1 Objectives

Seasonal products, such as fruit, are inherently difficult to quantify because they are only present for part of the year and often perishable and/or cryptic (they can be difficult to observe without careful search or are only easily seen for a short period of time). Therefore, if an assessment of annual productivity is required then yields have to be monitored frequently throughout the season to be sure that all fruits are counted. Furthermore, annual variation is usually high so that monitoring of yields over a number of years is required if yield estimation is required.

The present case study was commission to develop and test simple data collection techniques for a seasonal product. The product being wild edible fungi harvested from forest reserves in Malawi.

The Forest Research Institute of Malawi (FRIM) have an established network of mushroom sampling plots that have been monitored since 1999. Experience suggests that the data from these plots does not represent the productivity of the forest as a whole as species and volumes recorded in the markets where not reflected in the monitoring data. It is evident that the monitoring sites where not representative of the forest and the local harvesters where able to locate the mushrooms. The plots used in this study are fixed in location and relatively close to the road and is a likely source of the observed biases. It was therefore proposed that a combination of a biometric inventory protocol on sites identified by harvesters would be better able to better represent the mushroom productivity of the forest than the fixed plots. The intention being that the results of the field inventory would mirror data collected in the market place.

This case study was composed of three distinct element;

a) selection of mushroom sites identified by local harvesters,

b) enumeration of mushroom productivity on selected sites,

c) market data collection to verify field data.

The principal objective for the study was to develop a methodology for locating and sampling productive mushroom sites that mirrored species and productivity data derived from market records.

This report deals with the evaluation of how far this objective was met but also explores how the data collected can be used to increase understanding of mushroom ecology and productivity.

6.2 Product

Wild edible mushrooms in Malawi occur in the rainy season over a period of three to 5 months (Chipompha, 1994; Morris, 1987). The rainy season normally starts in October or November and ends in April or May. During this period various mushroom species appear in different areas and these are harvested by people for food. There are two major types of mushrooms that occur in

* "Original report done in English." For more details please contact FOPW webpage.

Malawi: those that are associated with termites and then those that are associated with woodlands- mainly miombo woodlands either symbiotically or saprophytic ally (Chipompha, Morris and . Mushrooms associated with termites are associated with open woodlands and fields. Termites survive better in open woodlands than closed woodlands. The termites cultivate these mushrooms for their own food, under favourable conditions these fungus grow into fruit bodies which are then harvested for human consumption. These mushrooms are common between Dedza and Ntcheu in Malawi. This area has large tracks of open woodlands. However, growth of these mushrooms is mostly restricted to the first one to two months of the rainy season, and do not form a significant part of food for most people in Malawi. These mushrooms will therefore not be focused on in this study. However, to sample these mushrooms require identification of mounds and sampling unites are tied to the termite mounds, and also sampling is restricted to the first two months of the rainy season.

Woodland mushrooms are very common in Malawi. Most of the woodland mushrooms are associated with miombo woodlands. High mushroom productivity is generally associated with wet miombo woodlands as compared to dry miombo woodlands. Most area under wet miombo woodlands are also very productive areas in terms of agriculture as such most woodlands under customary lands have been cleared for agriculture. The only remaining areas for high mushroom productivity are government protected Forest Reserves. In these woodlands there is a wide range of mushroom species which are collected for food and sale (Morris, 1987; Chipompha, 1994; Abbort, 1997). These mushrooms occur throughout the rainy season. In Malawi, wild mushrooms are collected and sold locally by indigenous Malawians.

Government protected Forest Reserves in Malawi have in the past been managed as biodiversity conservation centres. No utilisation of any resources was permitted, and as such the management regimes were basically total protection which include fire protection and patrolling against thief. However, with the advent of new government policy which targets poverty alleviation and opening up of management of forest resources, the Forest Department is slowly moving towards co-management of forest resources with village communities, individuals, NGOs, companies and other government departments. In developing co-management agreements, the Forest Department is faced with serious problems in deciding management regimes for indigenous woodlands as production levels of various resources in the woodlands are not determined.

6.3 Location

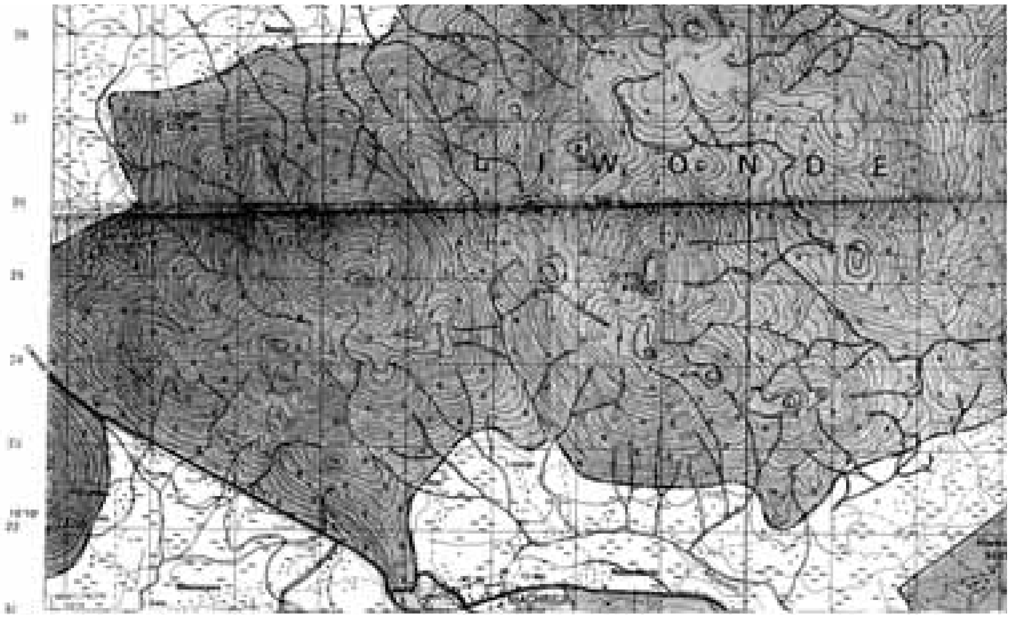
The trial was located in Liwonde Forest Reserve in Machinga District in the Southern Region of Malawi (see Table 6-1 for geographical details). Mushroom productivity data was collected from field plots established in the reserve between January and May 2002. Sampling plots were established at the end of January, but assessments did not commence until mid February to allow for training of data collectors.

Table 6-1 Liwonde Forest Reserve – geographical description

Region	Southern
District	Machinga
Geographical location	15^0 21'S 35^0 21' E
Altitude	800m to 2080m
Mean annual rainfall	500 – 800 mm
Mean annual temperature	22 – 25^0C
Rainfall months	December to April
Soil	Ferralitic latosols with an average pH of 5.2
Vegetation	Miombo woodland dominated by the *Brachystegia* and *Uapaca* species

The reserve is managed under total protection as a water catchment area for Lake Chilwa. Locals are allowed to harvest NTFPs such as wild mushrooms, medicinal plants, grass and wild fruits for free. They are also allowed to harvest firewood from dead branches of trees at a fee. Curios makers also harvest timber for curios making under licence. On the eastern side of the reserve the forest department is testing co-management of the reserve with local communities.

The villages and sites chosen for the study are located in Figure 6-1.



KEY
Red names – study villages
Red spots – plots in study sites
Yellow shading – collection sites
Grey shading – Liwonde Forest Reserve

Figure 6-1. Location of study sites within Liwonde Forest Reserve

Productivity data was collected from field plots established in Liwonde Forest Reserve between January and May 2002. Sampling plots were established end of January, but assessments started mid February to allow for training of data collectors.

6.4 Participatory information collection

A research team comprised of one forestry scientist, one forester and two forestry assistants conducted this part of the study from 13th January 2002 to 6 February 2002. Interviews were recorded on tape and notes were taken during the survey.

Several methods were used to collect information. Emphasis was placed on collecting as much descriptive data as possible. The methods used included: rapid resource assessment, key informant interviews and resource mapping. As a starting point a general literature search was conducted to establish if data was available on the productivity of various mushroom production sites (Meke *et al.* 2000). Unfortunately, the literature did not contain productivity information as most of it was either ethnobotanical or mycological studies.

A meeting was arranged with the Machinga District Forest Officer and his staff to learn more about mushroom activities and to establish which villages to visit in the area. At this meeting five villages were selected for the study. The choice of village were those that had a degree of dependency on wild mushrooms for food and cash generation. The study villages were located on the western side of the mountain near the main road and the reserve for logistical reasons, principally ease of access. The selected villages were: Lipongo, Mbalangwe, Chingoli, Matandika and Ndaje (see Figure 6-1 for the locations of the villages).

In each village, the headman was requested to assemble serious mushroom gathers for a meeting with us. At each meeting we had a mixed group of men, women, boys and girls of all ages so long as they were experienced mushroom collectors. In each village more than 20 people attended these meetings. The collectors were asked the following questions:

a. Which species are collected

b. Where are different mushroom species collected from in the reserve?

c. Roughly how much of each species is collected?

d. How much time is spent collecting mushrooms? When is the collection exercise started?

e. How are the collection sites selected?

f. Of the mushrooms collected in a day, how much are for sale and food?

g. How do collectors move in the reserve when they hunt for mushroom?

h. When collecting mushrooms, how far can one see to collect mushrooms? This was asked to; determine how far they can walk and to estimate the area scavenged in a day for mushrooms.

A visit was also made to the markets around the forest reserve (on market days) to check for mushroom marketing activities. This was done to make sure that we did not miss serious mushroom collecting villages away from the main road. Very little (or no) mushroom trading was observed at markets in villages far from the main road. However, some limited amount of mushrooms being marketed in town come from villages far away from the main road (Lowore and Boa, 2001). In the interest of time and limited financial resources, effort was concentrated on villages close to the main road.

6.4.1 Site selection

In the interview collectors indicated that they have specific sites they collect different mushroom species from. However, they also indicated that new sites are discovered all the time, and that productivity of sites vary from season to season. Sites shown on figure one shows that there are more collection sites near villages and the sites are scattered and fewer as you move further away from villages. Though it can be suspected that the large number of sites close to village areas is due to the fact that access to these sites is easy, it should also mean that these sites are thoroughly known by villagers. Therefore positioning trial plots in these areas will mean that productivity values developed will reflect the productivity of harvesting sites. However where minimum interference is of paramount importance, then locating plots in areas far from villages would be advisable. With regard to the terrain of the area, locating plots far from villages would mean data collectors will spend most of their time travelling to data collection sites, but the data would reflect the total productivity of the sites. Since the emphasis is on developing sampling methods for use by district forest managers who also have other pressing priorities, then sites close to the villages would be ideal.

A group of volunteer collectors from each of the five villages was requested to take us to the various mushroom collection sites in the reserve. Sites shown to us were then marked on the map and from these five sites chosen for detailed monitoring of mushroom production (see Table 5-1). The collectors where asked to identify sites known to be the 'best' sites for a range of species and those which were relatively close to the village were selected as the sample sites. A site not known to be particularly productive was also selected to act as a control.

Table 6-2. Study sites selected

Site	Species	Finding
1	*Amanita loosii.*	No instances of *A. loosii* were recorded for site 1. In the study as a whole only 2 instances of collections of *A. loosii* were recorded, both in site 2.
2	*Cantharellus cibarius*	Four times more *C. cibarius* collected at site 2 than the other sites (14.9 kg ha^{-1} compared to 3.3, 1.84, 1.64 and 0.8 kg ha^{-1}). However, *C. cibarius* was not the most common species on the site – it came 3rd with almost 10 times more *C. albiramea* - 143.2 kg ha^{-1}.
3	*Cantharellus longisporus* and *Russula schizoderma*	Results confirmed this as the best site for these species – it was also best for Russula with a pink tinge on.
4	Low productivity site (control)	Site never ranked higher than 3 for volume for most species. Exceptions were *Clavaria albiramea* and, on low values, *Russula* sp.
5	*Amanita vaginata* and *A. elegans*	No instances of either of these species were recoded, either at this site or any of the others

Figure 6-1 shows mushroom harvesting sites and villages that were sampled for collectors. Distance to collection sites varies with species wanted, quantity wanted and the general availability of mushrooms. If collectors are interested in harvesting large quantities of mushrooms, they travel to distant places. Sites closer to the villages are heavily harvested, as such there are fewer mushrooms closer to the villages. Species like *Cymatoderma dendriticum* occur further up the mountain on the reserve. Adults and teens searching in groups can easily get to these distant places. Loners are sometimes afraid to travel long distances into the bush, hence they collect in nearby areas.

In a collection trip, depending on availability of mushrooms, collectors can travel a continuous journey of between 5 to 15 kilometres in a day. Searching or foraging is concentrated in known productive sites. From one site to the other, collectors do not follow established paths. They wonder around in any direction in the hope that they will discover new site and also to avoid creating paths, which give away sites to other collectors. Depending on the bushiness and terrain of the site, the harvesters can see as far as 20 metres on open and sloppy areas, where as in bushy areas up to 2 metres. Bushy areas are avoided as visibility is very poor.

Mushroom growing sites do not have a definite boundary. The size of a site can range from 2 square metres to several hectares. Some sites are known for specific mushroom species while other sites have more than one species. The quantity of mushrooms harvested per site varies depending on the productivity of the sites or whether other people harvested from the same site before. Experienced collectors normally avoid sites they visited the previous day to allow mushrooms to grow before they are harvested. The amount of time a site is left to recover is based on the type of mushroom collected or whether there were button mushrooms coming up or a mycelia mat. Sites where small mushrooms were left and sites with mycelia mats are visited frequently. In some cases collectors may deliberately cover button mushrooms coming up or cover the mycelia mat, to hide them from other collectors.

In a mushroom growing site, if mushrooms are spotted, collectors search the site thoroughly. Normally they may search in a meandering manner to ensure that the site is thoroughly searched. In an open site where there is good visibility, they may travel in a transect which cuts across the site. In a day several sites can be visited. If the sites are very productive, fewer sites are visited and more time is spent searching each site. In the middle and towards the end of the rainy season, when species like *Cantharellus longisporus* are in large quantities, collectors do not travel long distances and do not have specific collection sites, as these species are not very site specific.

6.4.2 Other information from village meetings

This section of the report gives details of the results from the village meetings with mushroom harvesters. Besides providing useful information for those concerned with the harvesting of miombo mushrooms it illustrates the kind of information that can be collected from brief, informal discussion with harvesters.

6.4.2.1 Edible mushroom taxa

The names and productivity information for the 24 harvested species identified by the village informants is given in . Most of these mushroom are collected from the reserve. A few species, especially those associated with termites are also collected from within the homestead areas or from farmers fields. There were differences in edibility of some species. Some villagers indicated that *Cantharellus congolensis*, brown *Lacterius sp*, red *Russula atropurpurea* and the *Phaeogyroporus colossus* are not edible, while others said they eat them after processing as these species are believed to have some mild poison. The most preferred species for both food and sale were *Russula schizoderma*, *Cantharellus cibarius*, *Amanita loosii*, *Cantharellus longisporus* and *Termitomyces clypeatus*. The preference was mainly based on availability in the bush, easy of marketing and good taste.

Collectors are not very particular with the quality of mushrooms they harvest. They harvest all stages of mushroom growth, from button stage to fully-grown mushrooms, with the exception of rotten or heavily insect infested mushroom. However, for marketing purposes, different species are sorted into grades that buyers prefer, while the rejects are both processed and dried or used fresh for food. Mushrooms collected for food are usually mixed, while those collected for sale are sorted into different species.

Table 6-3 Edible mushroom taxa identified by the harvesters

Local name	**Scientific name**	**Remarks (information given by villagers)**
Chipatwe cha mandanda / M'nofu wankhuku	*Cantharellus cibarius*	Occurs in large quantity, collected for food and sale. Occurs from mid through to the end of the rainy season. Common in the higher areas.
Chipatwe chakuda	*Cantharellus congolensis*	Occurs in small quantity, occurs on top of the mountain. Common when rains are heavy.
Dodolido	*Russula* sp.	Occurs in large quantities near rock out crops and open areas.
Katerela/ kateresya	*Russula* sp., *Amanita* sp.	This name is mostly a generic name referring to slippery mushrooms, however, some collectors consistently referred to slippery *Russula* spp. All species are common, but do not occur in large quantities.
Kungulokwetiti/ Kum'mero kwa nang'oma	*Cantharellus longisporus*	This is the most common mushroom and occurs in large quantities throughout the reserve. Common when rains are heavy. Occurs from mid rainy season through to the end of the rainy season.
Liwuwula/ Kam'buwula	*Russula schizoderma* (big specimen)	Not very common, occurs near anthills and open places, just like dodolido.
Machende a kalulu	*Mycoamaranthus congolensis*	Not very common, occurs in open areas with small shrubs. Common when rains are heavy.
Magomba ga madyani/ Kamenya nyani/ fisi	*Phaeogyroporus colossus*	Occurs on top of the mountain in shrubby areas. Not very common, not a favoured species for food and sale.
Mangungunguli/ Chifuchang'ombe	*Cymatoderma dendriticum*	Common on top of the mountain, occurs when the rains are heavy.
Matwe	*Auricularia auricula*	Occurs on dead wood, not very common.
Nakajete/ Nakamchere	*Amanita goossensiae*	Not very common. Occurs when rains are heavy during the beginning and mid of the rainy season. Common in uapaca woodland
Nakajongolo/ Bongololo	*Amanita vaginata, A elegans*	Common mushroom but does not occur in large quantities. Common in uapaca woodlands.
Nakambalakata	*Lactarius cabansus*	Occurs when rains are heavy, occurs for a short period in the middle of the rainy season.
Nakambwanda/ Nakanyemba	*Russula lepida/ Russula atropurpurea*	A common mushroom species, but most people do not eat this mushroom, only collected when other choice mushroom species are not available. Available throughout the rainy season.

Local name	**Scientific name**	**Remarks (information given by villagers)**
Nakasowu/ Nakanmchombo	*Termitomyces clypeatus*	Common around termite active areas, common at the onset of the rainy season
Nakasuku/ Gundamsuku	Brown *Lacterius* sp, *Cantharellus longiporous*	This name normally refers to mushroom species associated with *Uapaca kirkiana*, but some members consistently refered to *Cantherellus longisporus* and a brown *Lacterius* species.
Nakatakasi/ Nakamsemamhpa	*Lentinus cladopus*	Not very common mushroom, but it is commonly associated with stumps of dead wood.
Nakatotosi/ Nakashitosi	*Amanita calopus*	Not very common mushroom
Nakatsache/ Masanjala	*Clavaria albiramea*	Occurs throughout the reserve but it is not a choice mushroom.
Nyozwe	*Termitomyces clypeatus*	Common at the onset of the rainy season, but does not occur in large quantities
Ujojo/ Ulundi	*Inocybe* sp.	Common when rains are heavy, but does not occur in very large quantities.
Usinda/ Chipindi	*Russula schizoderma*	Common mushroom, occurs in open areas and around rock outcrops. Occurs from mid through to end of the rainy season.
Utale	*Termitomyces titanicus*	Occurs towards the beginning of the rainy season on or around anthills.
Utenga/ndelema	*Amanita loosii*	Common mushroom, occurs in large quantities at the beginning of the season and towards the end of the season.

The species in bold type are those encountered in the field study.

Table 6-3 shows that there are 24 mushroom ethno-species, which are harvested for food or sale by people in the Liwonde area. Morris (1987) listed over 70 edible mushroom species in Zomba, Machinga and Mulanje. Since the list given by collectors was based on ethno-taxonomic expertise, it is likely that there could be more species present than those listed. Most of the local names used, refer to more than one species. For example Morris (1987) noted that most folk names are based on description of growing site, features on the mushroom, while others are based on taste, smell or colour. Species of the same colour would have the same name or species that are slippery would also have the same name. For example Katerera (slippery) would be used for different species of *Russula*s or *Amanita*s. In order to undertake a complete inventory there is need to do taxonomic studies to establish the number and identity of edible species harvested in this area. This can be done by sampling mushrooms collected by villagers or having a transect walk with villagers.

6.4.2.2 Seasonal variation in mushroom harvesting

The villagers indicated that the intensity of mushroom gathering varies from year to year. Harvesting intensity usually increases with famine and when there is low mushroom productivity due to erratic weather pattern. During such bad periods more people become desperate for food as a result more people join the professional mushroom collectors and in the process resulting in low harvest per individual, an increase in small mushroom harvested and collectors searching large areas for mushroom. The forest reserve areas close to villages are heavily harvested, with harvesting intensity decreasing further away from villages into the forest. However, professional collectors have specific sites they harvest mushrooms from. These sites are either discovered by chance or told to them by a family member or friends. With many years of mushroom collection, experienced collectors have lent to associate different habitats and weather patterns with different mushroom species. *Uapaca kirkiana*, *Brachystegia* spp., presence of anthills, bare areas, grassy areas, rainfall patterns are all associated with specific mushroom species. Appendix 1 indicates the site characteristics of some mushroom species.

In years of plenty, villagers are very selective; they harvest only those species that occur in large quantities or those that they like themselves or those that they will easily find a market for. In years of critical food shortage, villagers are not selective; they harvest a large diversity of species. The preferred mushroom species are mostly sold, while the collectors use the less preferred species which they cannot easily sale.

Availability of mushrooms in a rainy season changes as the season progresses. Some species of mushrooms are common at the onset of the season, while other are common towards the end of the season, with others common in between. Mushroom collecting sites change within a season and between seasons. In a season, mushrooms that are common at the onset of the rainy season such as *Amanita loosii* and *Termitomyces* species can come up from one particular site, while others like *Lactarius* species can come up from a different site.

6.4.2.3 Profile of mushroom harvesters

Mushroom collection is predominantly a female occupation. Women and children, especially girls, set off early in the morning to collect mushrooms. Sometimes, men and boys collect mostly for sale. Sometimes a husband and a wife can collect as a team together with their children. Sometimes, they share roles, such as when other family members go collecting others do other jobs in the family such as farming. School going youngsters mostly do their collection either early in the morning in near by bushes or on weekends. In weekdays, youngsters mostly assist in marketing after they have returned from school.

Older women and men have thorough knowledge of which species to harvest, where and when to harvest. It is believed that this knowledge is then passed on to the younger generation. However, collectors of all ages with the exception of children under the age of ten years had enough knowledge to collect wild edible mushrooms.

6.4.2.4 Harvesting

The study has revealed that harvesting intensity varies from one year to another. A famine season followed by a good year would mean that there would be more desperate collectors, and that each one of the collectors would be more thorough in mushroom search. Also there is a tendency to collect a large diversity of species as well. In years of desperation, it would mean that there would be a lot of interference in sampling plots. This would then mean that data collection in the plots has to be done before collectors get to the plots, as the plots are not fenced off. The mushrooms which would be sampled in a plot then under this condition would be those that grew the last 24 hours. In the event that we want to estimate collection from selected collectors, then this would not give a true reflection of the productivity of the area. This is so because the selected collectors would have collected in areas that have been harvested by others already. However, to get a good picture one would have to sample from the roadside markets. From the interviews it was clear that over 90% of the collected mushrooms in a desperation year are for sale.

All stages of mushrooms are harvested for consumption. Therefore for estimation of productivity total weight would be ideal. Numbers of mushrooms would not give a good reflection of volume harvested. Other measurements would vary a lot as all stages of growth of mushrooms are collected.

6.5 Field sampling

Field sampling for mushroom species and production was undertaken in each of the five sites for the period January to May 2002. The protocols and results of this work is presented in this section.

In order to assess general productivity, the great number of different mushroom species presents serious problems in deciding the size of the sampling unit. Since each mushroom can be expected to have its own distinct distribution and density pattern, the ideal would be to have a tailored design for each species. This is obviously impractical and the compromise is to base the design on one or a small number of prioritised species. US scientists have used a 2 x 50 m or 8 x 100 m plots to sample single species such as *Cantharellus* (Pilz et al 1998 and Pilz et al 1999). While in Zimbabwe a plot greater than one hectare has been used in pine plantation (Masuka, 1996). Under miombo woodland situation where the terrain is so erratic and rugged and also due to the heterogeneity of the forest understorey strips are considered appropriate. However to capture more diversity, then there should be more plots per site. In America, 5 to 6 plots have been used per site to study productivity (Pilz et al 1998 and Pilz et al 1999), in miombo woodlands where there is a wide variety of trees and varying terrain, a larger number of plots would be need. However, with the constraint of limited resources a lower number would be practical. In other productivity estimation studies currently being undertaken in Malawi, a maximum of 10 plots of 2 x 100 m have been used to estimated productivity (Meke 2000). This study adopted the same basic design for site sampling with the difference being the use of local harvesters knowledge to identify sites of known mushroom productivity.

6.5.1 Mushroom sampling protocol

Ten sample plots were laid out in each of the five study sites. The plots within a site were of fixed size, each measuring 2 by 50 metres. The strip plot dimensions were based on the plots used by Pilz and Molina (2002). Strip plots were chosen because the forest floor is covered with grass which makes searching for mushrooms in a square or circular plot difficult. The distances, aspects of slopes, direction of the plots in degrees have been given in the five site tables (see Appendix 2) below. To avoid attracting people with malicious intentions, landmark features such as big trees, and rocks were used to identify the plots. The landmarks were marked with paint or if they were trees they were blazed. Within the plot, two or more pegs were placed at equal distance to ease search of mushrooms within the plot. In each plot trees were recorded. The UTM reading from GPS were also recorded for each plot.

The precise boundaries of the productive sites identified by the collectors were not known and for this exercise plots were concentrated within the area where collectors agreed mushrooms do occur, leaving out much of the border area. Within each site the plots were located using a random walk starting from the centre, the overall area covered by the plots was between two to three hectares. The plots were located using a random number table to select a distance and bearing from the end of one plot to the next in what is termed a ‘random walk’. The distances between plots within a site were influenced by the size of the site, the general terrain and the availability of landmarks for plot identification. The smaller the site the closer together the plots, the more rugged the terrain the further apart the plots. This was done to promote visibility within the plot and also to ease movement within the plot.

At the time of plot establishment, an inventory of all the trees and shrubs was taken in the plot in order to characterise plot vegetation. Diameter at breast height and the name of the species were recorded. After establishment, data collectors visited the plots every weekday from Monday to Friday. Each plot was assessed daily from Monday to Friday, when collectors could not cope up with large volumes of mushrooms, the plots were assessed every two days. On each assessment, the species of mushrooms, number and weight were recorded. Trees whose canopy was covering the mushrooms or those trees at least within 10 metres of the plot were recorded as ‘associated trees’ whether they were in or outside the plot. The general micro-environment of each mushroom group including soil type, rockiness of the area, presence of grass and canopy openness were recorded.

Data collectors were taught how to identify common species. Where they encountered a new species they inquired from the local collectors to establish its edibility and its local name, if edible the sample was taken to FRIM for identification using reference collection and books, where samples could not be identified, specimen were preserved to wait for visiting specialists. Data collection was restricted to early morning hours before the local collectors got to the plots, as there were no restrictions on harvesting from the plots. Each time an assessment was done, all assessed mushrooms were harvested and removed from the plot and weighed. Each mushroom species was weighed separately.

Field data collection was conducted by two recruited data collectors who lived close to the reserve. The data collectors were given some training in data collection, mushroom identification, tree identification and sample collection before they started collecting data. The first month they were accompanied by a tree identification specialist, an experienced data collector from previous mushroom studies and a local mushroom collector. The data collectors were then visited twice a week to ensure that they were collecting the data properly. Weighing was done on an ordinary kitchen top loading scale or a hanging balance. All weight was taken as fresh weight.

Data collected was entered into excel spreadsheet and later transferred to an Access database. Since the data analysis required to establish productivity and the relationship between several aspects that are suspected to influence productivity and occurrence of certain tree species, assistance was sort from statisticians for data analysis. Data were analysed using correlation and anova analyses in the JMPIN statistical software.

6.6 Results

All the productivity results are expressed as weight per ha. Since each plot is 100 m² the weight per ha is simply the plot total multiplied by 100 or the site totals multiplied by 10. It is important to stress that the results are for the period of field sampling and not for the whole mushroom season. This means they can be used to examine between site variation in productivity but would need further adjustments to give annual production or for comparison between years.

Over the 2002 season, 13 species of mushroom were recorded in the five study sites. Table 6-4 shows mean mushroom yield per site. The yield means were statistically significantly different at $\alpha=0.05$. Sites 2 and 3 have the highest yields, while sites 1, 4 and 5 had statistically the same yields. This is an interesting result as site 4 was selected as representing a low yield area. In fact, sites 1 and 5 had the same overall yields. It may be that the extended drought which continued in 2002 reduced yields of the species for which 1 and 5 are well known.

Table 6-4 Site productivity

Site	Number of plots	Mean per site kg ha^{-1}	Standard error
1	10	44.45	5.77
2	10	93.98	14.10
3	10	65.68	12.49
4	10	43.72	7.15
5	10	43.00	5.84

Table 6-5 gives the mean production per ha for each mushroom species across all five study sites and the coefficient of variation (CV%)[1]. The species means are statistically different (t-test $\alpha=0.05$). *C. longisporus* yielded the most mushrooms followed by *C. albiramea* and *R. schizoderma*, while *Termitomyces* and *A. loosii* yielded less mushrooms per hectare. The low CV% figures for *Cantharellus longisporus, Russula schizoderma* and *Russula* sp. (Liwuwula) have much the same yields across all the sites. The other species have yields which vary dramatically between sites this being most pronounced for *Inocybe* sp. And *Termitomyces* sp.. These observations are borne out by the figures in Table 6-6 which give the total productivity of each mushroom species at each site. The shaded cells in Table 6-6 indicate the species which the harvesters said would be most abundant at each site. Site 2 and 3 have the highest yields of the mushrooms for which they are noted, while site 4 noted for low productivity has the next to lowest weight of mushrooms. However, for the other two sites (1 and 5) the species for which they are noted are not even present.

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[1] The CV% is the standard deviation of a sample divided by the mean expressed as a percentage. The smaller it is the more uniform the data, while figures greater than 100 indicate that the samples cover a wide range of values.

Table 6-5. Mean weight of different mushroom species across the five sites

Mushroom taxa	Mean kg ha^{-1}	CV%
Amanita loosii	0.972	90
Amanita mafingensis	0.82	164
Cantharellus cibarius	4.616	132
Cantharellus congolensis	2.24	84
Cantharellus longisporus	19.722	30
Clavaria albiramea	10.344	153
Cymatoderma dendriticum	4.65	74
Inocybe sp.	2.224	207
Russula atropurpurea	4.198	82
Russula schizoderma	9.49	42
Russula sp. (Liwuwula)	0.62	35
Russula sp. (Dodolido)	4.08	104
Termitomyces sp.	0.12	224

Table 6-6 Cap production by site (kg ha^{-1})

Scientific name	Site				
	1	2	3	4	5
Amanita elegans					
Amanita loosii		1.2			
Amanita mafingensis	3.1	1.0	0.1	1.6	1.9
Amanita vaginata					
Cantharellus cibarius	1.6	14.9	0.8	1.8	3.3
Cantharellus congolensis		2.5	4.6	0.7	3.4
Cantharellus longisporus	12.2	27.1	23.7	14.8	20.0
Clavaria albiramea	1.8	143.2	0.3	10.4	2.7
Cymatoderma dendriticum	6.3	1.3	9.6	2.7	1.5
Inocybe sp.	0.7	10.4			
Russula atropurpurea	8.3	5.7	1.4	1.1	2.6
Russula schizoderma	7.7	11.3	15.9	6.0	7.3
Russula sp.	0.6	0.6	0.3	0.9	
Russula with a pink tinge on stipe	6.8	1.1	10.1	2.4	0.7
Termitomyces sp.					0.6
TOTAL	49.1	220.3	66.8	42.4	44.0

6.7 Ecological analysis of monitoring data

Correlation analysis of microsite characteristics and mushroom abundance (as represented by weight) were inconclusive as most species did not respond to canopy density, grass cover, amount of rocks, soil type or aspect. Of the 13 species tested only *Russula* sp and *C. albiramea* were positively correlated with open areas while *C. albiramea* and *A. mafingensis* were more abundant in less grassy areas. *Russula* species and *Inocybe* species were not found in rocky areas, while *Russula* species tended to be influenced by soil type. *Inocybe* and *Russula* species were influenced by aspect. The relationship between productivity and tree density as represented by plot basal area were also weak.. However *C. cibarius*, *C. albiramea* preferred an area with more basal area, while *C. congolensis*, *Inocybe, C. dendriticum* R. *atropurpurea* and R. *schizoderma* preferred areas with lower basal area.

Many of the edible mushrooms form mycorrihzial associations with specific host trees. However, for most of the species the strength of these relationships is not known. An analysis of the tree records was undertaken in an attempt to understand some of these relationships. There are two types of tree data; the record of the trees occurring within the plots which is independent of the observed mushrooms and the associated tree records which are those closest to mushrooms counted within the plots. If there is no relationship between a mushroom and a specific tree then one would expect that the tree species associated with the mushroom would occur in proportion to the abundance of trees in the plots i.e. the tree most often associated with the mushroom would simply be the commonest tree in the forest. Over all the sites a total of 31 tree and shrub species were recorded as being associated with mushrooms.

Table 6-7 lists the top fifteen associated trees in order of the weight of mushrooms of any taxa recorded in close proximity to them.

Table 6-7. The relationship between tree species and total weight of all mushrooms

Associated tree species	Total weight of mushrooms (kg)	Number of visits mushrooms collected
Uapaca kirkiana	5.354	92
Brachystegia bussei	3.07	85
Pericopsis angolensis	2.592	65
Brachystegia spiciformis	2.366	35
Dalbergia nitidula	2.187	65
Parinari curatelliflolia	2.088	53
Pseudolachnostylis maproeniefolia	1.3	22
Diplorrhynchus condylocarpon	1.284	35
Brachystegia manga	1.194	26
Brachystegia microfila	0.99	19
Brachystegia utilis	0.96	34
Garcinia haullensis	0.9	26
Mundulea sericea	0.6	7
Brachystegia boehmii	0.492	6
Vangueria infausta	0.49	6

A greater weight of mushrooms were collected close to *U. kirkiana* trees than any other closely followed by *B. bussei* and *Pericopsis angolensis* while the lowest weight of mushrooms was collected near *A. venosum*. The number of visits to a tree species for mushroom collection also corresponds with amount collected, the higher the mushrooms quantity collected the more times it was found with mushrooms close to it. In each of the five sites a *Brachystegia* species (*B. spiciformis* or *B. bussei*) was the commonest species with *U. kirkiana* in 6th place. *B. spiciformis* is listed at 4th place in Table 6-7. These differences in ranking are more than would be expected by chance.

6.8 Market survey

A series of surveys of roadside mushroom sellers along the road linking Machinga district headquarters and Liwonde Township. The objectives for the surveys were:

1. To establish the species and quantities of mushrooms collected and marketed from Liwonde Forest Reserve.
2. To establish the gender and age profiles of mushroom harvesters.
3. To determine areas visited for mushroom collection and time spent mushroom collecting.

6.8.1 Methods

There were about ten roadside market stations from which data were collected. These marketing stations are located on a marked strip of the road. In this strip there is high activity of mushroom marketing. All the marketers collect their mushrooms from the forest reserve, mainly concentrating in forest adjacent to the marked area. Each marketing station was manned by between one and 25 sellers. The number of individuals manning a marketing station varied from day to day depending on availability of mushrooms in the bush and market response. Days of high mushroom productivity, where reflected in higher numbers of traders including children, while on low productivity days there were generally fewer traders.

Data were collected daily, in the afternoon except on Saturday, Sunday and public holidays. In the morning most of the villagers were out in field farming or in the forest collecting mushrooms. Though there used to be some villagers marketing mushrooms in the morning, most of them were marketing mushrooms in the afternoon after returning from collection trips. Depending on quantities being offered for sale, measuring the whole strip would be completed within two or three days. On the form the following information was recorded: Date of data collection, name of data collector, name of respondent, age, gender, species collected, fresh weight of mushrooms, associated tree species and general growing environment. Each species was weighed (on a five kg kitchen scale with a 20 gm scale) separately, and the weight was entered on a form.

Sampling was conducted over a total period of 3 months (90 days) from February to April. Sixty one of the 90 days were sampled with the remaining 29 being weekends, holidays or rainy days when sampling was not done. The highest encounter rate for a single trader was 21 days with the lowest being one day. Men were more often trading judging by the mean encounter rate of eight days for men and five days for women. Overall each trader was met on 7 days.

Over the sampling period, 193 people were sampled and out of these, 127 were women while 66 were men. The majority of traders were between 10 and 40 years old though older traders where more often found at the roadside. Interestingly, women tended to change their given names from one occasion to the next, sometimes they would use their maiden name, other times their husbands' and sometimes just their first name.

These data were entered into an Excel spreadsheet and analysed using pivot tables and one-way analysis of variance.

6.8.2 Species and quantities of mushrooms traded during season

Table 6-8 gives the list of mushroom species that were encountered during market surveys. There were a total of 16 species and out of these *Cantharellus* species and *Russula* species occurred the most. Eleven of the 13 species encountered in the field sampling were present in the markets. The exceptions being *Amanita magingensis* and *Russula atropurpurea* which is surprising as both of these occurred in reasonable quantities at all five sites (Table 6-6). This may be a result of the confusion between local and scientific names alluded to in Table 6-3 so that these species may be present in the market but under a local name which was not used in the field survey. This may also be an explanation for the missing five taxa which were in the market but not found in the forest though the sites used in the study may not have contained these species. Interestingly, *A. loosii* which was very rare in the field study was present in relatively large quantities in the markets this may be because the chosen field sites did not contain *A. loosii* even though site 1 was selected for this species.

Table 6-8 Mushroom species by month and frequency of recordings of each species

Mushroom species	February			March			April			Grand Total		
	Sum	N	SD	Sum	N	SD	Sum	N	SD	Sum	N	SD
Amanita sp	0.14	1	0.00	0	0	0.00	0	0	0.00	0.14	1	0.00
Amanita bingensis	1.90	7	0.04	0	0	0.00	0	0	0.00	1.9	7	0.04
Amanita loosii	55.45	56	0.15	7.93	7	0.36	3.74	12	0.04	67.12	75	0.12
Cantharellus cibarius	138.37	124	0.08	109.36	118	0.07	42.96	65	0.06	290.69	307	0.05
Cantharellus congolensis	3.50	5	0.28	53.56	21	1.97	79.03	78	0.12	136.09	104	0.40
Cantharellus longisporus	178.06	136	0.08	233.75	143	0.08	450.79	185	0.55	862.6	464	0.22
Clavaria albiramea	2.82	5	0.13	4.64	7	0.10	3.32	3	0.20	10.78	15	0.09
Cymatoderma dendriticum	19.24	31	0.07	18.44	28	0.09	9.80	25	0.05	47.48	84	0.04
***Inocybe* sp**	3.42	8	0.07	14.38	13	0.51	1.28	3	0.06	19.08	24	0.28
Lactarius cabasa	2.08	4	0.23	0.00	0	0.00	0.00	0	0.00	2.08	4	0.23
Lentinus cladopus	0.28	1	0.00	0.00	0	0.00	0.00	0	0.00	0.28	1	0.00

Psathyrella atroumbonata	0.65	2	0.12	0.00	0	0.00	0.00	0	0.00	0.65	2	0.12
Russula schizoderma	107.88	48	0.20	26.28	29	0.23	29.34	46	0.06	163.5	123	0.12
***Russula* sp** (Locally known as liwuwula)	0.00	0	0.00	0.76	1	0.00	5.06	6	0.31	5.82	7	0.27
Mushroom species	February			March			April			Grand Total		
	Sum	N	SD	Sum	N	SD	Sum	N	SD	Sum	N	SD
Russula* sp.(Dodolido)*	81.10	57	0.14	34.74	27	0.15	48.28	80	0.05	164.13	164	0.07
***Termitomyces* sp**	0.00	0	0.000	4.60	1	0.00	0.00	0	0.00	4.6	1	0.00
Total kgs	594.90	485	0.05	508.44	395	0.11	673.60	503	0.20	1776.9	1383	0.08

Names in bold are those found in field sampling

6.8.3 Other analyses of market data

Of the other analyses that can be performed on the market data the following have been included to illustrate what is possible. There were 16 mushroom 'species', which were being marketed, however a thorough taxonomic study can reveal more species. For, example *Cantharelus cibarius* was comprised of white specimen and yellow or gold specimen which may be two species . In this survey we deliberately left out mushroom species, which were collected solely for home consumption, as they were in very small quantities and also several species were mixed up and in most cases were not properly handled.

6.8.4 Income levels

The total value of the mushroom market sampled during the 61 days is given in Table 6-9 and Table 6-10. It is clear that the mushrooms have both very different quantities available for sale and widely varying prices. Normal supply and demand seems to operate with the rarest species fetching the highest prices (*Amanita* sp.) and the commonest the lowest (*Cantharellus longisporus*).

Table 6-9. Money realised from sales of different mushroom species

Mushroom species	Total Kwacha	Total kgs	Price per kg
Amanita sp.	20	0.14	142
Amanita bingensis	130	1.90	16
Amanita loosii	3,980	67.12	59
Cantharellus cibarius	16,477	290.69	57
Cantharellus congolensis	5,265	136.09	38
Cantharellus longisporus	47,771	862.60	55
Clavaria albiramea	700	10.78	65
Cymatoderma dendriticum	3,095	47.48	65
Inocybe sp.	1,115	19.08	58
Lactarius cabasa	170	2.08	82
Lentinus cladopus	20	0.28	71
Psathyrella atroumbonata	60	0.65	92
Russula schizoderma	6,930	163.5	42
Russula sp. (Locally known as Liwuwula)	620	5.82	106
Russula sp.(Locally known as dodolido)	9,576	164.13	58
Termitomyces sp.	300	4.6	65
Total	96,229	1,776.94	54

Table 6-10. Income realised by different sexes and age groups

Age range	Female	Male	Grand Total
<10 years		360	360
10-20 years	5,880	4,776	10,656
21-30 years	23,615	7,901	31,516
31-40 years	11,410	13,930	25,340
>40 years	18,862	9,495	28,357
Grand Total	59,767	36,462	96,229

Note: The currency is given in Kwacha, and the exchange rate at the time of study was K75.00 to United States $1.

Table 6-10 indicates that women obtain a higher income from mushroom trading than men with most going to women between 21-30 years of age. Among the men, those between 31 and 40 years of age make the most from mushroom trading. Most mushrooms are collected by people aged 21-30 though it is an activity that is undertaken by men and women of all ages but not that often by children.

Though not part of this study, people in this area are generally enterprising. Causal observation on sampling trips showed that men are mostly into firewood selling and curios making and selling, women at times do assist in firewood collection and marketing but not in curios making and selling. Most of the boys in general below the age of 20 are school going, leaving mostly girls to assist with household chores hence the larger number of girls collecting and selling mushrooms. In Malawian societies in general, relish gathering is generally the duty of women, hence more women search for mushrooms for food and also for sale. Abbort (1997) observed the same trend in Chimaliro, Kasungu. The monies generated from mushroom sales are generally used for buy maize and maize flour. Therefore for detailed studies to estimate how much is collected from a specific area, women would be ideal subjects for study.

People of all age groups were involved in collection and marketing of wild edible mushrooms. However the majority were in the age group 10 to 40 years. This is so because, children under the age of 10 years are either school going or can not keep up with the hard task of climbing mountains, even the few who are courageous can not properly identify mushrooms.
There are fewer people of the age range above 40 years collecting mushrooms because this age group is generally small (National Statistical Office, 1998), however, the few that are there put in more days in mushroom hunting and selling as other activities such as wood curving and firewood marking are too heavy for them. For detailed survey or productivity estimation, this group would be ideal to sample from.

When some women were interviewed during the survey they indicated that some men sell most of their mushrooms to mushroom vendors from town or they travel to town themselves to sell mushrooms. These mushrooms in general were not captured in the survey.

6.8.5 Quantities traded

Over the three months of the market survey marked differences in the quantities of mushrooms entering the market were observed (Figure 6-2). Some species were more abundant early in the season (*Russula schizoderma*) while others were more abundant (or larger) later in the season (*Cantharellus longisporus*). These differences mirror those found in the field survey.

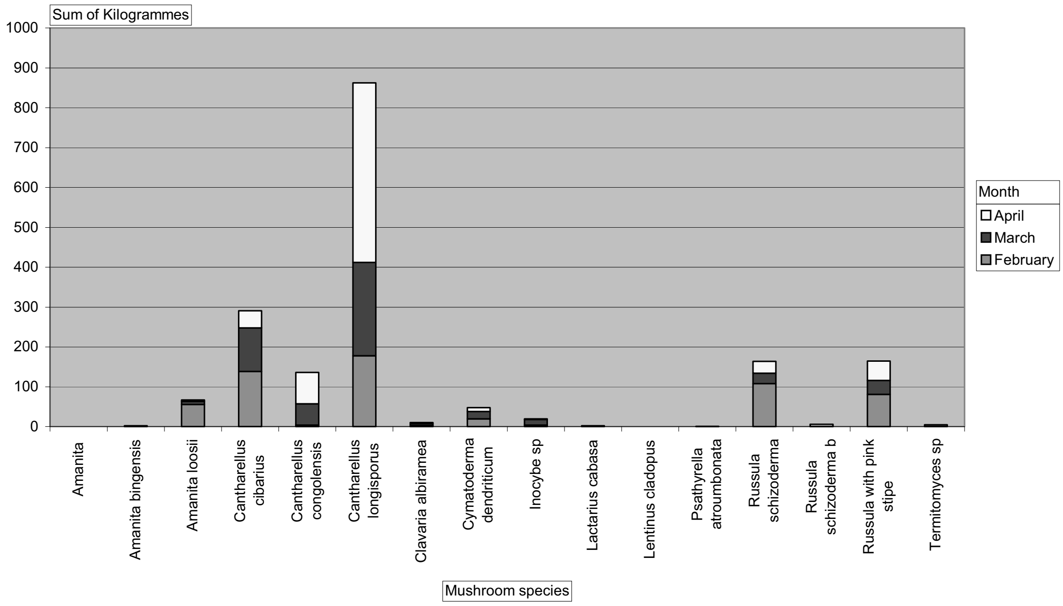

Figure 6-2. Total weight of mushroom species marketed in three months.

In total there was 1,776 kgs of mushrooms collected and market by 193 people over an average of seven days each for a period of 90 days. In terms of sampling this represents 2 people a day. This represents a small portion of the number of days and also the people who are involved in the marketing business. This was contributed by several factors such as: rain, rate starting of survey (in the afternoon), the collectors and sellers changing roles, the measuring and counting process was tedious. The strip, which was being sampled, has more than 10 marketing points and 5 to 20 people man each point and these numbers change on a daily basis. The collectors sometimes assist each other in marketing mushrooms if the other person is busy with other activities. In terms of estimation of total mushrooms marketed, the current study did not manage to estimate the volume of mushrooms harvested from the reserve. However, most collectors when asked how often they visit the forest to collect mushrooms said two to four times a week. And they said the number of visit is generally determined by the sales by the roadside and the availability of mushrooms in the forest. When sales are low, fewer visits are made to the mountain and when productivity is high, few trips are made as the markets are flooded with mushrooms or they may visit frequently and lower the prices or they may collect for drying. Based on this information one would come up with rough estimates of mushrooms marketed, however for a statistically sound estimate, there is need to employ 2 or more data collectors who need to collect the marketing data only on a daily basis. There is need to do a count of marketers on a daily basis, estimate volume of mushrooms on a daily basis. To estimate the area harvested there is need to accompany the collectors on their daily search of mushrooms. In the trip one would need to record time taken in the bush, estimate the distance travelled and the area searched. This would have to be done on people in different age groups and gender.

6.9 Evaluation of the sampling protocol

The sampling protocol generally worked well and was able to quantify the mushroom production per site (see Table 6-4) within 6-14% error. This is below the conventional target precision for forest inventories of 20% and would be acceptable for strategic planning purposes. If total production for the forest is required there are a few additional steps that would be required and a few issues that would need to be considered.

Step 1 – Estimate the area, in hectares, of mushroom picking sites would need to be estimated. This could be done from the participatory sketch maps as a first approximation and perhaps through GPS participatory mapping if more resources are available.

Step 2 – Stratify the mushroom sites according to species, or productive potential – do this using participatory techniques. Select sample sites from each strata – preferably more than one site per strata and randomly chosen.

Step 3 – Sample sites using protocol developed in this study over the whole mushroom season.

Step 4 – Multiply the mean production per sample site by the total area of the strata. Add strata total together to obtain total forest productivity.

If the results are required for monitoring, you may wish to consider using the same sample sites and plots each year. However, since there can be considerable variation between sites from year to year, further research is required to identify optimal monitoring protocols.

The remainder of this section discusses the results of the case study with respect to its objectives as laid out above.

6.9.1 Comparison of field and market data

The yield figures follow the market data in terms of the relative proportions of the different species harvested. Mushroom species which gave higher yield in field survey were also the most abundant in the market. This suggests that district forestry officers and plantation managers could use either of these two methods to estimate yield. This, however, has some limitations in that the search by villagers may not be as thorough as in the plots in which case the marketing figure should be lower than the actual productivity from sample plots. Not all mushrooms collected may be marketed as some are for food, and also data collectors may get to the collectors when some of the mushrooms have already been sold.

The field yield gives yield in terms of a unit area of forest while the market data gives the quantity per seller. However, in both cases if total yield for the season or forest is required then some means of bulking up the per ha and per person figures is needed. For the field data, the raw data is for known mushroom sites so an estimate of the proportion of the total area of the forest in each site type is required. The vegetation data and growing environment data show that there is a relationship between mushroom productivity and these factors. For estimation of total productivity of the reserve there is need to study the vegetation mix and establish the extent of conducive environments to extrapolate the figures. One way of doing this would be to use the relationship between tree species and mushroom productivity together with tree inventory data to estimate total productivity. Tree inventories have been carried out in some of the indigenous forest reserve (Chanyenga & Kayambazinthu, 1998; Lowore, Abbort and Swaine, 1999; Makungwa & Kayambazinthu, 1999) and these reports could be used in this exercise. The easier way is to use the collectors themselves to establish all the possible sites and then estimate total productivity based on those areas.

Likewise, bulking up from the market data requires estimates of the total number of sellers and market days and sites over the season. Unfortunately, during the time available to this case study it was not possible to undertake the additional work required to do this effectively.

Furthermore, if only one of the methods is used to estimate the size of the other, say market data being used to estimate forest productivity, then the form of the relationship between the two is required. This would itself require monitoring of both market and field data over a period of years together with significant socio-economic factors to build the requited predictive models. The limitation of funding did not allow us to follow the villages when they harvest mushrooms to estimate area searched and to collect other details such as growing environment and GPS reading of the sites. In America they used volunteers to collect this detailed information (Pilz & Molina, 2002). The volunteers included landowners, scientists form research stations, scientists from universities and mushroom harvesters. Information collected included area searched, species harvested, wet weight and dry weight of the mushroom, diameter of the cap and length of the stalk. In Malawi this could not be done, as the mushroom collectors are mostly illiterate. However, for the forest managers, they can establish a few plots, which they can use for estimating the productivity from a fixed area to convert market figures. In a co-management arrangement some collectors can be trained to take measurements in participatory resource assessment as is currently being done under a social forestry project in Malawi.

In the interest of time and limited resources the only parameter taken on mushrooms was weight. Collectors in Liwonde forest reserve are not particular on the size of mushroom they harvest and also they harvest more species than one. As the sizes and species are very varied, measurements such as length of stalk and diameter of the cap and counts would not be very meaningful.

The yield figure for *C. cibarius* compares with the yield figure reported in America by Pilz and Molina (2002) of a range of 2 to 20 kg per hectare. This suggests that the estimates obtained in this study are within range. There has not been any previous wild mushroom field productivity quantification study in the miombo woodlands with which to compare figures..

The study has shown that not all mushroom species are harvested to the same extent. Some mushrooms are harvested and marketed more than others. In light of limited funding, there is need to select a few species that are sold the most and do through studies on them, in this case the likely candidates would be *Catharellus* species and *Russula* species.

6.9.2 Participatory stratification

In this case study, interest was for estimating productivity of areas where villagers go to collect mushrooms. Sample plots were place in areas which were said to be productive. However, the results did not support this. There was only a weak relationship between mushroom species and sites (see Table 6-6). This may indicate that there is a poor predictive relationship between sites and species such that they only become apparent over several years of observations. Together with the observation that the poor mushroom site (4) was not in fact the lowest yielding suggests that site selection may not be critical and yields can be estimated from randomly located plots. Indeed, Pilz and Molina (2002) recommended adaptive sampling where plots are changed all the time to derive an unbiased estimate of productivity. This method, however, calls for more training and data analysis and is complicated. However in co-management arrangements where the villages have specific sites they collect specific NTFP from, interest would be knowing the productivity of the identified sites.

For management of the forests to enhance mushroom production, the forest managers have established the relationship between mushrooms and their environment. Correlation data between mushroom production and growing conditions served this purpose. There was generally a weak correlation between mushroom species and selected environmental factors such as soil, canopy closure however there was an indication species responded differently to different environmental condition. This suggests that for particular mushrooms of more interest more data can be collected to establish the relationship so that appropriate management decisions can be taken to influence production.

As most of the mushrooms collected form a mycorrhizal association with trees, the correlation between tree density and species was done. There is a general weak positive correlation between trees density and this study which suggests high density or basal area is associated with high mushroom productivity. However there is need to do controlled study where tree density is manipulated to determine conclusively the effect of trees density on mushroom production. Summaries of total mushrooms collected close to trees show that more mushrooms are collected close to *Uapaca* trees followed by *Brachystegia* species. This suggests that regeneration of trees mostly associated with mushrooms should be encouraged to promote productivity of mushrooms.

6.9.3 Constraints in the study

The study was affected by a number of problems. The study started after the mushroom season had already started. Some mushrooms especially those that occur at the onset of the rainy season such as *Amanita loosii*, and *Termitomyces* species were consequently missed during the sampling.

Due to limited resources the current study missed crucial information such as the total area visited for mushroom collection, the total number of people involved in the mushrooms business on a daily basis, maps of the areas visited. There is need to collect all this information in the next study. This would be facilitated by the availability of GPS software and equipment which would ease the collection and analysis of geographical data.

Capacity of the research scientist to handle data was a bit limited, in the event that such studies are repeated, upgrading the statistical capacity of scientist through training and visits of seasoned scientists in data management would be necessary.

6.10 Conclusions and recommendations

The following conclusions can be drawn from this study:

1. The study has established that there are several species of edible mushrooms that are eaten in the area, and that the sampling methods to be developed should aim at developing general productivity estimation methods for all the species collected.
2. Sampling plots should be located in the areas where villagers collect mushrooms.
3. Productivity of harvestable yield can be estimated from the roadside markets. However, for accurate measurement of harvestable yield, which would in turn give the productivity of sites visited, there is need to accompany collectors into the forest. The data enumerators would need to record area searched and quantity of different species collected.
4. Weight should be used for measuring yield, however, counts can complement weight measurements.
5. Ten randomly located plots of 2 x 100 m plots were able to capture mushroom production at a site.
6. Since the different mushroom producing sites were not characterised, plots can be repeated in blocks to maximise the accuracy of the yield estimate. However, with more resources, sites need to be characterised, and plots be blocked according to site characteristics. The blocks can be regarded as treatments as they represent different growing conditions. Also with more resources, the season can also be segmented and be regarded as blocks or treatments.

Since these studies were conducted to develop inventory guideline for non-timber forest products for use by DFO, it is clear that the current data set cannot be used to make recommendations for a statistically robust yield estimation method. There is need to carry on this study and focus it a little more one or three most important species. There is need to recruit data collectors who would be charged with the sole responsibility of collecting marketing data only.

Lack of statistical management packages and limited local statistical expertise in NTFP delayed the analysis and interpretation of the data. There is a need to ensure that such skills are available for any inventory exercise.

6.11 Data collection sheets

Data collection sheet 1 – Plot establishment inventory

Site number:…… Date:………………… Assessors:……………………

GPS readings for centre of site

Longitude: ……………………

Latitude: ……………………

Altitude: ……………………

Site condition: (soil moist, recent burning etc.)

Sketch map showing location of plots and main features: (include groups of trees, streams, paths etc.)

Tree species	DBH

Data collection sheet 2 - Plot enumeration

Site number:……Plot number:…………… Sheet ….. of ……… Date:………………… Assessors:…………………….

Plot layout Longitude: …………………… Latitude: …………………… Bearing: ……………………… Slope: ………………………..

No	Trees in section			Mushrooms in section		
	Name	dbh	Distance	Name	Number	Condition

Data collection sheet 3 – Marketing data collection form

Name of enumerator...Site..Date of interview.......................................

Respondents name	**Sex and age**	**Species**	**Amount collected**	**Count of caps**	**Total weight**	**Selling price**	**Site characteristics**

7 Comparartive assessment of alternative sampling designs for non-wood forest products in Mwekera National Forest – Kitwe, Zambia. *

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7.1 Objectives

During an expert consultative meeting on NWFP inventory guidelines held in Lusaka- Zambia between 15th and 17th October 2002, it was revealed that a lot of variations occur in the assessment of NWFP in Africa generally. Among the areas of concern, was the question of whether it is best to combine several species into a multi species inventory or to do separate inventories for each species. It was therefore decided that a case study be undertaken to evaluate and compare the effectiveness of carrying out a multi species as opposed to a single species inventory. Forests contain many harvested species and forest management plans need to include all of them. The current practice is to undertake a single inventory utilising the same sampling design for all products at the same time (multi species inventories, MSI). However it is often the case that such inventories yield data that has high sampling errors and is generally unsatisfactory for detailed management planning for individual species. There is little sense in promoting NWFP-based livelihoods on these resources if they cannot withstand increased or indeed current levels of harvesting. Better data will assist in the definition of sustainable harvesting schedules.

The project was carried out with the following objectives:

1. To evaluate the costs and benefits in terms of data quality of carrying out mult-species against single species inventory
2. To recommend some protocols in the assessment of the selected species and products.

The school of Natural Resources at the Copper belt University in Zambia did this case study. Due to the limitations in terms of time, funds and other necessary requirements, Mwekera National Forest was chosen as the study area, as this according to local knowledge was one of the major sources of NWFP and also being in near proximity of the Copperbelt University (CBU).

7.2 Species and products

Based on local knowledge about the most harvested products. Six species were selected for this study, four fruit species; *Uapaca kirkiana*, *Anisophyllea boehmii*, *Parinari curatellifolia* and *Strychnos cocculoides*, the two tuber/corms were; *Rhynchosia insignis (including Rhynchosia heterophylla)* and *Satyria siva*. Table 7-1 gives a brief description of each of these products.

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* "Original report done in English." For more details please contact FOPW webpage.

Table 7-1. Description of species and products used in case study

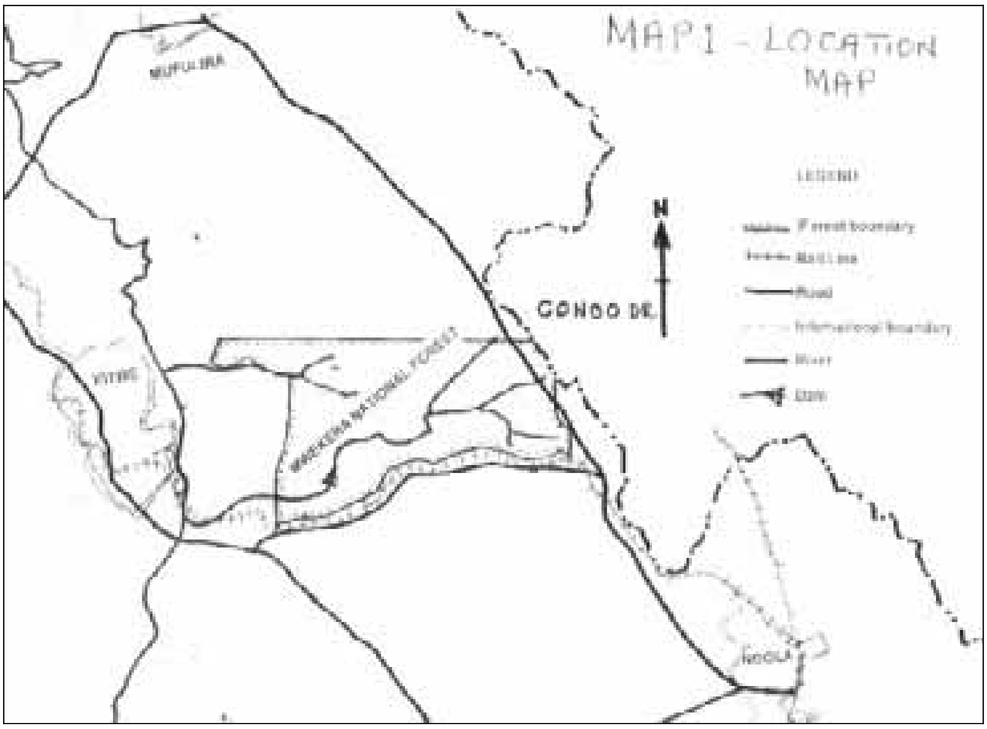
Species	**Description**	**Product**
Uapaca kirkiana Musuku, Wild Loquat	This is a tree belonging to the *Euphorbiace* family found throughout Zambia except Kalabo District. It is a small semi-deciduous tree growing up to 13m high. The tree is much branched with a shortish, occasionally twisted bole and a heavy flat rounded crown. The flowers are pale yellow and born on the old wood below the leaves and appear generally between January and April with casual flowering between September and November. The male flowers are in clusters and the female solitary.	The fruit is round yellow-brown fleshy (3-4cm diameter) that ripens between August and November but may be found in any other month. The flesh is yellowish, edible and sweet tasting with a pear-like flavour. The fruit is very much sought after and can be made into jam, eaten raw or used to produce a refreshing drink. There have been efforts to commercially process the fruit into wine and other products. During the peak production period of November, December, the fruit is found widely in most Zambian urban markets.
Anisophyllea boehmi Imfungo	The tree grows in most of the high rainfall areas of Zambia, thus it is absent from most parts of the southern, western and eastern provinces. This is an evergreen or semi-evergreen tree that grows up to 16m tall with a short usually crooked bole. Erect branches form the rounded heavy crown. The flowers appear from April to July with casual flowering from September to November.	The fruits mature from July to March. The fruit have a pale yellow flesh and contain a single hard stone seed. It is edible and very tasty. Fruiting tends to be poor and erratic.
Parinari curatellifolia Mupundu	The tree belongs to the family Rosaceae and is evergreen growing up to 2 1m tall. Occasionally, it has thick irregular buttresses up to 2m high. The heavy erect sometimes-drooping branches form a heavy somewhat rounded crown. The tree occurs throughout Zambia and is wide spread in the drier parts of tropical Africa from Senegal to Kenya and southwards to the Transvaal. It is found most frequently in chipyas, plateau, miombo and Kalahari woodlands but also occurs occasionally in other woodland types and in evergreen thickets. Flowers appear from July to October.	The fruit matures from May to November. The fruit is red, brown or green-brown and speckled. The fruit is warty, hairless and fleshy containing an edible fibrous and sweet but astringent pulp and contains one edible seed enclosed in a hard stone. The flesh contains vitamin C and high oil content. A large quantity is sold in town markets and is widely eaten in the rural areas either as relish or used to make both alcoholic and non- alcoholic drinks.
Strychnos cocculoides and *Strychnos espinosa* Kasongole, Bush / elephant orange, Sansa, Monkey ball	These are both semi- evergreen shrubs or small trees growing up to 9 m tall with spreading branches and a somewhat rounded crown. They have paired curved spines about 7 mm long in S. espinosa and over 1 cm in *S. cocculoides* Flowers appear between September and November.	Fruits ripen a year after flowering. These are spherical, usually mottled green and yellow, may also be yellow or orange and reach 10 cm in diameter and are edible. The fruit is also used in the preparation of eardrops.
Rhynchosia insignis and *Rhynchosia heterophylla* Munkoyo	This is a shrub that belongs to the family *Papilionaceae*. It hardly grows more than 50 cm.	The root is dug out and widely used in preparation of the popular beverage in most parts of the country. It is also widely traded in town markets throughout Zambia.
Satyria siva Chikanda	This is a hydrophilic herb belonging to the family *Liliaceae.* It hardly grows more than 20 cm tall. The tuber/corm of this herb has very good jellying and gumming properties.	Although a number of products can be made from the tuber/corm of the herb, it is commonly prepared for consumption as either a snack or a complementary food to starchy preparations. Traded widely in the northern half of the country.

7.3 Location

Mwekera National Forest is a protected forest reserve in the Copperbelt province of Zambia, lying between longitudes 28^{0} 17’ E and 28^{0} 30’ E, and latitudes 12^{0} 45’ and 12 ^{o} 52’ S. (see Map 7-1).

The dominant vegetation type of this area is miombo woodland, predominantly *Brachystegia* and *Jubernadia* species punctuated occasionally by open grassland and dambos, and has streams and rivers running through it most of them tributaries of the Kafue river, one of the four major rivers in Zambia. Among the major streams and rivers of this forest are, Mwekera, Nakolwe, Matupa and Kakolo rivers. Being in close proximity of two major cities in the Copperbelt Province that is 30 km from Kitwe (second largest city in Zambia), and 30 km from Ndola (third largest city in Zambia), this forest is a source of various edible and non-edible NWFP that include fruits, tubers/corns roots and mushrooms etc. At the onset of rains (November-December) and also just after the rains (March-July), a huge number of harvesters (residents) enter the forest to collect various NWFPs especially edible products such as wild fruits, roots, tubers/corms and mushrooms some of which supplement household nutritional requirements while others are supplied to Kitwe and Ndola.

Map 7-1. General location of Mwekere National Forest, Zambia



7.4 Methodology

This study involved the following activities:

Preliminary information collection from partners and local communities. This involved non-structured interviews with various stakeholders, which included Forestry personnel, marketers and harvesters of NWFPs. This was to determine the sample species, biological data and growing habits and locations.

- Development of sampling designs for both MSI and SSI.

- Field work for data collection i.e. MSI was done in April of 2002 while the SSI was carried out in September 2002.
- Data entry and analysis
- Report writing.

7.4.1 Multi species inventory (MSI)

In the MSI all six sample species were assessed at each sample plot (see Table 7-1). The sampling design used for the inventory was systematic cluster sampling. This was chosen following guidelines for selection of sampling design provided in the Lusaka workshop.

The design used for the MSI was a systematic design based on a 2 x 2 km grid. A cluster plot comprising four 50 x 50 m sub-plots arranged in a square 20 m apart were laid out at each grid intersection.

Figure 7-1 and Map 7-2. The coordinates for the grid intersections, that is the Eastings and the Northings of each cluster point was obtained from the Map of Mwekera Forest Reserve No. 6, series Z551, Sheet 1228 C4, IZS 1972. These coordinates were entered into the GPS which was used to locate the points in the field. Once the cluster point was located the plot was laid out by pacing. A total of 43 plots were anticipated from the map but in the field only 36 cluster points were actually sampled as seven plots were found to be inaccessible.

Map 7-2. Location of systematic cluster plots

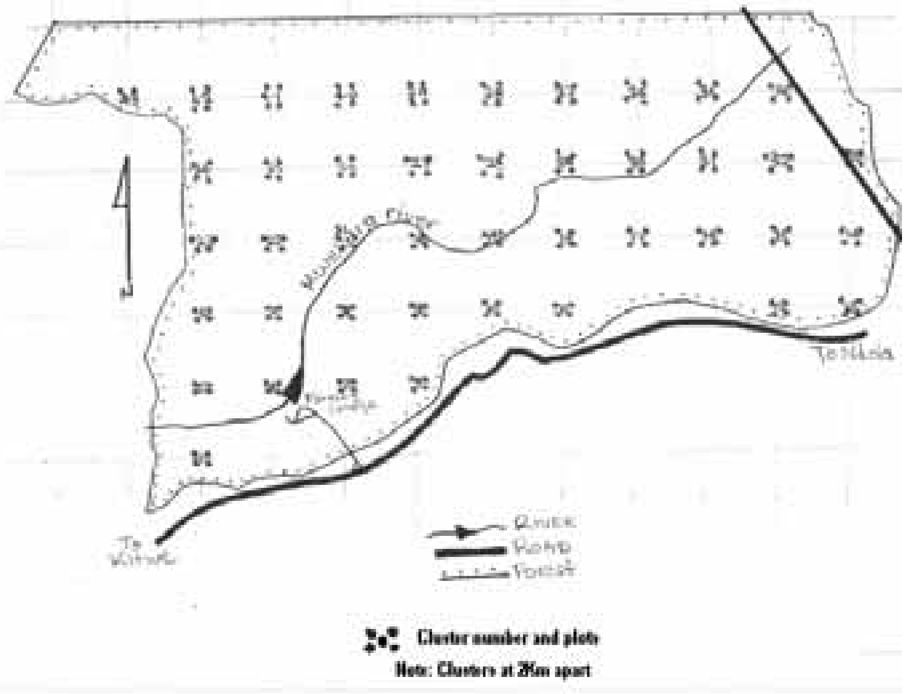
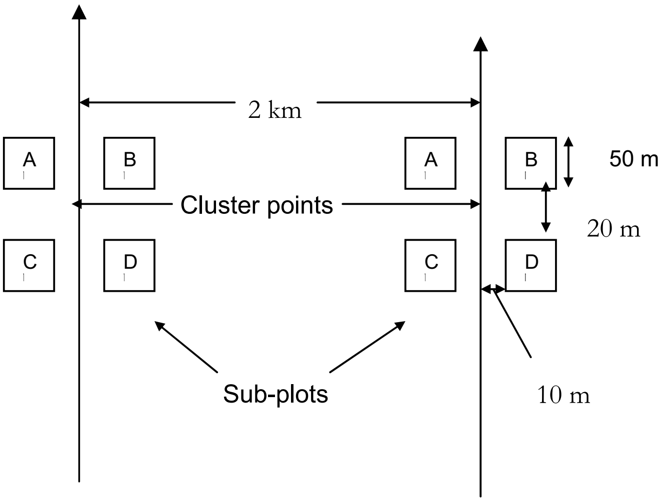


Figure 7-1. Cluster (with 4 subplots) along transects.



All plants of the six sample species that fell within the sample plot were then measured and the values entered or recorded in form 2a for regeneration and form 2b for the other parameters (see Appendices). In addition the diameter at breast height (d) for plants with diameter ≥ 5 cm were taken using calliper or diameter tape. Plants that were less than 5 cm in diameter were recorded as regeneration. Also the diameter of the canopy cover was estimated. This was done by estimating the diameter of the cover on the ground by use of linear tape, which was taken as the average of the longest, and the shortest estimated diameter of the canopy. None of the four species were in fruit at the time of sampling so it was not possible to measure fruit production.

7.4.2 Single species inventory (SSI)

When dealing with the SSI the on the ground experience gained from the MSI was applied. According to the actual situation, it was confirmed that the two herbaceous plants tended to grow around dambos and sparingly in the open savannah woodland. While the fruit trees tended to be present in greater numbers in the savannah woodland withy fewer in and around dambo areas. This therefore compelled us to treat the case of selection of the sampling design separately for the corms/tubers and the fruit trees.

Two species were selected for the SSI. These were *Uapaca kirkiana,* a fruit tree and *Satyria siva* a herbaceous plant. *Uapaca* was the commonest tree found in the MSI, while no individuals of *Satyria* were found in the MSI. These two species therefore would provide a good test of alternative designs with the emphasis on increasing efficiency for *Uapaca* and actually locating some indviduals of *Satyria* to record.

7.4.2.1 *Uapaca kirkiana* – simple random sampling

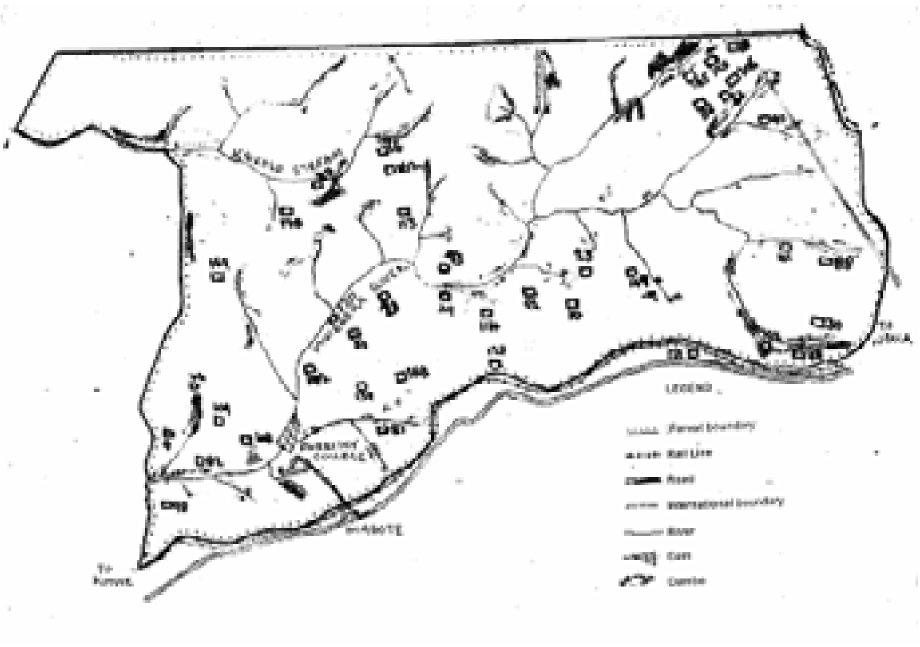
As *Uapaca kirkiana* proved to be evenly distributed in this forest it was decided to use simple random sampling as an alternative to the systematic design of the MSI. This would be a good test of whether it was better to systemtically or randomly sample for a relatively common species.

The random sampling was achieved by writing coordinates for points on a 0.5^0 grid onto pieces of paper which were picked at random from separate boxes for the eastings and northings. The pieces of paper were put back into their respective boxes and the process repeated mixing the boxes thoroughly each time a plot location was chosen. The co-ordinates were entered into a GPS which was used to locate the plots in the field.

In all, 172 sample plot locations were selected (see Map 7-3). The plots were 50 m x 50 m square plots similar to the subplots used in the MSI clusters. However, in the field only 45 of the 172 sample plots were visited. This was because many of the plots fell outside the forest and even among the plots that fell within the study forest they were so scattered that the time and resource limitation of the study meant it was not possible to visit them all.

The plots were the same as those laid out for the systematic sampling though only total plot counts were recorded. All the *Uapaca kirkiana* trees in the plots were enumerated and recorded on forms 2a and 2b. It is worth noting that the distinction between trees and regeneration was quite arbitrary though it was generally taken that plants with a diameter of less than 5 cm were recorded as regeneration. However, it was discovered that in some cases plants as small as 3 cm diameter were recorded as a tree.

Map 7-3. Location of random plots for Uapaca



7.4.2.2 *Satyria siva* – stratified systematic sampling

After careful consideration of the actual position on the ground and with consultation with the local community on the availability of these species, it was decided that a more intense type of sampling design should be used. The sampling was therefore restricted to the dambos as indicated in Map 7-4. The selected dambos were sketched mapped and their areas estimated. A series of parallel sample lines spaced 300 m apart were laid out within the dambos (see Figure 7-2). At 100 m intervals along the sample lines a 50 x 50 m square plot was laid out. In each plot, the number of Satyria plants was recorded using Form 2b. Since the corms of Satyria are present all year round it was possible to dig out some as samples to determine their weight. Fifty two plants were dug out at random and their tubers weighed.

Map 7-4. Location of dambos sampled for Satyria

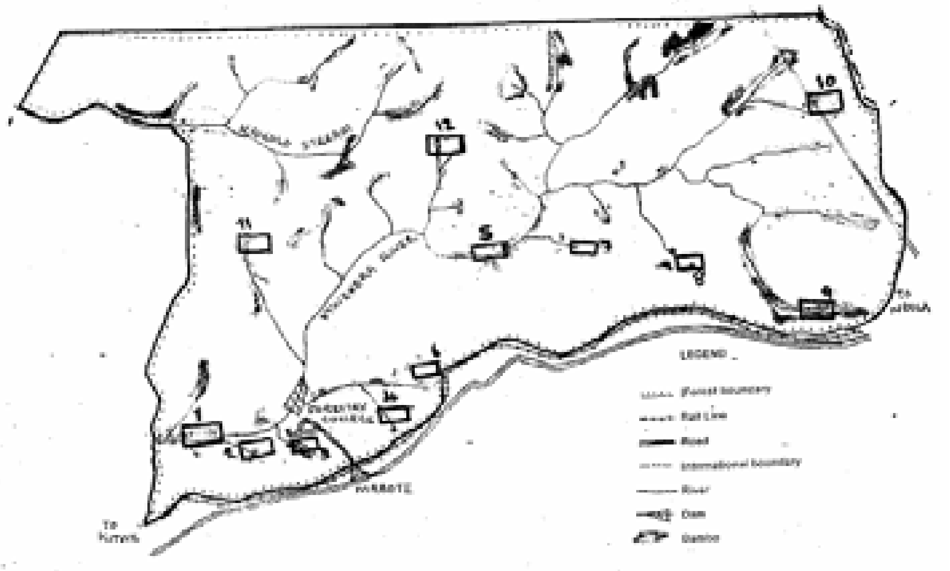
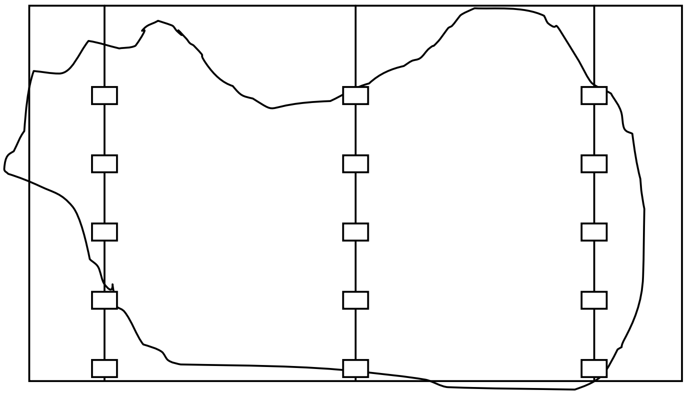


Figure 7-2. Layout of sampling strips and sample plots on an irregular shaped dambo



7.5 Results

The inventory data was entered into Excel spreadsheets for analysis. This is less than ideal but in the absence of specialised statistical software is adequate for most routine analyses.

7.5.1 Fruit tree inventory

Determination of species abundance was estimated by tallying or counting the number of plants in each sub-plot. The 'correct' way to calculate the mean of a cluster sample is to first calculate the mean for each plot (the mean of the four sub-plots) and then to calculate the mean of all plots. The final statistic is therefore expressed as stems per 0.25 ha sub-plot. Table 7-2 gives the results for the four fruit tree species from the systematic MSI. The sampling errors (SE%) for three of the species is much the same at around 70% and for the rarest twice this at 123%. Parinari is the rarest species with only three trees counted in the inventory. Uapaca is the commonest species with more than seven trees per ha. Strychnos and Anisophyllea have similar densities and sampling errors or 2-3 trees per ha.

Table 7-2. Systematic fruit tree inventory results

Species	Number of plots containing species	Number of plants sampled	Mean stems ha^{-1}	SE%
Uapaca	16	254	7.056	68
Strychnos	3	4	0.112	123
Parinari	19	103	2.860	67
Anisophyllea	14	118	3.276	67

Total number of plots = 36

During the inventory the land cover of the cluster points was recorded. Such records can be used to post-stratify the data to examine the preferences and density of trees in different land cover types (Table 7-3). The stratified results indicate that, as expected, the areas covered by natural woodland contain all four species at their highest densities. What is more revealing is the observation that all species also occur on cleared land at densities of between 15-40% of that in natural woodland. For Parinari the densities in cleared land is even slightly higher than in woodland which may be a consequence of human selection for the species. Densities in actual farmland is much lower than in cleared land which suggests that they are eliminated by farmers even though they are fruit bearing. The dambos are seasonally inundated and are not a preferred habitat for the fruit trees. Parinari appears as a very occasional weed in the plantations.

Table 7-3. Post-stratified data from the systematic inventory of fruit trees

Land type	Cleared		Dambo		Farmland		Plantation		Woodland	
N plots	8		3		12		4		9	
Statistic	Stems ha^{-1}	SE%	Stems ha^{-1}	SE%	Stems ha^{-1}	SE%	Stems ha^{-1}	SE %	Stems ha^{-1}	SE %
Uapaca	4.12	148	2.33	328	0.50	187	-		23.11	69
Strychnos	0.12	217	-		-		-		0.33	169
Parinari	6.12	123	4.00	527	0.16	325	0.25	367	4.33	66
Anisophyllea	1.62	131	-		1.08	127	-		10.22	73

The trees were measured as well as counted and the results are given in

Table 7-4. Here is it clear that Parinari is the largest tree while the other species are represented by small trees. In most areas there was heavy indiscriminate cutting of even these fruit trees for charcoal production. This is why the diameter is small, meaning most trees are young, especially for Uapaca as it seems to be one of the pioneer species, it was found to grow in open areas. In natural woodland it is expected that regeneration should outnumber mature individuals. The results indicate that this is only the case for Uapaca, for the other species regeneration only equals or is less than 'adult' trees greater than 5 cm d. Interpretation of these results is difficult without further information but it would appear that there is some cause for concern for the stability of the populations of fruit trees in Mwekere.

Table 7-4. Dimensions of sampled fruit trees

Species	Mean diameter (cm)	Average height (m)	Mean crown diameter (m)	Stems ha^{-1}	Regeneration plants ha^{-1}
Uapaca	8.72	6.98	2.28	7.056	10.027
Strychnos	6.88	4.25	1.45	0.112	0.083
Parinari	21.72	13.01	9.41	2.860	1.472
Anisophyllea	8.77	6.07	1.63	3.276	3.361

One of the purposes of this exercise was to compare the relative efficiencies of systematic and random sampling using Uapaca as a test species.

Table 7-5 gives the results of the two inventories for all tree density data. The numbers are roughly comparable especially for all trees with basically similar sampling errors. This suggests that there is little to choose between the two methods though the systematic inventory had fewer plots which might suggest a slight advantage for this design.

Table 7-5. Comparison of systematic with random sampling for Uapaca

Design	Plots	Trees < 5 cm			Trees >= 5 cm			All trees		
		N	Mean	SE%	N	Mean	SE%	N	Mean	SE%
Systematic*	36	361	10.03	67	257	7.14	61	618	17.66	61
Random	45	445	9.89	42	282	6.26	40	727	16.15	37

* These figures are calculated from the cluster plot sums rather than means to be more comparable to the data from the random plots. Slight differences with previous figures are the result of rounding.

7.5.2 Dambo inventory for Satyria

This inventory sampled 12 dambos at a much finer spatial resolution than the fruit tree surveys. The sampled dambos where randomly selected (see Map 7-4) and the results for each are given in Table 7-6. Satyria was only found in half of the dambos and in just over half of the sampled area. Within the dambos containing Satyria there was a wide range of plant density, two dambos had more than 20 plants ha^{-1} while the others all had less than 7 plants ha^{-1}. This would seem to confirm the general impression that Satyria is being over-exploited in the area with relatively few dambos left containing good populations. The weights of 50 exhumed corms were recorded and the average weight of corm on a plant was 5.38 gms.

Table 7-6. Satyria results for sampled dambos

Dambo	Number of transects	Number of plots	Number of plants	Plants ha^{-1}	SE%
1	3	27	-	0	
2	2	16	-	0	
3	2	10	-	0	
4	2	8	-	0	
5	2	8	-	0	
6	3	21	9	1.712	112
7	2	10	-	0	
8	3	21	30	5.712	82
9	2	16	19	5.428	102
10	2	20	112	27.712	29
11	2	12	21	7.000	87
12	2	14	84	24.000	48
All dambos		183	285	5.964	107

7.6 Evaluation of objectives

The purpose of this case study was to examine the relative efficiencies of different methods of sampling population of NWFP species in savannah woodland. The first observation is that the systematic design which is one which is very popular for tree inventories did not pick up a single individual of the two herbaceous species. Stratifying the area into habitats favourable to a particular species (Satyria) and sampling at a resolution appropriate to the habitat and species was able to successfully locate and quantify the species. It would appear that it is important to consider the habitat requirements and scale when inventorying herbs and these may not often be compatible with tree inventory.

The sampling errors for all species in Table 7-2 were not less than three times greater than the usual target for forest inventories of 20 %. Using the formula below it is possible to estimate the number of plots required to bring the sampling error within 20 %.

Number of sample plots to achieve 20 SE% $n = \frac{4(CV)^2}{20^2}$

Where the CV is the coefficient of variation which is the standard deviation expressed as a percentage of the mean. The number of plots required for each species is given in Table 7-7. These figures show that around 300 plots are required for the commoner species and more than 1200 for the rarest. This suggests that a single design would be possible for the commoner species as the same number of plots would achieve the same precision for all species. However, if the same precision was required for Strychnos a much large inventory would be required. It is obviously difficult to capture sufficient individuals of rare species to minimise errors so in this case it may be best to lower expectations and accept lower precision. It is therefore concluded that a single design would work for a number of species of similar size and lifeform, in this case for fruit trees. As mentioned above, although the figures in Table 7-7 suggest that the random design may be better than systematic for Uapaca, the figures for all sizes of tree in Table 7-5 show that there is in fact little to choose between the two methods. This confirms the general understanding that systematic sampling is as good as random with the added advantage of logistical simplicity and suitability for post-stratification of the type presented in Table 7-3.

Table 7-7. Estimated number of plots to achieve a 20% sampling error for fruit trees

Sampling design	Species	CV%	20%	Index of dispersion	Chi square	Pattern
Systematic	Uapaca	198	394	6.95	243.5	Highly clumped
	Strychnos	358	1286	0.36	12.5	Uniform
	Parinari	195	383	2.74	95.8	Clumped
	Anisophylla	194	379	3.10	108.7	Clumped
Random	Uapaca	131	173	10.82	454.6	Highly clumped

One of the basic assumptions of the FAO guidelines is that there is a relationship between the optimal sampling pattern and the spatial distribution of a species. One way of characterising the spatial distribution of a species is to plot frequency against the number of plants in a plot. If this conforms to a Poisson distribution the plant can be considered to be randomly distributed in space at the scale of the plots sampled. A feature of the Poisson distribution is that it is symmetrical so that the variance is equal to the mean. A simple test for a position distribution is therefore the Index of dispersion which should be 1. A simple chi-square test can be done to determine whether the species in question has a random spatial distribution (Krebs 1999 and see Box 7-1). If the index of dispersion is greater than 1 the population is said to be aggregated or clumped, while if it is less than 1 it is uniformly distributed. Table 7-7 gives the I and χ^2 and interpretation of the species distributions.

Box 7-1. Testing a species spatial distribution pattern

In a random, Poisson distribution the variance is equal to the mean.

Index of dispersion $I = \frac{s^2}{\bar{x}}$ - should equal 1

Chi square $\chi^2 = I(n-1)$

Accept the null hypothesis that the Poisson fits the observed distribution if: the probability that it is the same falls within 0.025 to 0.975.

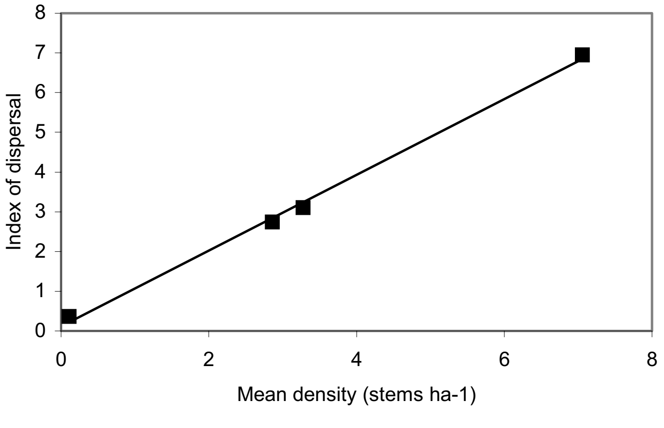
$\chi^2_{.975} \leq$ Observed chi-square $\leq \chi^2_{.025}$

The chi-square tests summarised in Table 7-7 reveal that none of the fruit tree species conformed to a Poisson distribution and so are distributed non-randomly. The test indicates that Strychnos is uniformly distributed i.e. is evenly spaced across the landscape but is also rare and only three tree were found in the inventory plots. The test results suggest that Parinari and Anisophylla are moderately clumped whereas both the systematic and random sampling patterns indicate that Uapaca is highly clumped.

Figure 7-3 is a plot of the index of dispersion against the mean density for each of the four fruit tree species. There is a remarkable linear relationship between these two variables indicating that as trees become more common they also tend to be more clumped at least in Mwekera National Forest. As illustrated in Table 7-3 Mwekera forest is made of a several distinct land cover types and not all species are found in every cover type which may have an influence on the data in Figure 7-3.

These results suggest that abundant species are more likely to be clumped but because they are common is it possible to obtain acceptable estimates from simple designs such as systematic sampling so there is no need to develop special designs for them. The need for special designs such as adaptive cluster sampling (Underwood and Burn 2000) really comes into its own for rare, clumped species; hence for Satyria rather than Strychnos which is rare but apparently isolated.

Figure 7-3. Relationship between the index of dispersal and mean for fruit tree species



Decisions about the relative merits of any particular inventory design cannot be made in total isolation from the costs and logistics of undertaking the fieldwork. All costs involved with the inventories were recorded and are listed in Table 7-8 in Zambian Kwacha. The summary figures were converted into US dollars at the prevailing exchange rate of US \$ 1= ZM K 3500 for the MSI and US \$ 1 = ZMK 4500 for the SSI.

Table 7-8. Inventory costs

Item	Multi species inventory	Single species inventory
Transport	2 301 100	1 850 000
Enumerators	1 900 000	835 000
GPS hire	300 000	300 000
Stationary	550 000	1 939 900
Researcher fees	3 000 000	3 000 000
Total	8 051 100	7 924 900
Total US$	2300.31	1761.09
Cost per plot US$	63.89	38.28

Cost in Kwacha unless stated

These costs were used to compare the cost efficiency of the systematic and random sampling patterns for Uapaca. The efficiency of two designs can be compared by weighting their total costs (in US dollars) with the variance (for the total number of trees) (Philips 1981).

$$\text{Comparison} = \frac{\text{Cost}_{\text{systematic}} \text{ x } \text{Var}_{\text{systematic}}}{\text{Cost}_{\text{random}} \text{ x } \text{Var}_{\text{random}}} = \frac{2300 \text{ x } 1131.1}{1761 \text{ x } 394.4} = 3.75$$

In the case of Uapaca, the comparison shows that the random sampling was 3.75 times more efficient than systematic sampling. This is because it was significantly cheaper and sampled more plots (45 compared to 36). However, it was noted that because of logistical difficulties it was found necessary to restrict the plots that were visited. It may be that this had the effect of introducing a bias to the results, not in terms of the accuracy of the results as they match those of the systematic sample but rather in terms of selecting plots all from a particular location or land cover type so that they were homogeneous than the systematic sample. This would have the effect of decreasing the variance. Another contribution could be the costings; the systematic plots would have taken longer than the random ones because measurements were being taken on four rather than one species. It is difficult to know how much cheaper a single species systematic sample would be but it was noted that the random sample was harder to undertake because of the large distances between plots. It would be expected that this would translate into higher costs but this is not apparent because logistically difficult plots were not visited. The results are therefore somewhat inconclusive and on balance it seems that there is probably little difference between the two designs and the choice between them should be made on other grounds.

7.7 Conclusions and recommendations

Based on the results of this case study is concluded that:

- A multi-species inventory should give acceptable results for groups of species with similar lifeforms, sizes and where rare trees are isolated rather than clumped.
- Herbs and trees cannot be sampled in the same design because the scales required are incompatible.
- There is little difference between systematic and random sampling in terms of cost efficiency though systematic sampling may have logistical advantages.
- There is no need to use special designs for abundant clumped species because it should be possible to capture sufficient individuals in a simple design to achieve acceptable precision.

- It is important to stratify for species which occur in discrete habitats.

Furthermore, it is very clear from this inventory that NWFP in Mwekera National Forest in Kitwe- Zambia, are heavily exploited. For the fruit trees, these are exploited both for their fruit and for their wood, especially for charcoal production. This is not healthy because fruits from these trees are known to supplement the nutritional needs of the local communities. There is therefore need for the forest authorities to address this issue quickly before the fruit trees are wiped out of the National Forest.

For the tubers/corms they are the first to be exploited by the illegal settlers that have literally invaded the area. These are harvested for sale in urban areas to earn an income and a little consumed locally.

The recommendation in this study is for inventories to be taken on regular basis for these NWFPs so that these can be incorporated in the local joint management plans that are now being introduced. This will help in the sustainable utilisation of these important forest resources.

7.8 Enumeration forms

Enumeration form 2a

REGENERATION

Enumerator…………………….. Time end …………………………..

District …………………………..

Forest area …………………………..

Date …………/…………/2001

Plot number……….

No	Species	Count (n)	DBH (cm)	Height (m)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

Enumeration form 2b

sheet …………/………

MAIN PLOT/ PERMANENT

Enumerator ………………….. Time start …………

District …………………….. Forest area ……………………..
Plot number ……………………..
Date ………../……../2001
Altitude (m)…………………… Bearing (°) …………………
GPS x (m), E…………………… SD (m) …………………
GPS y (m), S………………….. TD (m) …………………
Land use ………./…………… Intensity of fires ……………../…………
Vegetation type ……………../………… Soil type ……………../…………
Forest condition ……………../………… Undergrowth type ……………../…………
Potential and use …………../………… Previous treatment ……………../…………
Grazing ………./………… Treatment suggestion ……………../…………

No	Species	DBH (cm)	Height		Use		Bole character		Health Status		Dir (°)	Dist (m)
			Tree	Bole								
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

8 Lessons learnt

The case studies were intended to develop and test methods for inventorying NWFPs and to explore mechanisms for providing statistical advice to practioners. The partners in the case studies were all professional foresters, either researchers, university lecturers or forestry department officers. The priority problems addressed in the case studies were identified during expert consultation workshops as were the countries, partners and species. This experience has revealed many lessons both generic and more specific to the studied products.

8.1 Summary of lessons for NWFP inventory

Each case study was a useful exercise which sheds light on some of the dos and don't of NWFP inventory. The details are given in each case study and a summary of the main findings is presented here. Three main technical issues were addressed in the case studies; mensurational methods (bark, fruit and leaves), the optimisation of samping designs (ACS, MRI etc.) and the use of local knowledge in an unbiased manner.

8.1.1 Product mensuration

The testing of new methods and the development of mensurational protocols was the objective of three of the case studies (Cameroon, Benin and Kenya). The results from these studies are mixed though some useful results where obtained. The use of a phytosociological approach for Combretum leaves in Benin was unsucessful because this method was not suited to the quantification of leaf biomass but rather the characteristation of the vegetation community within which the shrub is found. The bark study in Cameroon was more successful though the techniques used for quantifying bark volume from branches relied heavily on the application of similar techniques for boles and did not attempt to link branch bark volume to tree architecture. The fruit quantification in Kenya was useful in that it demonstrated that randomised branch sampling would work for large parkland trees. The main lessons for product enumeration drawn from the case studies are:

- Choose a sampling regime that can quantify the population of the species in a manner conductive to the estimation of the product of interest i.e. if you count the number of leaves per stem how are you going to bulk this up into a per ha figure?
- Try and make the selection of sample individuals for derivation of a product table as unbiased as possible.
- Randomised branch sampling for fruit/leaves etc. has merit but further developments are required to determine the optimal within-tree sampling strategies.

8.1.2 Sampling design

Two case studies considered questions concerned with finding the best sampling strategy for a specific species. In CAR a trial of ACS revealed that it was inappropriate for use with a liana at least at spatial scales below 1 ha and further work is required to see if it might be useful at larger scales. However, the Gnetum data provided a useful case study of the procedures for optimising plot size and number. The Zambian case study was intended to compare the cost-effectiveness of two sampling strategies for a range of NWFPs both tree and non-tree products. The results indicate that MRI designs which are intended to provide data on a range of species at the same time can completely fail to observe small, understorey herbs particularly those restricted to scattered, small patches of habitat. For such species, individual sampling strategies are required. For other, less restrict and commoner species random or systematic designs will give similar results. The overall lessons for developing sampling designs are:

- Randomly located plots divided into grid cells can form the basis for a pilot study leading to the refinement of plot size and number.

- A multi-species inventory should give acceptable results for groups of species with similar lifeforms, sizes and where rare trees are isolated rather than clumped.
- Herbs and trees cannot be sampled in the same design because the scales required are incompatible.
- There is little difference between systematic and random sampling in terms of cost efficiency though systematic sampling may have logistical advantages.
- There is no need to use special designs for abundant clumped species because it should be possible to capture sufficient individuals in a simple design to achieve acceptable precision.
- It is important to stratify for species which occur in discrete habitats.

8.1.3 Use of local knowledge

The Malawian case study wanted to determine if local knowledge could be used to improve the representiveness of mushroom monitoring compared to market data. This was ambitious undertaking that involved a combination of field inventory and market survey over most of the 2002 mushroom season. The results of the study indicated that the use of sites identified by local collectors did correlate well with maket survey data. However, there is a need to undertake some mapping or areal estimatation of productive patches within the forest if bulked up per ha production figures are required.

8.2 Generic lessons

There are a number of key observations that were common to all case studies and may therefore be considered generic to NWFP inventory in Africa. These points are most relevant to the structure, content and format of the intended Guidelines for NWFP inventory.

- **Personal interaction between practioner and advisor is necessary for imparting new field techniques**

  The partners were briefed on possible approaches and techniques they could try for their assigned problems at the workshops. However, this was necessarily brief because of time limitations. After the meeting the partners variously requested further specialist assistance and this was provided in the form of references, other literature and e-mail correspondence. Several partners requested field visits by technical expert which were not possible given the constraints of the budget. Many of the shortcomings in the case studies could have been easily remedied in even short field visits which would have greatly enhanced communication and the joint development of innovative solutions. As it was, it was apparent that faced with a new problem there is a tendancy to fall back on familiar methods.

  This experience suggests that written advice needs to be very carefully structured – scientific style papers are not likely to be effective. Furthermore, as far as possible people should be supported through the application of techniques to particular situations by advisors, preferable on site and in person.

- **Communication links are not reliable**

  It was found to be almost impossible to maintain correspondence with several partners because of the unreliability of telephone and e-mail communications. This may seem like a trivial point but it suggests that the Guidelines will have to stand alone as a document. This point in conjunction with the one above present something of a dilemma which can only be effectively addressed by a training programme.

- **Data handling skills are limited**

  In all the case studies there were difficulties in data analyses which stemmed from inexperience with the handling of data using computer software. In all cases data was entered and analysed using a spreadsheet programme (Microsoft Excel). Spreadsheets certainly have their uses but they are not good at handling inventory data. Besides difficulties with maintainance of record integrity there are problems with using a spreadsheet for complex queries and statistics. Although the case study datasets were relatively small most would have been better served by use of database software such as Access or FoxPro. This is explained in more detail with a worked example of the advantages of using database structures to sort data into chapter 9.

- **No statistical software is apparently available**

  In none of the case studies was any statistical software used and Excel was used to perform analyses. Excel is know not to be ideal as a platform for statistics and has to be used with care and full knowledge of the algorithims to be used. It is assumed that the reason for the use of Excel is that no statistical software was available within the partner institutions or that there had not been sufficient training in its use. This means that the Guidelines will need to include the algorithms for undertaking routine analyses in a form suitable for use in Excel. Furthermore, since we should not assume that even a computer will be available advice should also be given on the calculation of simple statistics using a calculator.

- **Data interpretation advice and training is required**

  Many of the case study authors did not present an exhaustive interpretation of their results. This was in part a result of unfamiliarity with statistical questions being asked but also because there is little general guidance in inventory texts on the process of data and statistical interpretation. These skills are invaluable and difficult to relay. The Guidelines should include advice on data interpretation illustrated by examples as it is the process of reading a story from the data based on the objectives of the study rather than any particular sequence of tests that is important.

9 Access Training Database utilising Malawi MEF Data

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9.1 Introduction

The Malawi MEF Training Database illustrates the advantages of using an Access database to capture, store and analysis field data, particularly as compared to using Excel spreadsheets. The data here reported was collected during a field experiment studying MEF (mushroom) production in Malawi in spring 2002. Data from the three month trial was collated using Excel spreadsheets. The spreadsheets were designed in a logical manner to enable the trial results to be properly recorded but, upon completion of the fieldwork, a considerable amount of work was required to reorganise the data so that it could then be analysed. This was finally accomplished by copying the data into an Access database.

The Malawi MEF field data is now being used to illustrate the advantages to be gained if Access had been initially chosen as the medium for data capture and analysis.

9.2 Summary of Malawi MEF Field Trial

The Malawi MEF field trials tested the productivity of MEF under varying conditions to ascertain which species were most productive and to test under which conditions, if any, productivity was higher. Information was also gathered as to which tree species were associated with high MEF productivity.

Field trials took place on 10 plots in each of 5 sites (ie. 50 plots in all). Independent environmental data was collected for each plot - exact location, aspect, altitude, a description of the physical characteristics of the plot and a count of the number and species of tress and a measurement of the diameter of each tree.

MEF were harvested from each plot approx. 30 times over a 3 month period. MEF data available from each harvest was:

Total number and weight of each MEF species harvested, by date.
The species of the tree closed to each MEF growth.
A description of the micro-environment at the growth point of each MEF species harvested.

The original results of Malawi MEF field trials were presented in 3 or 4 spreadsheets.

Problems with this were:

- There were many instances of environment data being continuously repeated.
- Spreadsheets were designed to record field data, not to facilitate analysis.
- Input was not controlled so spelling and other key errors occurred
- Input was sometimes improvised to ‘squeeze’ data in
- Much effort was required to re-organise the data for analysis.

Eventually the data was transferred to an Access database for analysis. After analysis was complete, the project was used to illustrate the advantages to be gained if Access had been initially chosen as the medium for data capture and analysis.

9.3 Advantages of Using Access Databases

Using an Access database tends to dictate a different approach to data management. Often, particularly when using spreadsheets, design of data handling tends to be initially concentrated on data capture and, whilst analysis requirements may be kept in mind, organisation of data for analysis tends to be left until after field data collection is complete. Using Access, it is hard to separate the two stages. This requires the investment of more time at the start of a project to design and develop both the input medium and the analysis tools but such investment is recouped in the latter stages of projects, when time is usually at a greater premium. As is discussed below, this initial investment in design time is in itself an advantage as it forces discipline regarding the organisation of project data at an early stage.

Specific Advantages of using Access are:

- Input is more controlled, leading to less input errors and greater data integrity.
- There is greater control of analysis and the results of analysis are available quicker. Analysis can be easily undertaken on partial datasets, much earlier in the project than is usual, possibly pinpointing flaws in logic or field data collection. Corrections to erroneous data leads to automatic corrections in analysis.
- From a properly structured database it is easy to design further analyses as they become required.
- Access is widely used and recognised. Many other programs, either specialist packages or tailored systems, recognise Access tables and queries for input. Statistical packages such as JMP IN and spreadsheets such as Excel (which has better graph and chart features than Access) are particularly relevant. It is easy to format Access results so that data can be automatically exported to these specialist programs, as required.
- The complexity of Access input and reporting functions can be tailored to the requirements of the project and the skill level of the operatives. If the researcher is the sole operative then structures can be left loose, the researcher will be in personal control of the data. But if the project is large, if many operatives are employed or if the project is being undertaken remotely, possibly abroad, extra time can be expended to ensure that input, and therefore analysis and reporting, is tightly controlled.
- The database system has to be designed before data input can commence, which means the system has to be thought through at an earlier stage than is usually the case – good discipline that leads to earlier awareness of errors in experimental design and possible omissions in data being gathered in the field.

9.4 Rationale and Design of the Malawi MEF Access Database

The design of the Malawi MEF database and the rationale behind it is now explained. The purpose is to illustrate the advantages of using Access for research. It is not possible here to give a full explanation of the functionality of Access.

9.4.1 Tables

The key to gaining the most from an Access database lies in good system design and in particular, good design of the 'building blocks' of an Access database, the underlying tables. If this is accomplished the researcher can use the power of the Query function in Access to easily extract and analyse data with almost limitless flexibility.

Access tables should be designed so that data are grouped into discreet sets. The Access system for the Malawi MEF was designed around 4 main tables and 3 supplementary tables.

Two of the main tables contained static or environmental data:

Plot Data – containing static plot information and environmental data
Tree Data – containing information regarding the trees on each plot

Two contained data relating to the harvest:

Cap Data – into which MEF information from each species/harvest was input.
Associated Trees – data about the trees associated with each harvest

The three supplementary tables contained name codes:

[Codes for] MEF species
[Codes for] Tree species
[Codes for] Site Names

The above tables are simply lists of discreet data for each subject. For example, Plot Data has a single row (or record) of information detailing the environmental data for each plot; Cap Data has a single row (or record) containing information for each MEF harvest; Codes for Tree Species is a list of each tree species.

The most important field in each table is the primary key. It is through these keys that individual tables are linked to provide the integral logic of the system. For example, each plot on Plot Data is identified by a unique site/plot numeric reference (1.1 = site 1, plot 1; 2.3 = site 2, plot 3, etc.). All data relating to each plot then also carries the short plot reference, eg. all MEF harvests from plot 1.1 are referred to by this numeric and, unlike in the original MEF spreadsheets, plot data is not continuously repeated but located on the appropriate table via the key.

The main relationships in the MEF database are based around the Plot Data table. The table Cap Data contains harvest data – the details of each mushroom species harvested on a single day. Each entry is linked to the Plot Data table via the primary key so that the harvest can be simply linked to the plot.

Similarly, the Tree Data table contains information about individual trees, also linked to the plot by the plot primary key so that trees can be linked to individual plots.

It is an obvious requirement that tables relating to trees and individual MEF species should include their names. However, as the same tree or MEF species may have multiple occurrences on a plot, to avoid repetition on the table (and continuous re-typing) the long species names are held on the separate supplementary tables Tree Species and MEF Species. These are in turn linked to the Tree Data and Cap Data tables by their own numeric code/primary key. The same principle is used to link site names to the plot/site code on the Plot Data Table.

This principle is demonstrated again in the Associated Trees table, which contains only a primary key and a code. The key links the Associated tree to the harvest, the code references the tree name. This technique is required in this instance because the original spreadsheets used to collate data sometimes included multiple entries for trees associated with a harvest. It may be that, if Access had been used from the start of the project, this would have been disallowed and field workers forced to decide on a single associated tree.

The relationships between all the tables in the Malawi MEF database are shown in Figure 1 (held in the reports section of the database). The practical advantages of the design structure are illustrated by the example given in section 7.4.3.

9.4.2 Forms

It is possible to input data directly to an Access table in the manner in which input is made to a spreadsheet. However, when more control of the input function is requires, input is simplified by using an Access forms. If required, each table could have a form associated with it for input (more complex forms can be designed to input to multiple tables). The form controls the input of each research item (or row or record) on the table, ensuring that each field is input correctly and that all the required fields are input. Input can be controlled in various ways:

- If certain fields are compulsory, input of a record cannot be completed without them being included.
- Input can be restricted to items from a list, ensuring that extraneous or incorrectly spelt data is not input
- Input can be validated so that, for instance, text is not input to a field on which numeric calculations are made or incorrect formats are not used where data is required in a precise mode.
- The logic of the data is maintained so that, unlike in the MEF spreadsheets, several items are not input on the same 'line'.

If required, space can be allocated so that freeform comments can be added to controlled input items.

The relationship between forms and tables, input control and the advantages to be gained by using Access are illustrated in the following example.

9.4.3 Example 1 – Recording of Plot and Tree Data

Excel spreadsheets were used for recording field data during the MEF trial, including data for trees on the MEF plots. This provides an example to illustrate the use of tables and forms, as above, and of the advantages of using Access over spreadsheets.

It was a requirement of the trial to record the environment data for each plot, including the species and size of each tree. On the Excel spreadsheets tree data was included with the rest of the environment data in one spreadsheet. However, as there were many trees on each plot much of the data was repeated, sometimes up to 20 times. In Access repetition is avoided by splitting the data into basic Plot Data and separate Tree Data, linked by keys, as explained above.

There were a total of 1033 trees on the 50 plots. Figure 2 is an extract from the original Excel spreadsheet Malawi Plots and Trees, starting with the tree data for plot no. 1 at the Sitolo site. It can be seen that on this plot there were 17 trees of 14 different species. For each species the tree name is entered along with the plot characteristics, the latter being repeated for each entry. Additionally, as a data entry is made for each species rather than each tree, for multiple occurrences of tree species on a plot the diameter of every tree is entered on the same line of input. This fulfils the short-term objective of recording tree data but:

Much of the plot environment data is repeated, often 10 or more times
Before analysis, the tree sizes had to be separated into individual entries
For analysis to be meaningful, this data has to be manually (ie. by cut and paste) linked to other data

In the Access database three tables were used:

Plot Data – containing the plot environmental data, having the primary key of site/plot numbers.

Tree Data – containing details of each tree, each entry also having the primary key of site/plot number to link it to the relevant plot but also including a tree code.

Tree Species – linked to the tree data by the tree code.

Figure 3 (again in the reports section of the database) shows the field on each table and the relationship between them. This is a subset of the relationships shown in figure 1, extracted for clarity.

In these tables the data have been condensed and simplified. Whilst there still has to be 1033 individual entries for trees, Plot Data contains only 50 entries, one unique record for each plot and Tree Species contains only a code and name for each species (so that the species name only has to be input once and thereafter species can be referred to by the numeric code, making entry easy and lessening the likelihood of spelling mistakes). Moreover, although there are still 1033 individual entries for plot trees on the Tree Data table, the data structure ensures that only minimum data are held for each entry – Site/plot key, diameter, basal area and tree code.

The database incorporates a form for input to each of these tables. The Tree Data Input form illustrates both how Access can aid and control input. Of the five fields held on the Tree Data table to record each of the 1033 trees, of these only the diameter is actually entered, the others being selected from lists.

The site name and plot are selected from drop down boxes and the tree species is selected by name from the species list (though each is only held on the table as a numeric code). The tree diameter is input and the basal area calculated, ensuring no arithmetic errors, as occurred on the original spreadsheet.

By controlling the form in this way the input process is much quicker and there is less opportunity for error. The design of the tables ensures that data are held in a logical way and can be easily extracted, as is described below. Put together, these features ensure that there will be greater data integrity using Access.

9.4.4 Queries

One of the main functions of a database is to allow the operator to view the data in a variety of ways. In Access, queries afford the method by which data can be easily manipulated and organised so that it can be viewed and extracted as project requirements dictate. Provided that tables have been logically designed in the first place, queries allow any linked data or any defined subset of a table or logically linked data to be simply extracted from the database. Queries can also be used to sort, summarise and analyse data and, if specialist analysis is required, order data as required by the specialist programs.

A simple example of the flexibility of queries is given by the query Tree Data Query, which extracts data from the Tree Data Table. This is a simple query based on one table. Viewed in design mode it can be seen that any subset of the Tree Data Table fields could have been selected, the selection criteria could be used to include or exclude by Site/plot, Tree type or Size and the data could be sorted using any field. In the example shown only data for trees greater than 10cms in diameter from site 1 has been included, and these are been sorted by plot number. It can be seen that by using the same selection techniques data can be presented in any possible logical combination.

Queries give the researcher considerable control over the analysis process. Once the design structure of an Access database is in place and the queries have been tested there is less likelihood of logic errors being introduced. Also, manual manipulation of data is excluded so there is less likelihood of data being lost or incorrectly joined as it is moved around.

Queries should, for the most part, be written at the design stage of a project as tables and query design are inextricably linked. However, provided that the database has been logically designed, it is a simple matter to quickly refine or write further queries to extract data in a different way at a latter stage, if required.

9.4.5 Example 2 - MEF Production by Plot

This is an example of a more complex query. This summaries data for the Cap Harvest on each Plot. It extracts data mainly from the Cap Data Table but takes supporting data, site name and the scientific name for the MEF, from the Site Data and Cap Names Tables respectively.

The totalling function has been used so that the harvest data for each MEF species on each plot has been summarised on one line, giving the total number and total weight of caps harvested.

The Expression Builder has been used to calculate the Mean Cap Weight of each species on each plot.

The query reports all MEF species on each plot. A selection criteria has been applied to exclude species not present so that the query is not cluttered with nil values.

The MEF code has been used to look up the species name but the 'Show' feature has been used to suppress this internal code from the query view.

9.4.6 Reports

Reports can be used when data needs to be presented in a more formal manner, for instance, for project reports or when project findings are presented. Sometimes reports allow data to be ordered with greater clarity than queries, where data can be repeated.

The Tree Summary by Plot Report provides a simple example, giving summary information about the trees on each plot. This report is based on the query Tree Summary by Plot. Reports can also be based simply on Tables. If required, greater complexity can be introduced by driving reports from more complex queries.

9.5 Linking Data to Other Software Packages

As the underlying data in an Access database can easily be manipulated in any logical manner, it is a simple matter to do so to present data to other software packages. The exact manner depends on the requirements of the target software. Examples are given here of a package that requires data to be sent to it (Excel) and a package that simply 'locks on' to existing Access tables (JMP IN).

Excel might be used to graph or chart data held in the Access database. The required data is accumulated in a table or manipulated into the form required using a query. The data can then be sent to the target Excel spreadsheet, or a new spreadsheet can be created, using the Export function. Data can be exported 'manually' or, if the same table or query is to be repeatedly exported, a simple Macro can be written to ensure the correct data and target are always selected. In the training database, the Macro Export to Excel sends the Cap Harvest data to the spreadsheet Cap Harvest Chart were it is presented as a barchart.

JMP IN takes Access tables as direct input to its statistical analysis routines. No intervention by the operator is required. Provided the table contains the required data JMP IN will use its own routines to extract the data. If there is not an appropriate table a query must be written to manipulate the data, as required. Unfortunately, JMP IN cannot link to directly to Access queries but this is resolved within Access by utilising a 'make a table' query. This type of query extracts data by using the relationships defined and creates a new table comprising of this data. As JMP IN links directly to Access tables so there is no need to export the data.

9.6 The Discipline of Design

Determining the logical relationship between the data in each of the tables in the Malawi MEF database was the key to efficient design of the system. As with any research project (indeed, also any other computers application) the designer needs to understand the logic between the input data and output data.

It has been stated that Access tends to force design of a complete data system at an early stage. When using spreadsheets for data capture they is a strong temptation, often caused by time constraints, to do no more than design simple sheets for holding field data at the initial stage of a project, as was the case with the Malawi MEF trials. Whilst the researcher will always have in mind the results and analysis required of field trials, the need to design a complete data structure at the outset of a project compels that the logic between input and output data be thoroughly examined earlier than might otherwise be the case. This leads to earlier awareness of errors in experimental design and possible omissions in data being gathered in the field and, whilst there may be time constraints early in the project, it is more often the case that time is at a greater premium toward the latter stages.

9.7 Scope and Scale

Even though the more complex Access functions have not been touched on in this document, from the above it can be seen that Access is a very powerful tool with which to manage data to aid research. If required, Access can be used to perform highly complex routines and, linked with Visual Basic, at this level it becomes a computer programming language.

However, it is important for researchers using Access not to ‘get carried away’ and invest disproportionate time developing a highly sophisticated data handling systems out of all proportion to the research at hand. Equally, it is important that researchers running small projects are not put off by the seeming complexities of using Access, believing the advantages to be not worth the initial effort required. Utilisation of Access should and can be tailored to be in proportion with the scale of a project.

On the smaller scale, it may be thought that project data is sufficiently straightforward to not warrant the time investment in developing an Access database. However, whilst Access can be highly complex, the basic methods of handling data are simple to understand and master. Certainly, they are no more difficult to learn than those required for the use of spreadsheets. Once understood, it becomes as easy to develop tables and forms for even small datasets as it is to develop spreadsheets, and the researcher then has the power of the query functions to quickly manipulate and analyse data. At this scale, particularly if the researcher is the sole project operative, it is unlikely that the more sophisticated input controls will be utilised. The researcher will be very closely associated with the data and likely to be very aware of errors and anomalies. Self-checking and validation is more likely to be appropriate.

With larger scale projects with many operatives, particularly when fieldwork and data input are remote, the benefits of having a tightly controlled system are more likely to justify the development time required. Even with the modest scale of data collected for the Malawi MEF project, the time required for initial development of an Access database would have been well spent, being more than recouped as excessive time was required for input and re-organising data before it could be analysed.

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11 Data

The data from the four case studies in ACCESS and EXCEL format will be put onto a CD-ROM to accompany the publication. The ACCESS database refered to in section 8 will be included for reference.