RELATIONSHIP BETWEEN WOODY BIODIVERSITY AND USE OF NON-TIMBER FOREST PRODUCTS IN THE SAVANNA BIOME OF SOUTH AFRICA

Benjamin Delali Komla Dovie

A Thesis submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD) in Science

Johannesburg, 2006

DECLARATION

I declare that this thesis is my own original work. It is being submitted for the Degree of Doctor of Philosophy (PhD) in Science in the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination in any other University.

Supervisors:

Professor Ed T. F. Witkowski

University of the Witwatersrand, Johannesburg, South Africa.

Professor Charles M. Shackleton

Rhodes University, Grahamstown, South Africa.

....

(Signature of candidate)

18th day of April 2006

ABSTRACT

This study seeks to combine the knowledge of science and society to elicit the relationship between the harvesting of woody plant species and the local availability of woody species in South African savannas. Ten villages located in the former communal areas and homelands within three broad vegetation types (i.e., Mixed lowveld bushveld, Eastern thorn bushveld, and Natal lowveld bushveld) were studied. The study, conducted in the framework of the coupled human-environment system poses challenges to both scientists and managers (e.g., setting common goals). Data were collected using modified Whittaker plots (MWP) and focus group discussions (FGD), denoting ecology and society, respectively. There were nine 1000m² MWP plots sampled per village, each having nested 1m², 10m² and 100m² subplots. The FGD involved six groups of local people based on gender and age. The study revealed that the harvesting of woody plant species is a source of local disturbance to woody vegetation. Generally, there were more woody species in locations farther from settlements, having a mean of 41.97 ± 3.9, than for the intermediate (38.27 ± 5.6) and near locations (19.9 ± 4.2) within the 1000m² plots, the result of the reduction in species closer to settlements from higher harvesting levels. The larger sampling plot size of 1000m² of the MWP had the highest diversity, decreasing sequentially to the smallest scale (1m²). The density of the woody species was highest in the intermediate locations (517 ± 80 plants/ha), followed by the far and near, relative to the settlements. The Natal lowveld bushveld broad vegetation type had the highest mean density of trees (573 ± 71 trees/ha) compared to the Mixed lowveld bushveld (366 ± 64 trees/ha) and the Eastern thorn bushveld (312 ± 40 trees/ha). The stem diameters of trees were generally higher in the villages of the Mixed lowveld bushveld than the other two vegetation types. The study reaffirmed that anthropogenic disturbances within savannas impact vegetation and need to be studied concurrently with other disturbance factors (e.g., biotic and abiotic or environmental). The mean total coppice shoots of stumps within the 1000m² plots was relatively higher in the near locations (38.4%), than the far (33.0%) and intermediate (28.7%). This difference in coppicing shows that although near locations were less species rich, which is a result of disturbance, the growth of shoots may nevertheless be greater. Harvesting disturbance will possibly favour the regeneration of some species, as well as the maintenance of biodiversity. Whilst 135 woody species (from a total 191 from 42 plant families) sampled in the field were used by the local people, the community knowledge yielded almost twice as many (267 species, from 69 plant families). The ratio of mean useful woody species to total woody species remained relatively constant at about 1.0:1.1 from the near to far locations around the villages and accompanied by increased woody species diversity with distance from village. The MWP sampling yielded eight broad use categories (i.e., medicinal, wild edible fruits, fuelwood, housing and fencing poles, craft (e.g., carving), cultural, local beverages (e.g., alcohol)), and nine for the FGD (the eight for the MWP plus indigenous furniture). According to the local people, the highest number of species was used for medicine (27.8% of species), followed by fuelwood (19.2%) and wild edible fruits/seeds (19.1%). Over half of the species had multiple uses (i.e., three to eight uses), raising questions of possible threats to their persistence. Useful woody species were not restricted to any particular location or vegetation type. Large sized trees were subjected to even more uses than smaller trees, another source of conservation concern. Fifteen of the woody plant species are presently protected by law in South Africa (e.g., *Adansonia digitata, Podocarpus latifolius, Mimusops caffra, Philenoptera violacea*), while others are facing various forms of regional threats (e.g., *Alberta magna, Catha edulis, Ocotea bullata*). There is the need to popularise and make people (both local and outsiders) aware of the state of NTFP species, using local and village level information as an additional criterion for describing conservation threat (e.g., proposed "Locally Brown List" – Chapter 4). The older generation of local people were highly knowledgeable in terms of the woody species used for medicine, craft, fencing and housing poles, the middle aged in beverage making species, and the younger generation in fuelwood species. Overall, older males were highly knowledgeable of the useful species. The generally strong correlation (r = 0.99, p <0.0001) between the cumulative woody species diversity from field and community knowledge suggests the need to integrate data using multi-disciplinary approach and also to manage NTFP species. Although threat reduction assessments (TRA) and monitoring have previously been suggested, the participation of local people, harvesters and users will be crucial in making TRAs effective. In conclusion, the harvesting of NTFPs, and the impacts of the changes in the NTFP species on total diversity in savannas need to be understood in order to move towards a more holistic approach to conserving the woody species that may be at risk of extinction through harvesting. Disturbance criteria that describe harvesting levels should be set to guide research and management protocols. Finally, when discussing NTFPs and the species from which they are harvested, management should aim at incorporating all the factors that affect sustainability, such as land and resource tenure and local participation, the political economy, appropriate production and development cycles.

Keywords: Communal areas, disturbance, focus group discussion, local knowledge, Locally Brown List, management, modified Whittaker plots, NTFPs, savanna, species diversity.

DEDICATION

I wish to first dedicate this work to the Glory of God for seeing me through.

Secondly to my mum and dad, Lena and Geoffrey, respectively.

ACKNOWLEDGEMENTS

I am highly indebted to my Supervisors, Professor Ed T. F. Witkowski and Professor Charles M. Shackleton for their role in nurturing and supervising such a challenging interdisciplinary research project and secondly, for the mentorship and supervision as well as for their commitment and the diversity of opinions.

I wish to thank the other members of my Research Committee, Professors Dave Mycock and Kevin Balkwill both of the School of Animal, Plant and Environmental Sciences for offering their specialist advice. I am grateful to my colleagues and friends, Drs. Taelo Letsela and Kirsten Neke for sharing their work with me from which I learnt a lot. This work would not have been complete if I had not received constructive advice and comments from several practitioners, specialists and Professors in similar fields of the research from within South Africa and overseas. There is a long list of such personnel that I am extremely appreciative and trust that they will continue to support my work. I am thankful to a number of people who I worked with both at the University of the Witwatersrand (administrative and technical staff) and in the field. Special thanks to Marc Leroy who provided a lead Research Assistantship for all my fieldwork and Kevin Balkwill and Mervyn Lötter for their role in identifying some of the difficult woody species. John Kekana assisted with the difficult work that was associated with the soil samples whilst Sinah and Edward provided the fun that often released tension. All the community and opinion leaders, councillors as well as my numerous field assistants in the villages that I worked are thanked for their hard work and cooperation. Without the willingness of the members of the villages in which I worked, some objectives of the study would not have been achieved. Messrs Samuel Assiamah and Ellis Ayayee have been a source of inspiration.

Additionally, I owe my dearest parents a lot of gratitude for their encouragement, moral and other support throughout my studies, and thank you to my beloved wife Adjoa for all her support. I thank my sister and other family members for their diverse contributions. My uncle, Dr Benjamin Gbeve has been a source of encouragement. Thanks to Prof. Samuel Awudetsey and entire family for providing home, comfort and company during lonely times.

The completion of this thesis has been made possible through funding from the Global Change SysTem for Analysis, Research and Training (START), Washington, USA of the International Geosphere-Biosphere Programme (IGBP) in Stockholm, Sweden and the International Human Dimensions Programme (IHDP) of the Global Environmental Change Community (GECC), Bonn, Germany. The fund was administered through an African

Doctoral Fellowship programme. The National Research Foundation of South Africa also contributed from the Grant-Holder Bursary scheme on the "Conservation and Management of Ecosystems and Biodiversity" focus area, through the Research Office of the University of the Witwatersrand. The Rufford Small Grant Programme provided funds to accomplish a conservation project that was one of several outcomes of this research, when it was still at its initial stages. Come Again!

CONTENTS **PAGE**

LIST OF FIGURES

Chapter 1

Chapter 2

Chapter 5

Chapter 6

LIST OF TABLES

Chapter 1

Chapter 2

Chapter 3

Chapter 4

LIST OF SYMBOLS & ACRONYMS

NTFP(s)	: Non-timber forest product(s)
FGD	: Focus group discussion
MWP	: Modified Whittaker plot
FAO	: Food and Agriculture Organisation of the United Nations
PCA	: Principal component analysis
CCA	: Canonical correspondence analysis
S_s	: Sorensen's similarity index
GLM	: General linear models
H'	: Shannon Wiener diversity index
IUCN	: World Conservation Union
DCA	: Detrended correspondence analysis
DWAF	: Department of Water Affairs and Forestry
ANOVA	: Analysis of variance
HSD	: Honest significance difference test
GPS	: Global positioning system
Ca	: Exchangeable Calcium
pH	: Acidity / alkalinity
N	: Total Nitrogen
K	: Exchangeable Potassium
Cu	: Copper
Mg	: Exchangeable Magnesium
Mn	: Exchangeable Manganese
Zn	: Zinc
PO_4	: Phosphate
J′	: Pielou's index of evenness
SID	: Simpson's index of diversity
UNEP	: United Nations Environment Programme
SE	: Standard error

GLOSSARY OF FREQUENTLY USED TERMS

Biodiversity: Refers to the variety and variability among living organisms and the ecological complexes in which they occur. [UNEP, 1999. Global Environment Outlook 2000. United Nations Environment Programme, Earthscan Publications Ltd, London]

Community, local or indigenous knowledge: These are judgement structures, perceptions and institutions developed over several generations by society through close interactions with the natural and biophysical environment. [Posey, D.A., 1993. Indigenous knowledge in the conservation and use of world forests. In: Ramakshina, K., Woodwell, G. (Eds.), World Forests for the Future, their Use and Conservation, Yale University Press, New York]

Disturbance: Disturbance is any relatively discrete event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability, or the physical environment and ecosystem characteristics. It is therefore a change in the organised entity of an object in this case plant communities caused by external factors. [White, P.S., Pickett, S.T.A., 1985. Natural disturbance and patch dynamics: an introduction. In: Pickett, S.T.A., White, P.S. (Eds.), The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, Orlando, pp. 3-13]

Focus group discussion (FGD): This is a carefully planned discussion designed to obtain perceptions on general issues pertaining to a whole community and useful for generating detailed discussion and creative insights and ideas about the subjects under discussion. [Kreuger, R.A., 1988. Focus groups: A practical guide for applied research. Sage, London]

Human livelihood: Entails various means of supporting life and meeting individual and community needs. It can be expressed in cash, kind or both, in addition to associated social institutions. Thus formal and informal employment streams, land-based sources such as crops, livestock and natural resources, as well as social and economic capital. [Forsyth, T. Leach, M., Scoones, I., 1998. Poverty and Environment: Priorities for Research and Policy. UNDP Report. IDS, Brighton]

Modified Whittaker plot (MWP): This is a field ecological method for estimating and measuring diversity. It consists of an outer contiguous overlapping 0.1ha plot (20m x 50m) with three types of sub plots as follows: (i) one 5m x 20m, (ii) two 2m x 5m, and (iii) ten 0.5m x 2m, from which the woody plants were sampled. [Stohlgren, T.J., Falkner, M.B., Schell, L.D., 1995. A Modified-Whittaker nested vegetation sampling method. Vegetatio 115, 113-121]

Non-timber forest products (NTFPs): These are natural resources of biological origin from a given land and extracted for diverse purposes, and often coincidental to the primary management objectives of the land from which they are extracted. [Scoones, I.C., Melnyk, M., Pretty, J. (Eds.), 1992. The Hidden harvest: wild foods and agricultural systems. A literature review and annotated bibliography. 111.1, ODI, London; Shackleton, C.M., 1996. Potential stimulation of local rural economies by harvesting secondary products: a case study from the Transvaal Lowveld. South Africa. Ambio 25(1), 33-38]

Pielou's evenness index (*J'*): Is the measure of the equality of the species in a sample, and if all species are equally abundant, *J'* will approach the maximum (i.e. 1) and decreasing towards zero as relative abundance diverges from evenness. [Waite, S., 2000. Statistical Ecology in Practice. A Guide to Analyzing Environmental and Ecological Field Data. Pearson Education Ltd., Essex]

Simpson's index of diversity (SID): Denotes the probability that two individual species drawn at random from a population will belong to the same species. [Waite, S., 2000. Statistical Ecology in Practice. A Guide to Analyzing Environmental and Ecological Field Data. Pearson Education Ltd., Essex]

Species diversity: Measured using the Shannon–Wiener index (*H'*), and defined as $H' = -\sum p_i \ln p_i$ where, $p_i = n_i / N$ is the relative abundance of species, n_i = individual species number, and N = total number of individual species. [Magurran, A.E., 2004. Measuring biological diversity. Blackwell Publishing, Malden, Oxford, Carleton]

Species richness: The number of woody plant species per unit area. [Magurran, A.E., 2004. Measuring biological diversity. Blackwell Publishing, Malden, Oxford, Carleton]

FOREWORD AND STRUCTURE OF THIS THESIS

Although many studies have touched on peoples' use of diverse woody plant species, the direct relationship between total biodiversity and the use of plant diversity by humans is poorly understood. Issues relating to the selection criteria of species and parts to use, where or 'places' to access and harvest them and why those 'place' are often omitted in ecological and conservation assessments. However, the link between useful plants and biodiversity at local levels are becoming important within conservation debates. This encompasses the culture of human resource use based on ecological and evolutionary processes. The local management of the factors influencing the link between locally available species and usefulness remains the biggest challenge to the new 'sustainability science'. The focus of this study has been on non-timber forest products (NTFPs), the use of which presents potential threats to biodiversity. The gap in knowledge on communal tenure areas in savannas is immense. As a result this study will in no doubt make a significant difference in existing knowledge. This study will largely contribute to science, policy and development of the extensive savannas of South Africa, with wider applicability to other savannas regionally and globally.

The sustainability of NTFPs and their habitats can only be achieved through a management process that recognises humans and their decision-making as active parts of biodiversity rather than proximate drivers of negative change. Until anthropogenic issues are directly incorporated into restoration ecology research, vegetation management may not be able to cope with the high expectations and the growing interest in plant resources. This implies that a new outlook be given to ecological research, encompassing a localised definition of biodiversity within areas of high human impact and presenting a multifaceted case for conserving biodiversity in savannas. This study, in fulfilment of the requirements of the degree of Doctor of Philosophy in Science (PhD), therefore seeks to develop understanding of the relationship between woody plants, having uses to humans and the local availability of total woody plant species richness and diversity and implications for managing local diversity. The aggregate value of consumption is also explored. The thesis has six chapters, comprising of an introduction, four central chapters (major study report) and concluding chapter (synthesis and conclusions). The chapters are in formats readily suitable for publishing in peer-reviewed journals hence some items (e.g., site description, methods and references) may be repetitive. Each of the central chapters has a complete abstract, introduction, methods, results, discussion and conclusions.

CHAPTER 1

GENERAL INTRODUCTION: Relationship between woody biodiversity and use of non-timber forest products in the savanna biome of South Africa

1. INTRODUCTION

1.1. Background

The understanding of the coupled human-environment system that shapes the biophysical and socio-political dimensions of biodiversity has re-emerged in recent times (Farina, 2000; Koziell, 2001; Kumar and Ram, 2005; Crivos et al., 2004). This is because development, livelihoods and biodiversity conservation need to complement one another. In view of these, attempts to sustain livelihoods and to reduce poverty whilst maintaining species diversity will constitute core global challenges to sustainable development (Millennium Ecosystem Assessment, 2005). However, the capacity to achieve these objectives will be undermined by a threatened natural resource base (Koziell, 2001; Arnold and Ruiz Pérez, 2001; Dovie, 2003; Ticktin, 2005). Biological diversity (i.e., genetic, species and ecosystem diversities) is an indispensable component of this natural resource base. Biodiversity refers to the variety and variability among living organisms and the ecological complexes in which they occur (UNEP, 1999; Chopra and Kumar, 2004) and in recent years, human dimensions are being incorporated (e.g., Cromwell et al., 2001; Moore et al., 2002; Dovie et al., submitted).

Biodiversity provides three core types of services necessary to sustain life: (a) a source of the raw materials vital for all human activities; (b) a sink for waste and residue generated by human activities; and (c) a means of maintaining essential life support functions by maintaining quality ecosystem health (UNEP, 1995, 1999; Daily, 1997; Bass et al., 2001; Millennium Ecosystem Assessment, 2005). The products and services derived from biodiversity are therefore diverse and benefit people at the local, national and global levels (Daily, 1997; Turner et al., 2001). However, there is widespread agreement that environmentally destructive and exploitative practices destabilise biodiversity, hence biodiversity is in a continuous state of flux (Koziell, 2001; Ticktin et al., 2002; Dovie, 2003; Ghimire et al., 2005). This is because such practices interact dynamically with biodiversity, irrespective of their spatial configuration (Arnold and Ruiz Pérez, 2001; Ghimire et al., 2005; Ndangalasi et al., in press). As a result, sustainable production and consumptive activities and processes must replace increasingly unacceptable societal and environmental costs to biodiversity. Biodiversity's proven or potential utility for human benefit is vital and related anthropogenic trends ought to be properly understood. This is because they can provide the basic local information that will enhance local scientific knowledge, technical expertise and the initiation of sound and appropriate biodiversity conservation planning tools.

1.2. Types of benefits of biodiversity

The direct benefits of biological diversity to humanity are myriad. Humans depend on animal, plant, fungal, and microbial species for food, fuel, fibre, medicines, drugs, and raw materials for a host of manufacturing technologies and purposes. The productivity of agricultural systems, pharmaceutical and food-processing mechanisms is a result of continual alteration of biological resources over thousands of years of once wild plant and animal germplasm (Cromwell et al., 2001). Although direct values of biological diversity are not always reflected in market prices (Dovie et al., 2002a; Dovie, 2003; Shackleton and Shackleton, 2004a; Lawes et al., 2004), they are more amenable to measure than other values (e.g., non-use) hence the focus of most economists. Beyond direct values (Figure 1), biological diversity provides ecological services that are more difficult to measure with precision. All these uses are broadly categorised as use values, indirect uses, option and non-use values (Figure 1). Without this diversity, humans will lose the ability to adapt to the ever-changing needs and conditions of human population and industrialisation. Sustainable agriculture could then not be achieved in many of the world's different production environments.

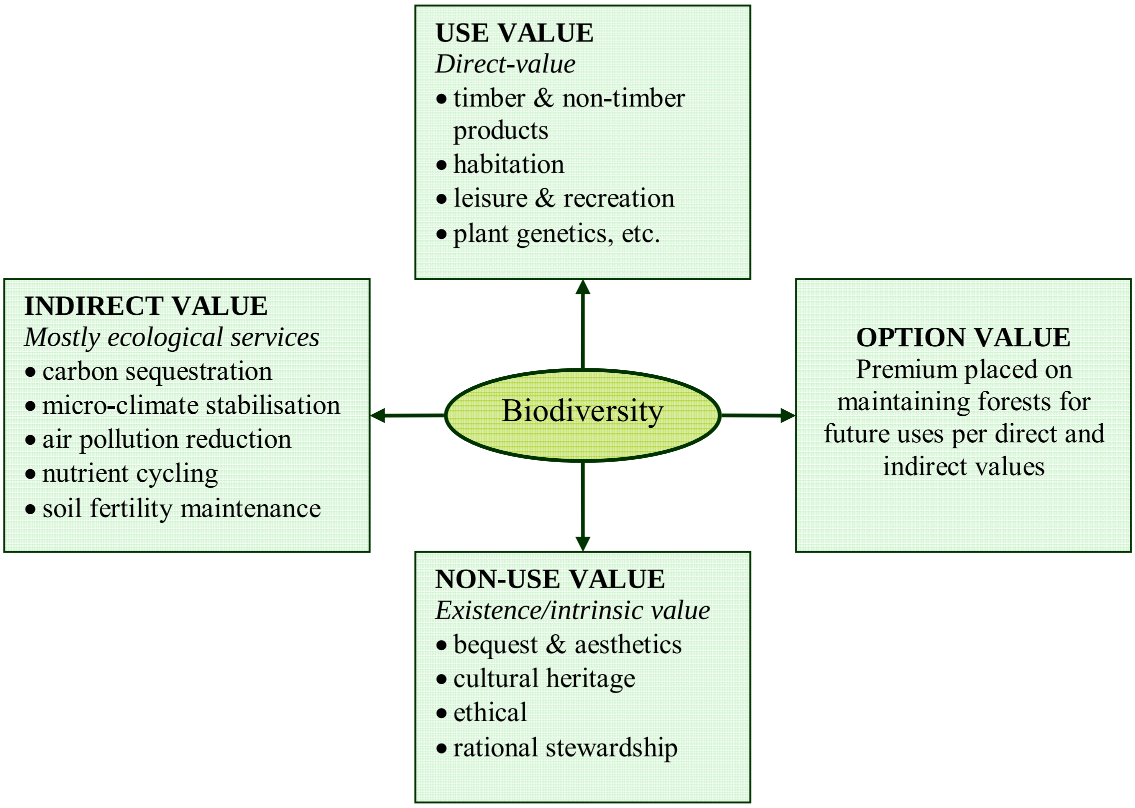

Figure 1. Different values of biodiversity (Emerton, 1996; Turner et al., 2001; Bass et al., 2001).

1.3. Threats to biodiversity

1.3.1. Proximate and underlying factors

Although the maintenance of biodiversity is vital to human survival it is increasingly threatened around the world (UNEP, 1999; Farina, 2000; Koziell, 2001; Millennium Ecosystem Assessment, 2005). Some of the most immediate and proximate causes include habitat destruction, mainly through agricultural expansion, wood extraction and large scale infrastructure development (Parsons et al., 1997; Geist and Lambin, 2001; Sagar et al., 2003). Pollution from industrial emissions that cause acid rain and global climate change constitute other proximate causes (BSP, 1996; Geist and Lambin, 2001). In addition, there are fundamental driving forces that underpin the proximate threats, some being economic, technological, policy and institutional factors (de Wet, 1997; Geist and Lambin, 2001; Kumar and Ram, 2005). The culture of resource use and socio-political factors that include livelihoods and demographic issues have come under intense scrutiny for their impacts (Kumar and Ram, 2005; Shackleton et al., 2005; Ghimire et al., 2005). This is because they encompass public attitudes, values and beliefs and consumer behaviours that have potential impacts on the attributes of biodiversity.

1.3.2. Implications of disturbance for woody plant diversity

The majority of the mechanisms that influence and change the status of biodiversity are mediated through disturbance. Disturbance is any relatively discrete event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability, or the physical environment and ecosystem characteristics. These characteristics can be species diversity, nutrient output, and biomass, as well as changes that reset succession in one or more sites (White and Picket, 1985; Turner et al., 1993; Ndangalasi et al., in press). Disturbance can be acute and impacts felt immediately and within a short period of time, or chronic, with impacts that may be insignificant at one point in time but are cumulative over longer periods of time to cause severe change. Because disturbances come in various degrees of intensity and occurring within different ranges, it has been argued that disturbances do not only result in negative impacts but also produce certain benefits to biodiversity (Sagar et al., 2003; Kumar and Ram, 2005). The term therefore is often associated with results of physical agents such as floods, fires, drought and wind as well as a biological activity such as herbivory may be considered as a disturbance. Disturbances are major sources of both temporal and spatial heterogeneity in the structure and dynamics of natural communities and are often the reasons for the mortality of some individual species and resulting in population decline through the creation of patch mosaics (White and Picket, 1985; Silvertown and Lovett-Doust, 1993). Humans are parts of this disturbance either through their consumer and producer activities or conscious efforts to manage biodiversity (Balmford et al., 2002; Crivos et al., 2004; Kumar and Ram, 2005), deliberately or accidentally causing harm to biodiversity and at times resulting in positive impacts. In spite of this, it is now a well-known fact that humans have mostly modified what we see today for generations (McNeely, 1992; Balmford et al., 2002). The majority of biodiversity rich areas (e.g., hotspots) have been found to coincide with areas of high human presence (e.g., the eastern arc mountains of Africa), and as a result are parts of a cultural landscape (Farina, 2000; Moore et al., 2002; Cordeiro et al., in press).

The factors responsible for disturbance may be categorised into endogenous (coming from within the object community) and exogenous (external to the object community), creating a process of changing disturbance regimes. The regimes may be defined as the cumulative effects of the types, intensities and frequencies of disturbance through time in a regeneration niche. For instance, plant density and dispersion are known to be sensitive to size and intensity of disturbance. Growth rates are influenced by the level and pattern of resource availability after disturbance. Age structure may be a function of intensity and frequency of disturbance. Plant community structure and composition are known to change in relation to disturbance, such that there is a gradient of community attributes (such as biomass, productivity, species richness) moving away from the centre of the disturbance intensity, such as human settlement (Shackleton et al., 1994; Parsons et al., 1997; Li et al., 2004).

1.4. Woody plant diversity

1.4.1. Richness and diversity

Diverse relationships exist between species richness and biophysical and environmental variables such as latitude, climate, biological productivity, habitat heterogeneity, habitat complexity, disturbance, and the sizes and distances of unique landscapes and patches (Schluter and Ricklefs, 1993; Clinebell et al., 1995; Waite, 2000; Magurran, 2004). Diversity has generally been measured only in terms of species richness, or in the form of indices combining richness with abundance (e.g., diversity indices). Diversity indices provide more information about community composition than simply species richness; they also take the relative abundances of different species into account (Waite, 2000; Magurran, 2004). The value of a diversity index depends not only on species richness but also on the evenness, or equitability with which individuals are distributed among the different species. Diversity indices therefore provide important information on rarity and commonness of species in a community and towards the better understanding of community structure and species assemblages (Waite, 2000; Magurran, 2004). It is important therefore that unrepresented attributes (e.g., specific uses, economic and monetary values, plant parts used) of species are also well captured and included in the analysis of richness and diversity. The analyses must be done within frameworks that account for the biotic distinctness in species composition over a broad spectrum of environmental scales (Colwell and Coddington, 1995). The ecological complexity of local richness and diversity remains the biggest challenge of sampling scale (Schneider, 2001; Barnett and Stohlgren, 2003). For it has been argued that increasing the numbers of sampling points and areas will increase the efficiency of detecting more species. However, there are certain drawbacks such as time and costs that may be associated with this. The laying of smaller size plots in large numbers such as in the modified Whittaker plots may increase efficiency compared to few large size plots (Stohlgren et al., 2000; Barnett and Stohlgren, 2003). The highly positive aspect of the modified Whittaker plots as a sampling approach is that the four nested plot sizes cover four orders of magnitude with outcomes (e.g., species curves) that allow reasonable interpolation to larger areas and readily comparable with other studies using different plot sizes. Yet, these may depend, to a large extent, on the unit of sampling whether it is localised or at landscape level.

1.4.2. Woody plants as a source of non-timber forest products (NTFPs)

1.4.2.1. The role of NTFPs for livelihoods

The majority of rural people are known to depend largely on plants and animals obtained from the "wild" in the form of NTFPs, as part of their livelihood strategies (Chamberlain et al., 1998; Campbell and Luckert, 2002; Cocks and Dold, 2003; Shackleton and Shackleton, 2004a; Dovie et al., 2005). NTFPs are materials of biological origin used mostly for subsistence living rather than highly commercialised ventures although a number of them are traded locally, such as poles for construction and fuelwood for subsistence use (e.g., Figure 2). Additionally are uses such as wild edible herbs and fruits, medicine, alcoholic beverages, fungi, and bush meat, among several others. The harvesting and consumption of NTFPs may account for the greater majority of species used and the bulk of products extracted, representing a significant percentage of the potential and actual value of forests and savannas (Dounias, 2000; Campbell and Luckert, 2002). Yet the lack of proper documentation of these resources because they are either for subsistence use, or they often do not have formal markets has underrated the economic and biodiversity potentials of the sector. The

International Institute for Environment and Development (IIED) demonstrated the importance of “wild” resources (mostly NTFPs) under “The Hidden Harvest” project (Scoones et al., 1992). These were noted to be important over the whole range of rural livelihood systems and not limited to the exclusive preserve of classical “hunting and gathering” societies (Scoones et al., 1992; Guijt et al., 1995). In savannas, large amounts of NTFPs are consumed and traded yet the sector has received very little formal recognition (Campbell and Luckert, 2002; Dovie et al., 2002a,b; Twine et al., 2003; Shackleton and Shackleton, 2004a; Shackleton et al., 2005).

Figure 2. Top left: Wild edible fruit from a *Strychnos* spp. Top middle: Woodcraft products of hoe handle, different sizes of wooden spoons, pestle and mortar. Top right: A pile of wood for fuel energy. Middle left: Types of fencing of kraals and homesteads using wood only. Middle right: Fencing poles combined with barbwire. Bottom left, middle and right:

Indigenous poles for different types of housing walls; wood only, with mud and stone, respectively (Photos: DBK Dovie).

Many NTFPs have significant economic values, thus often replacing the need for costly options and as natural safety nets to cash-poor households (Scoones et al., 1992; Guijt et al., 1995; Emerton, 1996; Campbell et al., 1997; Dounias, 2000). NTFPs also have cultural values (Cocks and Dold, 2003; Lawes et al., 2004), but less well defined "existence" values. Several NTFPs may be harvested from over-utilized, marginal and areas of nutrient poor soils of villages. Such areas may extend from the immediate neighbourhood of settlements. Such areas have been assumed to be self-regulating "wastelands", rather than productive ecosystems which are the partial product of human activity and design (Bell, 1995; Daily, 1997; Dovie et al., in press). Failure to recognise the value of these "wastelands" means that they are either subjected to intense commercial use, such as industrial plantations, or else high external input agriculture (Bell, 1995). The result is the displacement of more diverse traditional agro-ecosystems, biodiversity and livelihoods most especially in view of the high expectations and growing interest in plant resources.

1.4.2.2. Monetary value of NTFPs

In order to establish the value of NTFPs, monetary values have been used in the past two decades. These were to help give NTFPs a new financial and economic image as “not free goods”, but are key resources making substantial contributions to the gross domestic product of many countries (Godoy and Bawa, 1993; Constanza et al., 1997; Wollenberg and Nawir, 1998; Gram, 2001). The valuation of NTFPs has involved the use of different techniques that allocate market values, ranging from ecological (mostly on production per hectare) to economic analysis (i.e., capturing household level consumption). For all those measures, the use of current market prices and the value that society places on the resources as well as the demand and supply conditions are the benchmarks for the valuation (Godoy et al., 2000; Batagoda et al., 2000; Shackleton and Shackleton, 2004b; Dovie et al., 2005; Shone and Caviglia-Harris, 2006). NTFP values may be heterogeneous even within the same environment as a result of the influence of differences in the economics of use, local institutions, household characteristics and the local availability of the resources (Chopra and Kumar, 2004; Janse and Ottitsch, 2005). Other proximate factors underlying access to NTFPs are the access to other land uses (e.g., farms), significant cultural differentiation, extraction arrangements (e.g., open access to common property regimes), formal and informal jobs, as well as the proximity to formal markets and urban centres (Campbell et al., 2002; Chopra and Kumar, 2004). In recent years, households' wealth and education status have been identified as playing important roles for the high dependence on NTFPs (Narendran et al., 2001; Shackleton and Shackleton, 2006; Shone and Caviglia-Harris, 2006). On a household analysis basis, the relative values of NTFPs have been found to be as high as 50% of total household income but depending on the number and types of livelihoods analysed (Narendran et al., 2001; Campbell et al., 2002; Dovie et al., 2005).

In southern Africa, the monetary valuation of NTFPs is well documented (e.g., Campbell and Luckert, 2002; Dovie et al., 2002a; Shackleton et al., 2002a,b; Twine et al., 2003; Shackleton and Shackleton, 2004b). Of this valuation, direct-use values are known to range from R3609 to over R10500 per household per annum (adjusted to 2005 values), and found to be comparable to, or in some cases higher than on-farm income (Shackleton et al., 2002b; Dovie et al., 2005). In South Africa, the total mean gross values in 2005 of all the NTFPs combined (plants, animal and earth resources) was R5450.1 ± 640 per household per annum (i.e., R454.2.1 ± 53.3 per month), and mean total national rural aggregate of 7 billion Rand (i.e., R7.08 ± 0.69 billion per annum). Using the estimates of Dovie et al. (2002a) and Shackleton et al. (2002b), the gross aggregate translates into a mean net national aggregate of 5.7 billion Rand (i.e., R5.71 ± 0.5 billion per annum), ranging from 5.21 to 6.21 billion Rand per annum in 2005 (net R3878.91 ± 516.09). On a monthly basis, the gross value was estimated at R454.18 ± 53.33 per household (net R366.25 ± 43.01). The woody plant components (i.e., medicinal plants, wild edible fruits, fuelwood, housing and fencing poles, indigenous furniture, wooden utensils) were estimated at R2566.72 ± 218 per household per annum and nationally aggregated at around 5.6 billion Rand (i.e., R5 640 ± 478 million) in 2005. Fuelwood had the highest relative value of 63.3% with estimated aggregate value of 3.5 billion Rand (Table 1). Wild edible fruit was the next highly valued resource to fuelwood, and estimated to be less than half the aggregate value of fuelwood, with these two alone contributing to over 90% of the value generated by resources of woody species origin (Table 1). The national aggregate value of the extraction of NTFPs represents approximately 28% of the agricultural GDP in the former homelands.

Table 1. National aggregate values of specific individual resources from woody species for all rural households in the former homelands of South Africa in 2005.

Resource	**Value per household (R)**			**Aggregate value (R million)**	
	Mean	**Range**	**(%)**	**Real**	**Discounted**
Fuelwood	1626.5	1382.2-1870.8	63.3	3 904.0	3 572.0
Wild edible fruits	706.9	517.7-896.2	27.5	1 697.0	1 552 .0
Wooden utensils	110.6	31.1-189.1	4.3	265.0	243.0
Fencing poles	71.0	46.5-95.5	2.8	170 .0	156.0
Medicinal plants	29.8	16.2-43.4	1.2	72.0	65.0
Housing poles	11.7	3.4-20.0	0.5	28.0	26.0
Furniture	10.3	0-20.7	0.4	25.0	23.0
Total Rand				**6 160.0**	**5 640.0**

1.4.2.3. Proximity of formal market and urban centres, and monetary valuation

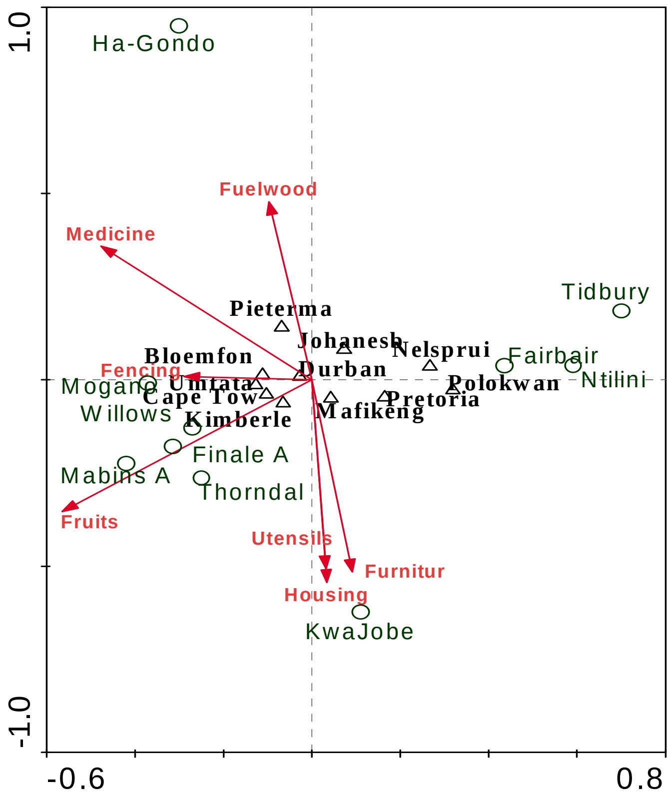

Figure 3. The canonical correspondence analysis (CCA) triplot of links between the monetary values of seven selected NTFPs of woody plant species origin and proximity to cities.

The use of NTFP, accompanied monetary values of the specific relationship between the sources of harvesting and proximity to market and urban centres is little studied yet important for natural resource accounting. This is because the access to forest products and consumption by urban dwellers could contribute immensely to the actual value of NTFPs traded and consumed. A continuum of the use of NTFPs exists between urban and rural dwellers, mostly linked to the processing and marketing in urban areas that are conservatively known to be associated with rural environments. Selected important market routes linking the villages and urban formal market centres were quantitatively derived using distances in kilometres in relation to the economic values of NTFPs for the specific villages. Spatial analysis was found to be more suitable for the data especially because the variables had different magnitudes hence the use of a CCA. Of seven NTFPs analysed in relation to the proximity of the NTFP sources to formal and urban market centres (Figure 3), two of them (medicinal plants and wild edible fruits) were important for the city markets, showing higher canonical lambda values than the other five resources based on the distance of the cities from the NTFP sources. The two further correlated strongly with the cities axis 1 (Figure 3). Fencing poles appeared to be less important with respect to the cities, and having a much smaller rate of change compared to the other resources (Figure 3). The Eastern Cape province villages (Tidbury, Fairbairn, Ntilini) drifted from the NTFPs and the market centres, coinciding with their remoteness from these centres. Generally however, distance of cities or areas with highly developed formal market centres may have no significant impacts on NTFP consumption in rural areas and hence the monetary value of most NTFP resources (Figure 3).

1.4.2.4. Indigenous knowledge and NTFP harvesting regimes

It is important to recognise that NTFPs have been nurtured over many centuries by indigenous human communities through their relationships with the environment (Garcia-Brokhausen, 1997; Moore et al., 2002; Crivos et al., 2004). These relationships are possibly mediated through judgment structures of indigenous origins. Kinship ties for example form the basis for local level decision-making on aspects of livelihoods and resource management in several indigenous communities. The knowledge base of local people is therefore important for assessing NTFP use because biodiversity has different values for different people and defining the magnitude of management practices. Ethnoecological and ethnobotanical studies are increasingly recognising the role of indigenous knowledge about ecological and evolutionary patterns related to people's use of plant diversity (e.g., Salick et al., 1999; Cocks and Dold, 2003). It has been established that increased useful woody plant species have direct relationship with overall plant diversity in a forest landscape of Mt. Kinabulu in Borneo (Salick et al., 1999). Season also plays a major role in determining the harvesting of some NTFPs. Many NTFPs can only be collected or harvested at certain times of the year (Campbell et al., 1997).

1.4.2.5. The future of NTFP use in South Africa

In South Africa, problems with land tenure have prevented rural communities from effectively managing their own commercial endeavours, and hence having to depend largely on natural resources that are supposedly “free”. Delays in land redistribution and appropriate polices on natural forests and woodlands have prevented options for conservation agencies to allow subsistence harvesting of NTFPs from protected areas (de Wet, 1997). The National Forestry Action Programme has proposed access by local people to forests for social purposes in state forests (DWAF, 1996) and arrangements for direct harvesting of plants including permits have been stated in the 1998 Forest Act. Based on this Act, sustainable harvesting arrangements have been reported in some state forests (Venter, 2000). Some studies (e.g., Dovie et al., 2002a; Dovie et al., 2004; Shackleton and Shackleton, 2004a), have shown that there is a considerable decrease in the availability of specific NTFPs, in specific communal areas of South Africa, although there are resource exceptions (Dzerefos et al., 1999, 2003; Emanuel et al., 2005; Shackleton et al., 2005). As a result, there is the possibility that some species that were utilised many years ago are no longer in adequate supply and/or have been substituted or their habitats colonised by non-endemic species. There is therefore a general concern for the sustainability of NTFPs (e.g., Dovie et al., 2004; Shackleton et al., 2005, Ticktin, 2005).

State conservation policy options unfortunately and more frequently overlook the importance and value of NTFPs to deprived people. The majority of private and state land users also fail to allow access for harvesting of NTFPs and this has been particularly experienced in the post-apartheid era (de Wet, 1997). Considering the above issues therefore, how will a balance between conservation, socio-economic development, and political rights be maintained? A market approach maintains that improved producer prices, adding value locally and organizing people to own the resources and take active part in management will make a positive impression (Crook and Clapp, 1998). These can therefore lead to the goals of long-term economic rights of people to access NTFPs using commercial initiatives. However, there are concerns that the lack of regulation of NTFP harvesting will negatively impact on the industry. This can lead to over-harvesting, degradation of the resource base, conflicts and increased tension among stakeholders (Chamberlain et al., 1998).

1.4.2.6. The harvesting and management of NTFP resources

Extraction of any NTFP will potentially produce measurable impacts on the structure and genetic composition of the harvested plant population (Cunningham, 2001; Arnold and Ruiz

Pérez, 2001; Ticktin et al., 2002; Ghimire et al., 2005; Ndangalasi et al., in press). The expansion of markets of NTFP has been found to be directly proportional to increasing human population (Cunningham, 2001). It has also been reported that activities of non-resident NTFP harvesters pose recognisable threats to NTFP species that are difficult to monitor and control under unfavourable land tenure practices (Dovie et al., 2002b; Dovie, 2003). Harvesting and marketing impacts of forest resources need to be clearly defined and isolated for appropriate management. The impacts of harvesting can become severe under high levels of exploitation in response to market demand. In response, Dovie et al. (2002b) argue that adaptive management strategies involving adequate involvement of stakeholder diversity will minimise conflict of use and overexploitation. The areas of low forest production priority due to the absence of highly valued species will require significant improvement on the quality of products obtained from the less charismatic locally available species. The inadequate information on the ecology, conservation biology and physiology of NTFP species is the major drawback to initiatives to manage the resource base (Ticktin, 2005). It has however been suggested that unless the population dynamics and several other parameters of the plant resources are thoroughly assessed, it will be very difficult to sustainably manage these resources (Arnold and Ruiz Pérez, 2001; Ticktin, 2005). For the human dimension surrounding NTFP use, it is important that the culture of plant selection, the type of use, plant parts harvested, season and methods of harvesting, are well known. The only way this can be achieved is the active involvement in local research and NTFP product development by the local population, harvesters and users.

1.5. Rationale of the study

People whose livelihoods depend largely on NTFPs are the ones who enjoy the direct use values of biodiversity and in the context of this study, woody plant species diversity. The non-use values of benefits of biodiversity mainly accrue to people who may be distant from the source or origin of the biodiversity being enjoyed (Brown, 1998). The indirect and existence values associated with biodiversity are considered bequest or legacy for the environment, humans or both, whilst the intangible benefits that come with it are realised by people conserving biodiversity (Kunin and Lawton, 1996; Emerton, 1996; Balmford et al., 2002). The investment of the international community in programmes and policies aimed at supporting conservation at the local level often target indirect uses of species and ecosystems. However, many of these programmes focus on the flagship, charismatic or high value species, for example timber, pharmaceutical species and wildlife of mega diversity origins

(Heywood, 1995; Kunin and Lawton, 1996). There is very little attention paid to the broader spectrum of species upon which people depend for their daily lives. In the broader scheme of things, it is these species used daily for human livelihoods, which account for a considerable proportion of the total biodiversity in natural and subsistence agro-ecosystems. Yet there is limited understanding of the effect of changes in species richness and diversity as a result of the usefulness of the majority of species for NTFPs. It is now known that the direct link between plants that are useful to humans and local biodiversity at plant community and ecosystem level are more important than is previously thought (Salick et al., 1999).

In line with the 1997 South African National Forestry Action Programme (NFAP), the Department of Water Affairs and Forestry (DWAF) recognised the need to include local communities in the management of resources within natural forests and savannas (NFAP, 1997). In the process, savanna woodlands became part of this initiative and hence a recent concern for DWAF when the new National Forest Act was announced in 1998, resulting in policy development on woodlands management. In response, DWAF established a research programme to generate knowledge in support of the NFAP and the result was the collaborative institutional research projects to investigate the role of NTFPs for rural livelihoods in South African woodlands and seeking to provide a common methodology for valuing the direct-use of NTFPs (Magasela, 2001; Shackleton et al., 2002b; Twine et al., 2003). However, questions related to the sustainability of harvesting, linkages with locally available woody plant species richness and diversity remain largely unanswered. The study was carried out in ten diverse communal tenure area villages across the savannas located in three provinces (Figure 4), with diverse socioeconomic and environmental characteristics.

1.5.1. Aim of study

To develop an understanding of the relationship between locally available woody plant species richness and uses as NTFPs by rural households within communal areas.

1.5.2. The objectives of the study

The study sought to address the following:

a) To assess woody plant species richness and diversity along a disturbance gradient of human harvesting impacts, in communal savannas.
b) To examine the relationship between local woody plant species richness and the species used as NTFPs by local people.

c) To determine whether the available woody plant richness and diversity used locally differs between various genders and age groups of users.

d) To compare local level knowledge of useful woody species and local ecological information.

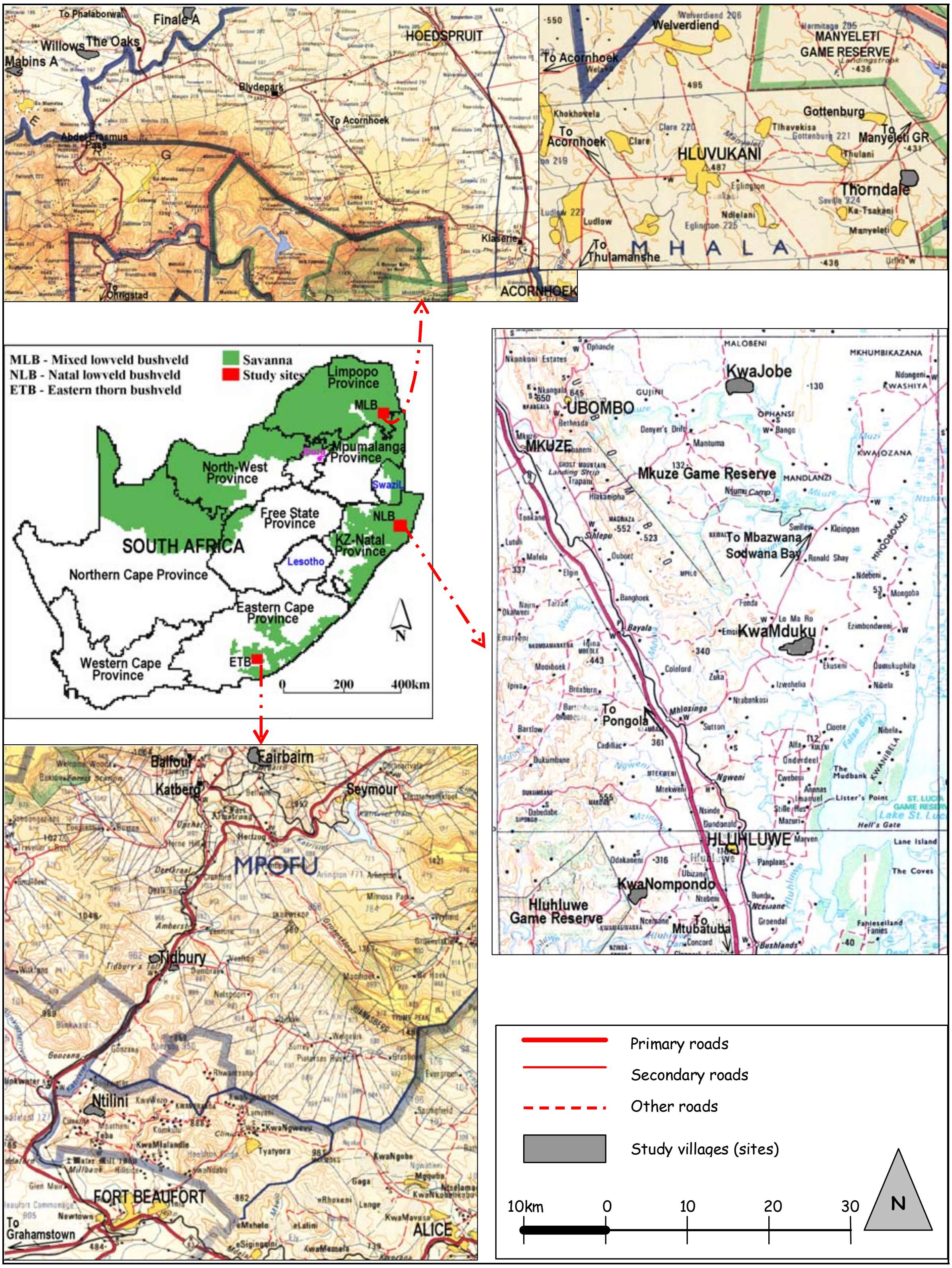

Figure 4. Map of South Africa showing the national provinces and study villages/sites.

References

Arnold, J.E.M., Ruiz Pérez, M., 2001. Can non-timber forest products match tropical forest conservation and development objectives? Ecological Economics 39, 437-447.

Balmford, A., Brooks, T., Moore, J.L., Burgess, N.D., Hansen, L.A., Lovett, J.C., Tokumine, S., Williams, P., Rahbek, C., 2002. People and biodiversity in Africa. Science 293, 1591-1592.

Barnett, D.T., Stohlgren, T.J., 2003. A nested-intensity design for surveying plant density. Biodiversity and Conservation 12(2), 255-278.

Bass, S., Hughes, C., Hawthorne, W., 2001. Forests, biodiversity and livelihoods: linking policy and practice. In: Koziell, I., Saunders, J. (Eds.), Living off Biodiversity: Exploring Livelihoods and Biodiversity Issues in Natural Resources Management. IIED, London, pp. 23-73.

Batagoda, B.M.S., Turner, R.K., Tinch, R., Brown, K., 2000. Towards policy relevant ecosystem services and natural capital values: rainforest non-timber products. CSERGE Working Paper GEC 2000-06, CSERGE, London.

Bell, J., 1995. The hidden harvest. Seedling 12(3), 23-31.

Brown, D., 1998. Participatory biodiversity conservation - rethinking the strategy in the low tourist potential areas of tropical Africa. ODI Natural Resource Perspective 33. ODI, London.

BSP, 1996. Biodiversity: facts on the foundation of life. Biodiversity Support Programme, Washington DC.

Campbell, B.M., Luckert, M., Scoones, I., 1997. Local level valuation of savanna resources: A case study from Zimbabwe. Economic Botany 51(1), 59-77.

Campbell, B.M., Jeffery, S., Kozanayi, W., Luckert, M., Mutamba, M., Zindi, C., 2002. Household livelihoods in semi-arid regions: options and constraints. CIFOR, Bogor.

Campbell, B.M., Luckert, M.K., 2002. Towards understanding the role of forests in rural livelihoods. In: Campbell, B.M., Luckert, M.K. (Eds.), Uncovering the hidden harvest: valuation methods for woodland and forest resources. CIFOR, Bogor, pp. 1-16.

Chamberlain, J., Bush, R., Hammett, A.L., 1998. Non-timber forest products: the other forest products. Forest Product Journal 48(10), 10-19.

Chopra, K., Kumar, P., 2004. Forest biodiversity and timber extraction: an analysis of the interaction of market and non-market mechanisms. Ecological Economics 49, 135-148.

Clinebell II, R.R., Phillips, O.L., Gentry, A.H., Stark, N., Zuring, H., 1995. Prediction of neotropical tree and liana species richness from soil and climatic data. Biodiversity and Conservation 4, 56-90.

Cocks, M.L., Wiersum, K.F., 2003. The significance of plant diversity to rural households in Eastern Cape province of South Africa. Forests, Trees and Livelihoods 13, 39-58.

Colwell, R.K., Coddington, J.A., 1995. Estimating terrestrial biodiversity. In: Hawksworth, D.L. (Ed.), Biodiversity measurement and estimation. Chapman and Hall, London, pp. 101-118.

Cordeiro, N.J., Plumptre, A., Dovie, D.B.K., Kaplin, B., Burgess, N. (Editors), in press. Conservation in areas of high population density in sub-Saharan Africa. Biological Conservation (Special Issue) XX.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grassor, M., Hannon, B., Limburg, K., Naeem, S., Neill, R.V.O., Paruelo, J., Raskin, R.G., Suton, P., Belt, M.V.D., 1997. The value of the world's ecosystems services and natural capital. Nature 387, 253-260.

Crivos, M., Martínez, M.R., Pochettino, M.L., 2004. Nature and domestic life in the Valle del Cuñapirú (Misiones, Argentina): Reflections on Mbyá-Guaraní ethnoecology. Agriculture and Human Values 21, 7-21.

Cromwell, L., Cooper, D., Mulvany, P., 2001. Agriculture, biodiversity and livelihoods: issues and entry points for development agencies. In: Koziell, I., Saunders, J. (Eds.), Living off Biodiversity: Exploring Livelihoods and Biodiversity Issues in Natural Resources Management. IIED, London, pp. 75-111.

Crook, C., Clapp, R.A., 1998. Is market-orientated conservation a contradiction in terms? Environmental Conservation 25, 131-145.

Cunningham, A.B., 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan Publications Ltd, London.

Daily, G.C. (Ed.), 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington DC.

de Wet, C., 1997. Land reform in South Africa: a vehicle for justice and reconciliation, or a source of further inequality and conflict? Development Southern Africa 14, 355-362.

Dounias, E., 2000. Review of ethnobotanical literature for Central and Western Africa. Bulletin of the African Ethnobotany Network Vol. 2.

Dovie, D.B.K., 2003. Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa? International Journal of Sustainable Development and World Ecology 10, 247-262.

Dovie, D.B.K., Shackleton, C.M., Witkowski, E.T.F., 2002a. Direct-use values of woodland resources consumed and traded in a South African village. International Journal of Sustainable Development and World Ecology 9(3), 269-283.

Dovie, D.B.K., Shackleton, C.M., Witkowski, E.T.F., 2002b. Accessing natural resources: implications for sustainable management and livelihoods. In: Benjaminsen, T., Cousins, B., Thompson, L. (Eds.), Contested Resources: Challenges to Governance of Natural Resources in Southern Africa. Programme for Land and Agrarian Studies, University of the Western Cape, Cape Town, pp. 336-348.

Dovie, D.B.K., Shackleton, C.M., Witkowski, E.T.F., in press. Conceptualizing the human use of wild edible herbs for conservation in South African communal areas. Environmental Management XX.

Dovie, D.B.K., Witkowski, E.T.F., Shackleton, C.M., 2004. The fuelwood crisis in southern Africa – relating fuelwood use to livelihoods in a rural village. GeoJournal 60(2), 123-133.

Dovie, D.B.K., Witkowski, E.T.F., Shackleton, C.M., 2005. Monetary valuation of livelihoods for understanding the composition and complexity of rural households. Agriculture and Human Values 22, 87-103.

DWAF, 1996. White paper on sustainable forest development in South Africa. Department of Water Affairs and Forestry, Pretoria.

Dzerefos, C.M., Shackleton, C.M., Witkowski, E.T., 1999. Sustainable utilisation of woodrose-producing mistletoes (Loranthaceae) in South Africa. Economic Botany 53, 439-447.

Dzerefos, C.M., Witkowski, E.T.F., Shackleton, C.M., 2003. Host preference and density of woodrose-forming mistletoes (Loranthaceae) on savanna vegetation, South Africa. Plant Ecology 167, 163-177.

Emanuel, P.L., Shackleton, C.M., Baxter, J.S., 2005. Modelling the sustainable harvest of *Sclerocarya birrea* subsp. *caffra* fruits in the South African lowveld. Forest Ecology and Management 214, 91-103.

Emerton, L., 1996. Valuing the Environment: Case Studies from Kenya. African Wildlife Foundation, Nairobi.

Farina, A., 2000. The cultural landscape as a model for integration of ecology and economics. Bioscience 50(4), 313-320.

Garcia-Brokhausen, S., 1997. Genetic Resources - Biodiversity is the tropical forest's "greatest treasure". GATE, technology and development 2, 18-22.

Geist, H.J., Lambin, E.F., 2001. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52(2), 143-150.

Ghimire, S.K., McKey, D., Aumeeruddy-Thomas, Y., 2005. Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC. and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. Biological Conservation 124, 463-475.

Godoy, R., Wilkie, D., Overman, H., Cubas, A., Cubas, G., Demmer, J., Mcsweeney, K., Brokaw, N., 2000. Valuation of consumption and sale of forest goods from a central American rain forest. Nature 406, 62-63.

Godoy, R.A., Bawa, K.S., 1993. The economic value and sustainable harvest of plants and animals from the tropical forest: Assumptions, hypotheses and methods. Economic Botany 47(3), 215-219.

Gram, S., 2001. Economic valuation of special forest products: an assessment of methodological shortcomings. Ecological Economics 36, 109-117.

Guijt, I., Hinchcliffe, F., Melnyk M., 1995. The Hidden Harvest: the value of wild resources in agricultural systems. International Institute for Environment and Development, London.

Heywood, V.H., 1995. Global biodiversity assessment. Cambridge University Press, Cambridge.

Janse, G., Ottitsch, A., 2005. Factors influencing the role of non-wood forest products and services. Forest Policy and Economics 7, 309-319.

Koziell, I., 2001. Diversity not adversity: sustaining livelihoods with biodiversity. IIED, London.

Kumar, A., Ram, J., 2005. Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, central Himalaya. Biodiversity and Conservation 14, 309-331.

Kunin, W.E., Lawton, J.H., 1996. Does biodiversity matter? Evaluating the case for conserving species. In: Gaston, J.K. (Ed.), Biodiversity: biology of numbers and difference. Blackwell Science Ltd. London, pp. 283-308.

Lawes, M.J., Obiri, J.A.F., Eeley, H.A.C., 2004. The uses and value of indigenous forest resources in South Africa. In: Lawes, M.J., Eeley, H.C., Shackleton, C.M., Geach, B.S. (Eds.), 2004. Indigenous Forests and Woodlands in South Africa: Policy, People and Practice. University of Natal Press, Durban, pp. 227-273.

Li, J., Loneragan, W.A., Duggin, J.A., Grant C.D., 2004. Issues affecting the measurement of disturbance response patterns in herbaceous vegetation – A test of the intermediate disturbance hypothesis. Plant Ecology 172, 11-26.

Magasela, B.B., 2001. An assessment of the direct use value of woodland resources in the Hlabisa District of KwaZulu-Natal. Unpublished Master of Arts Thesis, University of Durban-Westville.

Magurran, A.E., 2004. Measuring biological diversity. Blackwell Publishing, Malden, Oxford, Carleton.

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: Biodiversity synthesis. World Resources Institute, Washington DC.

McNeely, J., 1992. Nature and culture: conservation needs them both. Nature 28(3), 37-43.

Moore, J.L., Manne, L., Brooks, T., Burgess, N.D., Davies, R., Rahbek, C., Williams, P., Balmford, A., 2002. The distribution of cultural and biological diversity in Africa. Proceedings of the Royal Society of London 265, 1645-1653.

Narendran, K., Murthy, I.K., Suresh, H.S., Ravindranath, N.H., Sukumar, R., 2001. Non-timber forest product extraction, utilisation and valuation: a case study from the Nilgiri Biosphere Reserve, southern India. Economic Botany 55, 528-538.

Ndangalasi, H.J., Bitariho, R., Dovie D.B.K., in press. Harvesting of plant parts and implications for conservation in two montane forests of East Africa. Biological Conservation XX.

NFAP, 1997. Strategy for sustainable forest development in South Africa. Department of Water Affairs and Forestry, Pretoria.

Parsons, D.A.B., Shackleton, C.M., Scholes, R.J., 1997. Changes in herbaceous layer condition under contrasting land use systems in the semi-arid lowveld, South Africa. Journal of Arid Environment 37, 319-329.

Sagar, R., Raghubanshi, A.S., Singh, J.S., 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest Ecology and Management 186, 61-71.

Salick, J., Bium, A., Martin, G., Apin, L., Beaman, R., 1999. Whence useful plants? A direct relationship between biodiversity and useful plants among the Dusun of Mt. Kinabalu. Biodiversity and Conservation 8, 797-818.

Schluter, D., Ricklefs, R.E., 1993. Species diversity: and introduction to the problem. In: Ricklefs, R.E., Schluter, D. (Eds.), Species diversities in ecological communities. Historical and geographical perspectives. University of Chicago Press, Chicago and London, pp. 1-10.

Schneider, D.C., 2001. The rise of the concept of scale in ecology. BioScience 51, 545–553.

Scoones, I.C., Melnyk, M., Pretty, J. (Eds.), 1992. The Hidden harvest: wild foods and agricultural systems. A literature review and annotated bibliography. 111.1, ODI, London.

Shackleton, C.M., Shackleton, S.E., 2006. Household wealth status and natural resource use in the Kat River valley, South Africa. Ecological Economics 57(2), 306-317.

Shackleton, C.M., Guthrie, G., Main, R., 2005. Estimating the potential role of commercial over-harvesting in resource viability: A case study of five useful tree species in South Africa. Land Degradation and Development 16, 273-286.

Shackleton, C.M., Shackleton, S.E., 2004a. Use of woodland resources for direct household provisioning. In: Lawes, M.J., Eeley, H.C., Shackleton, C.M., Geach, B.S. (Eds.), Indigenous Forests and Woodlands in South Africa: Policy, People and Practice. University of Natal Press, Durban, pp. 195-226.

Shackleton, C.M., Shackleton, S.E., 2004b. The importance of non-timber forest products in rural livelihood security and as safety nets: evidence from South Africa. South African Journal of Science 100, 658-664.

Shackleton, S.E., Shackleton, C.M., Netshiluvhi, T.R., Geach, B.S., Balance, A., Fairbanks, D.H.K., 2002a. Use patterns and value of savanna resources from three rural villages in South Africa. Economic Botany 56, 45-65.

Shackleton, C.M., Shackleton, S.E., Ntsudu, M., Ntzebeza, J., 2002b. The role and value of savanna non-timber forest products to rural households in the Kat River Valley, South Africa. Journal of Tropical Forest Products 8(1), 45-65.

Shackleton C.M., Griffin N.J., Banks J.M., Mavrandonis J.M., Shackleton S.E., 1994. Community structure and species composition along a disturbance gradient in a communally managed South African savanna. Vegetatio 115, 157-167.

Shone, B.M., Caviglia-Harris, J.L., 2006. Quantifying and comparing the value of non-timber forest products in the Amazon. Ecological Economics 58(2), 249-267.

Silvertown, J.W., Lovett-Doust, J., 1993. Introduction to Plant Population Biology. Blackwell Scientific Publications, Cambridge.

Stohlgren, T.J., Owen, A., Lee, M., 2000. Monitoring shifts in plant diversity in response to climate change: a method for landscapes. Biodiversity and Conservation 9, 67-86.

Ticktin, T., 2005. Applying a metapopulation framework to the management and conservation of a non-timber forest species. Forest Ecology and Management 206, 249-261.

Ticktin, T., Nantel, P., Ramírez, F., Johns, T., 2002. Effects of variation on harvest limits for non-timber forest species in Mexico. Conservation Biology 16, 691-705.

Turner, G.M., Romme, W.H., Gardener, R.H., O'Neill, R.V., Kurtz, T.K., 1993. A revised concept of landscape equilibrium: Disturbance and stability of scaled landscapes. Landscape Ecology 8, 213-227.

Turner, R.K., Bateman, I.J., Adger, W.N., 2001. Ecological economics and coastal zone ecosystems' values: an overview. In: Turner, R.K., Bateman, I.J., Adger, W.N. (Eds.), Economics of Coastal and Water Resources: Valuing Environmental Functions. Kluwer Academic Publishers, London.

Twine, W.C., Moshe, D., Netshiluvhi, T.R., Shipugu, V., 2003. Consumption and direct-use values of savanna bio-resources used by rural households in Mametja, a semi-arid area of Limpopo province, South Africa. South African Journal of Science 99, 467-473.

UNEP, 1995. Global Biodiversity Assessment. United Nations Environment Programme, Cambridge University Press, Cambridge.

UNEP, 1999. Global Environment Outlook 2000. United Nations Environment Programme, Earthscan Publications Ltd., London.

Venter, S., 2000. Non-timber forest utilisation – basket making from Secamone spp. in the Northern province. In: Seydack, A.H.W., Vermeulen, W.J., Vermeulen, C. (Eds.), Towards Sustainable Management Based on Scientific Understanding of Natural Forests and Woodlands. Department of Water Affairs and Forestry, Knysna, pp. 246-249.

Waite, S., 2000. Statistical Ecology in Practice. A Guide to Analyzing Environmental and Ecological Field Data. Pearson Education Ltd., Essex.

White, P.S., Pickett, S.T.A., 1985. Natural disturbance and patch dynamics: an introduction. In: Pickett, S.T.A., White, P.S. (Eds.), The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, Orlando, pp. 3-13.

Wollenberg, E., Nawir, A.S., 1998. Estimating the incomes of people who depend on forests. In: Wollenberg, E., Ingles, A. (Eds.), Incomes from the Forest: Methods for the Development and Conservation of Forest Products for Local Communities. CIFOR, Bogor, pp. 157-187.

CHAPTER 2

Harvesting of woody plants as a measure of vegetation disturbance in the communal tenure areas of South African savannas

Abstract

The study of disturbance regimes in communal tenure areas has often focused on livestock grazing and gradients in environmental factors. Where direct anthropogenic disturbance is considered, land cover change at the landscape level is emphasised rather than the local changes in species communities. The harvesting of woody plants for non-timber forest products is analysed in the context of disturbance theory to capture the local level patterns of species richness and diversity at particular spatial locations (near, intermediate and far locations) around human settlements. The hypothesis that the species richness and density of woody plants increases from near to far locations from settlements in communal tenure areas is tested across three broad vegetation types within South African savannas. The modified Whittaker plots were used for the sampling. The farthest locations had more woody species (41.97 ± 3.9 species) within the 1000m² plots than for the intermediate (38.27 ± 5.6) and near (19.9 ± 4.2) locations. The difference in richness between locations was generally significant, but varied at individual sites. Statistically, there were no differences in the richness between the intermediate and far locations, underscoring the importance of these two locations in local resource use patterns. Highly significant differences were recorded between the four plot sizes across the combined sites for species richness, Shannon Wiener diversity (*H'*), Simpson's index of diversity (SID) and Pielou's evenness (*J'*). The mean total woody species number decreased from 31.6 ± 4.5 (1000m² plot), to 6.7 ± 1.2 (100m²), 3.9 ± 0.6 (10m²) and 2.8 ± 2.8 (1m²). There was a relatively higher average proportion of coppice shoots from stumps per hectare of harvested woody plants in the near locations (38.4%) than the far (33.0%) and intermediate (28.7%), matching the expected levels of harvesting intensity with distance from village. This suggests that under a certain harvesting intensity, or level of allowable harvesting, regeneration (or post-harvest recovery) of woody plants is favoured (through coppicing). The mean density of trees decreased from the far to near locations. A number of soil nutrients (e.g., total N, Mn and Cu, exchangeable Mg and Ca) and other environmental variables (elevation and slope inclination) significantly correlated with plant community organization. The harvesting of woody plants as a disturbance variable provides useful information for understanding communal tenure area plant species richness and diversity, which will assist in developing appropriate management practices for these areas.

Keywords: Communal areas, modified Whittaker plots, NTFPs, woody plant species locations, species richness, sampling scale.

1. INTRODUCTION

Plant communities change gradually along disturbance gradients as a result of the complex interaction between several biophysical factors of both natural and anthropogenic origin (Ramírez-Marcial et al., 2001; Sekhwela, 2003; Li et al., 2004; Fédoroff et al., 2005). The responses by individual plants to these changes determine the distribution and community assembly of the plants (Givnish, 1999; Huerta-Martínez et al., 2004; Shackleton et al., 2005). Considerable information exists on changes in plant community organization resulting from the relationship between vegetation and climate, fires, elevation and soil properties (e.g., Schluter and Ricklefs 1993; Clinebell II et al., 1995; Austin et al., 1996; Dube and Pickup, 2001; Huerta-Martínez et al., 2004). Changes in plant communities in human inhabited areas within tropical rainforests are well documented. Although similar disturbance information generally exists on savannas (e.g., Campbell and Du Toit, 1994; Sullivan, 1999; Lykke et al., 1999; Dahlberg, 2000; Luoga et al., 2002, 2004), harvesting of plants by local communities in savannas is hardly presented within the context of disturbance theory and specifically for communal tenure areas of South Africa, other than the work of Shackleton et al. (1994). For example, within forests, plant richness and diversity have been found to be higher in low-elevation high-human disturbance forests, whilst tree density decreases under high or moderate disturbance, but increases under low disturbance (Kumar and Ram, 2005). Similar information and understanding is hard to find on communal tenure area savannas especially because the emphasis has not historically been on considering harvesting as having patterned disturbance. The distribution of woody plant species in human dominated savannas and drylands has been noted in recent years to be largely affected by the harvesting of woody plants for commercial wood, non-timber forest products (NTFPs) and also by livestock grazing (Dube and Pickup, 2001; Luoga et al., 2002; Dovie, 2003; Sekhwela, 2003; Dovie et al., 2004; Dembélé et al., 2006). Apart from the emerging anthropogenic impacts on the distribution of woody plant species, environmental stresses such as severe droughts, fires and impacts of large herbivores (wild and domestic) have also wrought changes (Dai et al., 2004).

The disruption of vegetation structure and function by natural and anthropogenic disturbances affects species composition, with varied implications for biodiversity (Pickett and Parker, 1994; Heywood, 1995; Farina, 2000; Geist and Lambin, 2001). Disturbances are major sources of both temporal and spatial heterogeneity in the structure and dynamics of natural communities, through accelerated mortality of some individuals, scaling up to localised population declines and patchiness (White and Picket, 1985; Silvertown and Lovett-

Doust, 1993; Turner et al., 1993; Tálamo and Caziani, 2003). Anthropogenic disturbance often takes the form of rapid and explicit change through overexploitation of resources, but can also be chronic with a gradual disappearance of vulnerable species (Singh, 1998; Stuart et al., 2000; Kumar and Ram, 2005; Martorell and Peters, 2005). Human disturbance is considered the most widespread form of disturbance and is as destructive other forms, occurring slowly, cumulatively and gradually over long periods and are difficult to quantify (Singh, 1998; Tálamo and Caziani, 2003; Li et al., 2004; Martorell and Peters, 2005).

It has been hypothesized that plant communities experiencing intermediate disturbance are most likely to exhibit the highest diversity in forest ecosystems (see Connell, 1978). But for some aspects of ecosystem function such as competition, predation or productivity, this is not always the case (Worm et al., 2002; Li et al., 2004). The understanding of the response of plant communities to disturbance is influenced by the choice of disturbance gradient, community variables measured, the time of assessment following disturbance and scale of application (Li et al., 2004). Disturbance may not always be detrimental and if it is of suitable intensity it will be favourable to some species and/or communities (Sheil, 1999; Ramírez-Marcial et al., 2001; Sagar et al., 2003; Li et al., 2004; Martorell and Peters, 2005). Large disturbances due to environmental change may however result in the localised loss of some well established species compared to what can be potentially replaced by invasives and immigrants (Sheil, 1999). Some species may therefore tolerate the disturbance whilst others disappear as a cumulative outcome of the differential responses (Sagar et al., 2003).

The majority of well-documented information on anthropogenic disturbance of vegetation including the intermediate disturbance hypothesis (IDH) is well known for tropical forests (e.g., Connell, 1978; Heywood, 1995; Stuart et al., 2000; Geist and Lambin, 2001; Li et al., 2004; Kumar and Ram, 2005). The often generalization of such information to include savannas has overshadowed their relevance to plant communities in communal tenure areas as important and unique parts of the cultural landscape of savannas. This is because the hypothesis was developed on the basis of rainforest conditions with very little disturbance in general, having much lower intermediate disturbance than in savannas. Consequently there is a need for greater understanding and predicative capacity on plant community structure, composition and assemblages in areas of high human population density in savannas, such as the communal tenure areas of South Africa (Fabricius et al., 2002). The use of (a) single biotic indicators or expert knowledge assessment through direct observation and (b) remote sensing techniques and landscape level analyses for studying changes in savanna vegetation in high human inhabited environments such as communal tenure areas (e.g., in South Africa) have hampered the understanding of anthropogenic impacts on local level patterns in plant communities. Few studies (e.g., Shackleton et al., 1994; Sekhwela, 2003) have attempted to define the attributes of woody plant species along ordinal harvesting gradients in southern African communal tenure areas, and also in a West African savanna (Dembélé et al., 2006), in these coupled human-environment systems. There is an overall consensus that plant communities far from human settlements are less impacted than the nearer ones. The choice of methods for sampling vegetation and the extent of the measurements, towards the assessment of species community structure and composition in communal tenure areas will determine the usefulness of specific information gathered towards the management of plant biodiversity in these areas. In recent times, the importance of plot size and design used in various sampling techniques (e.g., modified Whittaker plots) has been highlighted (Shackleton, 2000a; Barnett and Stohlgren, 2003). It has been observed that the inbuilt variability that characterizes natural landscapes needs to be considered in inventories at local and landscape scales, although this is difficult to achieve. High spatial heterogeneity across landscapes may be best suited to simple single scale designs but then it may be accompanied by sacrifices in information quality, cost limitations and the in depth understanding of local patterns in species richness, diversity and evenness (Stohlgren et al., 2000; Barnett and Stohlgren, 2003). More small plots may however improve data obtained at localized scales with human impacts on vegetation that tend to create finer-scale patterns of change.

It is noteworthy that social and economic changes are leading to the intense commercialisation of NTFPs from woody plant species that were previously meant for subsistence use. The ensuing changes in woody plant communities will be better understood by analysing current trends in plant diversity and resource use gradients. To do this, a study in ten diverse communal tenure area villages of South African savannas was undertaken. The aim was to predict the relative differences in plant community structure and composition using the harvesting of woody plants for NTFPs as the major disturbance variable. The objectives were (a) to examine the trends in changes of woody plant species attributes in relation to location from human settlements, and (b) to evaluate the relationships that exist between the woody plant species attributes, environmental factors, and vegetation types.

2. STUDY SITE DESCRIPTION

The study villages (Table 1) are located in the communal tenure areas within the savanna biome of South Africa. Three vegetation types based on Low and Rebelo (1996) were adopted as Mixed lowveld bushveld, Eastern thorn bushveld and Natal lowveld bushveld that represented three broad geographical areas (Table 1). The villages (sites) are Thorndale, Finale A, Mabins A and Willows (Limpopo province); Tidbury, Fairbairn and Ntilini (Eastern Cape) and KwaNompondo, KwaMduku and KwaJobe (KwaZulu-Natal). The villages are remote from the major centres of commercial activity and have limited access to social infrastructure. Although the majority border game reserves, access to the reserves for any subsistence use is generally prohibited. Land is mostly categorized into arable and residential plots (although some parts are cultivated, and also used for kraals), and residents are allowed free access for grazing and the extraction of non-timber forest products (NTFPs) in the remaining areas. Hence, land is characteristically open access with no individual title deeds, having a long history of frequent fires and general grazing by cattle as the key environmental factors shaping the vegetation.

Table 1. The biophysical and land use characteristics of the study sites.

Village (site)	**Landscape**	**Climate and vegetation**	**Geology**	**Major land uses**
Thorndale (24º39'S: 31º21'E) Finale A (24º19'S: 30º42'E) Mabins A (24º22'S: 30º32'E) Willows (24º21'S: 30º57'E)	Flat to undulating landscapes noted to be between 350 and 500m above sea level and located in the Limpopo province.	Mixed lowveld bushveld vegetation with rainfall varying between 450 mm and 1000 mm annually and temperatures averaging 22°C. The mixed vegetation is dense bush on the uplands, open tree savanna in the bottomlands, dense riverine woodland on river banks, characterized by some *Combretum* spp., *T. sericea, S. madagascariensis,* and *Sclerocarya birrea*, some *Acacia* and *Albizia* spp. in the bottomland.	Substrate extensively defined by sandy soils in the uplands and clayey soils that exhibit high sodium content in the bottomlands. Granite and gneiss with numerous dolerite intrusions and areas covered by gabbro are noted for the geology.	Cattle and game farming are predominant, with local people depending largely on woodland resources and dryland agriculture.

Tidbury (32º38'S: 26º39'E) Fairbairn (32º33'S: 26º42'E) Ntilini (32º42'S: 26º36'E)	Characterized by the Kat River valley of the Mpofu district of the former Ciskei homeland and now part of the Eastern Cape coast, on dry upland ridges above valley thicket.	Eastern thorn bushveld vegetation, having average annual rainfall under 450 to 900 mm per annum, and temperatures averaging 18°C. Vegetation is characterized by small (less than 3 m tall) *Acacia karroo* trees, *Rhus* spp., *Scutia myrtina, Maytenus polyacantha, and Ehretia rigida.* There is a corresponding change in vegetation along a rainfall gradient, dominated by *Acacia karroo* around Fairbairn (in the valley), to more succulent thicket in the south characterised by *A. karroo* and *Olea europaea*.	Deep loamy soils derived from shale, mudstone and sandstone of the Beaufort Group of the Karroo Sequence.	Livestock farming (mainly goats and cattle) at commercial and subsistence levels. Additionally is the extraction of woodland resources.
KwaNompondo (28º04'S: 32º10'E) KwaMduku (27º51'S: 32º24'E) KwaJobe (27º36'S: 32º20'E)	Constitutes much of the Lowveld of Zululand which lies between 150 and 450m altitude with variable topography.	Located in the Natal lowveld bushveld. Rainfall is 650 mm to 900 mm per year and mostly falling in summer and mean annual temperatures from 10°C to about 30°C. KwaJobe and KwaMduku mimic sub-tropical environments. The vegetation is a mix of scrub and savanna. The most common tree species include *Acacia tortilis, A. karroo, Berchemia zeyheri, Boscia albitrunca, Euclea schimperi,* and *Spirostachys africana*.	Variable geology and soil conditions, underlain by Beaufort shale, sandstones and Stomberg basalts. Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.	The major uses are commercial cattle production, and game farming, sugar cane and subtropical fruit farming. Harvesting of non-timber forest products.

3. METHODS

3.1. Ecological sampling

Field sampling was by means of modified Whittaker plots (MWP) (Stohlgren et al., 1995; Barnett and Stohlgren, 2003) and undertaken in the year 2003. This was to allow the local examination of the number and diversity of woody species at different scales. Following the approach of Shackleton et al. (1994) three transects were located, radiating out from the periphery of each village. Three MWPs were located and sampled along each transect. These plots were randomised using a Global Positioning System (GPS) that specified the distances between the plots based on the total distance from the periphery of the village to a representative area of the least impacted vegetation surrounding the corresponding settlement. Consequently, along each transect there was one MWP close to the village, one far away in the least impacted vegetation, and one intermediate between these two extremes (Figure 1a: top left and right – near locations; middle left – intermediate; middle right – far). This design was based on the assumption that harvesting and disturbance intensity decreases with distance away from human settlements (villages), and thus defining an ordinal disturbance gradient (Shackleton et al., 1994; Sekhwela, 2003). The near location was at least 100m away from the last built area of each village, the far located within a representative stand of the most intact vegetation for that area, but avoiding edge effects due to other infrastructure (e.g., roads) and farms (Figure 1a: bottom left – game farm; bottom right – unsealed road). The mean near location across all sites measured 0.7 ± 0.2km from the last built area of human settlement, intermediate (1.7 ± 0.3km) and far location (2.7 ± 0.4km).

A total of nine plots were sampled in each of the 10 villages (n = 90). Sub-sampling was carried out within the largest, 20m x 50m (1000m²) plot (Figure 1b). The sub-plots of the MWP are one 5m x 20m (100m²), two 2m x 5m (10m²) and ten 0.5m x 2m (1m²). The three sub-plot sizes are independent and non-overlapping. Only woody species were sampled and diameter at breast height (dbh) measured at approximately 1.5m above ground level depending on the height of plants. Based on the work of Comiskey et al. (2001) and Campbell et al. (2002) the woody species were categorised into trees (stems of dbh = 2cm and over) and seedlings (stems of dbh <2cm). Voucher specimens were collected and prepared for post field identification and confirmation in the H.E. Moss Herbarium, Witwatersrand University. Cut stems and stumps of harvested species were counted and height and basal diameter measured. All cut stems were identified, counted and checklists produced.

Figure 1a. Top left and right: These represent the physiognomy of the woody plant species in the near locations. Middle left: intermediate location of woody species. Middle right: the generally least impacted feature of species in far locations although a few sites had denser intermediate locations with large stem trees. Bottom left: A far location bordering a Game Reserve and MWPs placed to avoid edge effects. Bottom right: Unsealed road linking a small town Hluvukhani, Thorndale and the Manyeleti Game Reserve (Photos: DBK Dovie).

The topsoil of each MWP was sampled at the depth of 0-15cm using an auger with five replicates at random points and combined to form a single soil sample for each 1000m² plots. Soil samples were then air-dried and analysed in the laboratory for pH, nutrient and chemical properties. This was carried out by the Soil Fertility and Analytical Services of the KwaZulu-Natal Department of Agriculture and Environmental Affairs at CEDERA, South Africa. The nutrients were total Nitrogen (N), Phosphate (PO_4), Potassium (K), Calcium (Ca), exchangeable Magnesium (Mg), Zinc (Zn), Manganese (Mn), and Copper. Environmental variables (i.e., elevation, slope, aspect, rockiness, and fire) were assessed for each plot across all sites. An altimeter was used for measuring elevation, aspect with a compass, rockiness and fire by physical assessment and rated on a scale as high (>50% of plot burnt or made of rocks), intermediate (>10% - <50% of plot burnt or made of rocks) and low or none (<10% of plot burnt or made of rocks). Slope was assessed on a 3 – point scale (very steep, steep, and uniform).

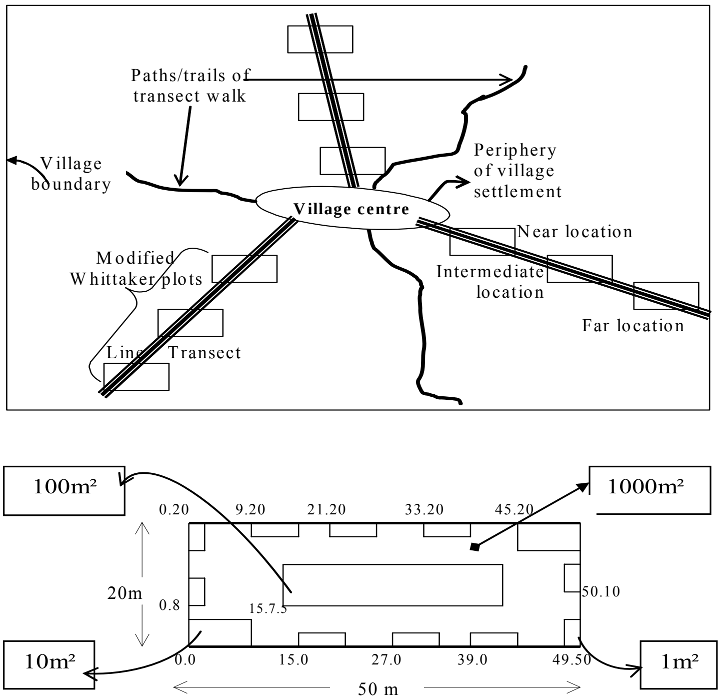

Figure 1b. Sampling design showing the placement of modified Whittaker plots (MWP) and paths for transect walks relative to the settlement area (top), and detailed MWP with the placement of the nested plots (bottom).

3.2. Data analysis

3.2.1. Community diversity and composition

Woody species richness was determined as the number of species of woody plants per unit area of the 1000m² plots. Community diversity was assessed with the Shannon–Wiener index (*H'*), with values influenced by species richness and evenness, and defined as $H' = -\sum p_i \ln p_i$ where, $p_i = n_i / N$ is the relative abundance of species, n_i = individual species number, and N = total number of individual species (Magurran, 2004). Pielou's evenness index (*J'*) is the measure of the equality of the species in a sample, and if all species are equally abundant, *J'* will approach the maximum (i.e., 1) and decreasing towards zero as relative abundance diverges from evenness, $J' = H' / \ln N$ (Waite, 2000). The Simpson's index of diversity (SID) denotes the probability that two individual species drawn at random from a population will belong to the same species. The higher the value of SID, the lower the diversity of the sampling unit (i.e., $SID = 1 - \Sigma p_i^2$). Density was calculated as the number of stems/ha from the MWP. The relative densities of individual species per plot was derived from $(n_x / N_y)\, x\, 100\%$ where n_x = total stem number of individual species, and N_y = the sum of the stem numbers of all species present. The assessment of species richness, diversity and evenness within the contiguous overlapping and the nested subplots provided a measure of the effects of scale of sampling for the sites.

3.2.2. Statistics

Descriptive, univariate and multivariate statistics were used for the analyses of the woody plant species data. Values were generally expressed as means (± standard error). Differences in the means of richness, diversity, evenness, dbh, stem density and plants heights were compared between plot sizes, location and sites using ANOVA. Where conditions of ANOVA (e.g., homogeneity, absence of outliers) were not met, the data were appropriately transformed before the analysis was carried out. The Tukey honest significance difference test (HSD) was used to determine specific differences between variables in the multifactorial ANOVAs that were significant. A multivariate analysis using the canonical correspondence analysis (CCA) was used to establish the expected correlation between the vegetation types, woody plant species, locations relative to the human settlement area and selected environmental variables using the CANOCO version 4.5A package (ter Braak, 2003). CCA was the preferred measure for constrained analysis involving species, samples and environmental gradients (Lepš and Šmilauer, 2003). The canonical axes were tested for their significance to influence the species composition data. The Monte Carlo permutation test with 499 permutations in the CANOCO package was used. The environmental variables that showed significant outcomes were included in the predictive model using a forward selection. High *lambda* values of the environmental variables represented the extents of importance in the canonical ordination model. Unless specifically stated, all statistics were performed with the S-PLUS 2000 program (MathSoft, 1999).

4. RESULTS

4.1. Woody plant community composition and structure

4.1.1. Richness, diversity and evenness

Given the three geographical areas and corresponding broad vegetation types, it was found that the Natal lowveld bushveld had the highest mean species richness (51.3 ± 5.75), and accompanied by highest diversity indices (Shannon: 1.96 ± 0.09, Simpson: 0.79 ± 0.02) across the combined locations at the 1000m² plot scale. It was followed by the Mixed lowveld bushveld (27.1 ± 3.54) and Eastern thorn bushveld (24.3 ± 4.06) for species richness, and accompanied diversity indices of (*H'*: 1.61 ± 0.08, SID: 0.73 ± 0.02) and (*H'*: 1.2 ± 0.13, SID: 0.56 ± 0.05), respectively.

Woody plant species locations generally had significant effects on diversity across all three vegetation types (p <0.05). Thus ($F_{2,85} = 6.4$) and ($F_{2,85} = 3.4$) for *H'* and *J'*, respectively. At individual sites, KwaMduku and KwaJobe in the Natal lowveld bushveld vegetation sites had the highest species richness followed by Thorndale in the Mixed lowveld bushveld (Table 2). Species richness was generally high for the far locations in six villages and low for the near locations whilst the intermediate locations exhibited highest richness in four villages (Table 2). For combined sites, species richness differed significantly between the locations ($F_{2,87}$= 9.1, $p < 0.001$), mostly between the near and intermediate locations, and between the near and far, but not between the intermediate and far (HSD test). The mean woody plant species richness for the far locations was higher than for the intermediate and near across the combined sites in the 1000m² plots (Table 2).

On the basis of the location of species, the Mixed lowveld bushveld exhibited a clear trend for the Shannon diversity index, increasing from the near to the far locations, with high evenness in the near and highest richness in the far locations (Figure 2). In the Eastern thorn bushveld, richness and diversity increased from the near to the far locations with high evenness in the intermediate (Figure 2). The woody species richness in the Natal lowveld bushveld increased from the near to the far locations whilst the intermediate locations exhibited high diversities and evenness compared to the near and far locations (Figure 2).

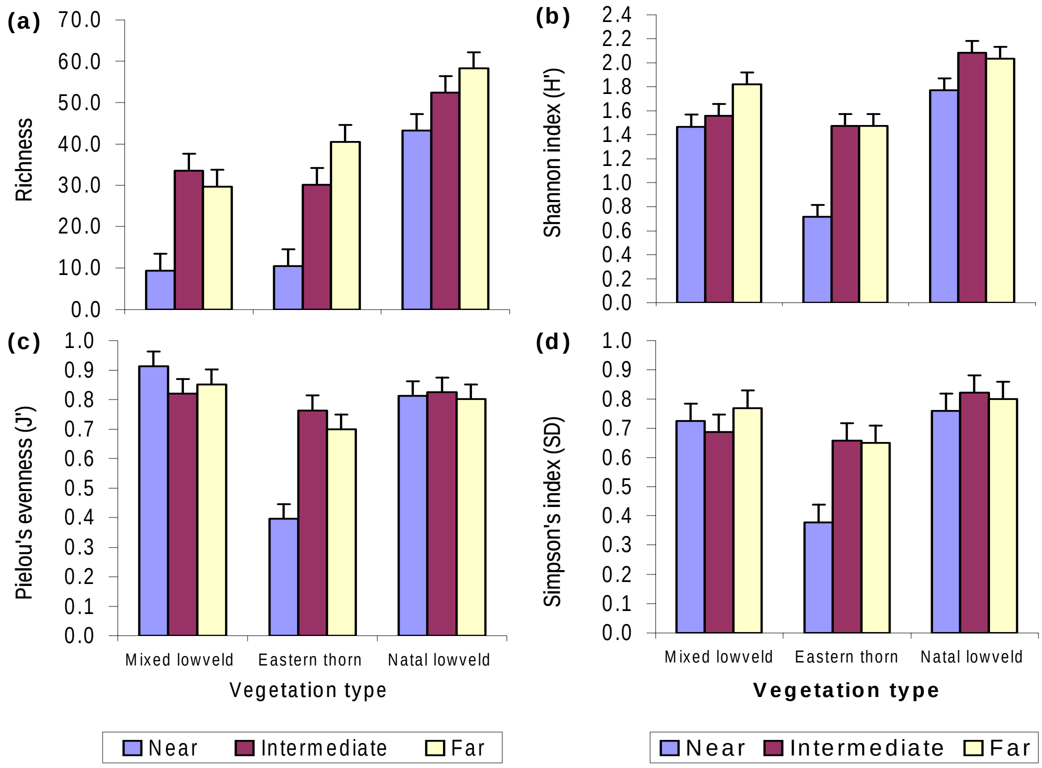

Figure 2. The mean (± SE) values of woody plants at the 1000m² scale across three vegetation types for (a) number of woody species per plot area (richness), (b) Shannon-Wiener diversity index (*H'*), (c) Pielou's evenness (*J'*) and (c) Simpson's index of diversity (SID), in relation to the location of the species relative to human settlements.

Overall, the top ten species that occurred most frequently in the near locations were *Acacia karroo, Terminalia sericea, Pteleopsis myrtifolia, Combretum apiculatum, Spirostachys africana, Euclea natalensis, Strychnos spinosa, Sclerocarya birrea, Strychnos madagascariensis*, and *Acacia burkei*, in a decreasing order. In the intermediate locations, *Acacia burkei, C. apiculatum, A. karroo, Ziziphus mucronata, S. spinosa, Combretum zeyheri, S. madagascariensis, Vangueria infausta, Combretum hereroense*, and *Aloe africana*, were the top ten species that occurred frequently. In the far locations, *A. africana* was the highest, followed by *C. apiculatum, A. burkei, Euphorbia tetragona, C. zeyheri, S. madagascariensis, Dichrostachys cinerea, Aloe thraskii, A. karroo*, and *T. sericea*.

Table 2. The mean (± SE) species richness of woody plants based on location of plots for the 1000m² plots.

Sites	Near	Intermediate	Far	All locations
Thorndale	4.67 ± 0.88	16.00 ± 0.00	9.67 ± 0.88	10.11 ± 1.68
Finale A	7.33 ± 2.03	6.67 ± 1.67	7.67 ± 0.88	7.22 ± 0.81
Mabins A	5.67 ± 0.88	7.00 ± 4.04	10.67 ± 4.06	7.78 ± 1.83
Willows	4.00 ± 1.00	4.00 ± 0.58	7.67 ± 1.45	5.22 ± 0.81
Tidbury	2.67 ± 1.67	10.67 ± 1.76	10.67 ± 2.40	8.00 ± 1.66
Fairbairn	1.67 ± 0.67	5.67 ± 2.03	6.67 ± 1.20	4.67 ± 1.04
Ntilini	4.67 ± 0.88	7.33 ± 2.19	6.67 ± 1.45	6.22 ± 0.89
KwaNompondo	5.67 ± 0.88	6.67 ± 0.33	10.67 ± 3.71	7.67 ± 1.34
KwaMduku	13.33 ± 0.88	21.33 ± 5.78	18.33 ± 0.67	17.67 ± 2.06
KwaJobe	9.67 ± 1.86	12.67 ± 2.40	11.33 ± 1.45	11.22 ± 1.06
Combined sites	5.93 ± 1.08	9.83 ± 1.72	10.13 ± 1.06	8.63 ± 0.56

Overall, the Shannon-Wiener index of diversity (*H'*) differed significantly between the near, intermediate and far locations $(F_{2,87} = 4.9,\ p < 0.05)$, although it was not significant between the locations at the majority of the individual sites. The *H'* was generally higher in the far locations (1.78 ± 0.1), than the intermediate (1.69 ± 0.2) and the near (1.33 ± 0.2) along a decreasing harvesting disturbance gradient from the settlement. The high far location *H'* values occurred in the majority of the villages compared to the intermediate and the near locations. The *H'* also differed significantly between the villages $(F_{9,60} = 7.9,\ p < 0.001)$, with the Natal lowveld bushveld vegetation sites having the highest *H'* (1.94 ± 0.1) followed by the Mixed lowveld bushveld (1.59 ± 0.1) and the least in the Eastern thorn bushveld (1.20 ± 0.1).

The Pielou's index of evenness (*J'*) did not differ significantly between locations within individual sites, but differed significantly between villages $(F_{9,60} = 4.85,\ p < 0.001)$. The *J'* was highest in the Mixed lowveld bushveld (0.86 ± 0.0), then the Natal lowveld bushveld (0.81 ± 0.0) and the Eastern thorn bushveld (0.62 ± 0.1)(Figure 2c). The mean *J'* was similar for the intermediate locations (i.e., 0.80 ± 0.0) and the far (0.79 ± 0.0) both higher than the near (0.73 ± 0.1), but were not significantly different $(F_{2,60} = 0.28,\ p > 0.05)$. Species evenness was higher for the Mixed lowveld bushveld vegetation than the other vegetation types (Figure 2c). Its value was higher for the intermediate than for the near and far locations.

Simpson's index of diversity (SID) for species did not differ significantly between locations across the combined sites. The SID was higher in the Natal lowveld bushveld vegetation sites than for the other two vegetation types. The SID was equally high in the far and near locations in most villages and low for the intermediate. Overall, across the combined sites, SID was higher for the far locations than the intermediate and near locations, and accompanied values of 0.74 ± 0.0, 0.72 ± 0.0 and 0.63 ± 0.1, respectively. At the vegetation level, the trend for SID was the same as the richness, and the Natal lowveld bushveld having the highest (0.79 ± 0.0), then the Mixed lowveld bushveld (0.73 ± 0.0) and Eastern thorn bushveld (0.56 ± 0.01) in a decreasing order (Figure 2d).

At the individual village level, there were no distinct trends in the species indices as one moved away from the near to the far locations. It was in only one village, Tidbury in the Eastern thorn bushveld, that all three indices increased concurrently from the near to the far location along a decreasing disturbance gradient.

4.1.2. Effects of sampling scale (different plot sizes) on richness, diversity and evenness

All the diversity measures (Table 3) differed significantly between the four plot sizes across the combined sites (p <0.00001). Apart from woody plant species richness that differed significantly between the plot sizes in response to the effects of the location of the species relative to settlements (i.e., near, intermediate, far), *H'*, *J'* and SID were not significantly different between plot sizes from the effects of location (Table 3). Additionally, apart from *J'* which differed significantly between plot sizes under the combined effects of site and location, all the other three diversity measures were not significant (Table 3).

Table 3. The ANOVA output of the plot scales and the effects of other factors such as location and sites (probabilities; ****p <0.00001, ***p <0.0001, **p <0.01, p <0.05, ns – non-significant).

Factors	**df**	**Species diversity measure**			
		F, richness	**F, *H'***	**F, *J'***	**F, SID**
Intercept	1	764.49	682.02	608.83	689.92
Site	9	15.86****	12.28****	7.33****	11.12****
Plot size	3	281.61****	96.14****	36.33****	75.27****
Location	2	19.55****	13.83****	11.50****	15.24****
Site*plot size	27	6.15****	2.00**	1.65*	1.85**
Site*location	18	3.06****	2.44**	2.79**	2.87***
Plot size*location	6	7.88****	1.39^{ns}	1.46^{ns}	0.44^{ns}
Site*plot size*location	54	1.12^{ns}	0.99^{ns}	1.67**	1.39^{ns}

With the exception of the near location for the 1000m² plot where evenness was higher than the intermediate location (Figure 3a), all the diversity measures increased from the near to the far locations and all decreasing concurrently from the 1000m² plot to 1m² plot (Figure 3a). The slope of the 1000m² curves for woody species richness and diversity decreased towards the smaller plot sizes for the cumulative increases in the number of plots (Figure 3b). For Simpson's diversity curve, the highest slope was observed for the 100m² plots and the least for the 1m² (Figure 3b: equation). The slope of the evenness curve was highest for the 100m² plot just as the SID but the least for the 1000m² plot (Figure 3b: equation). Apart from the 1m² plots where the SID decreased with increasing number of plots, all the diversity measures of all plot sizes increased with increasing number of plots (Figure 3b).

The three most abundant species in each plot size within the three locations belonged to 12 plant families. With the exception of the family Combretaceae having three species, the remaining 11 families had one species each. They are Aloaceae, Anacardiaceae, Capparaceae, Celastraceae, Ebenaceae, Euphorbiaceae, Flacourtiaceae, Fabaceae, Ochnaceae, Sapotaceae, and Verbenaceae. *A. karroo* and *C. apiculatum* were present in all plot sizes in high numbers. *A. karroo* occurred frequently in the intermediate locations, at parity with *T. sericea* and *C. apiculatum* in the near and far locations, respectively.

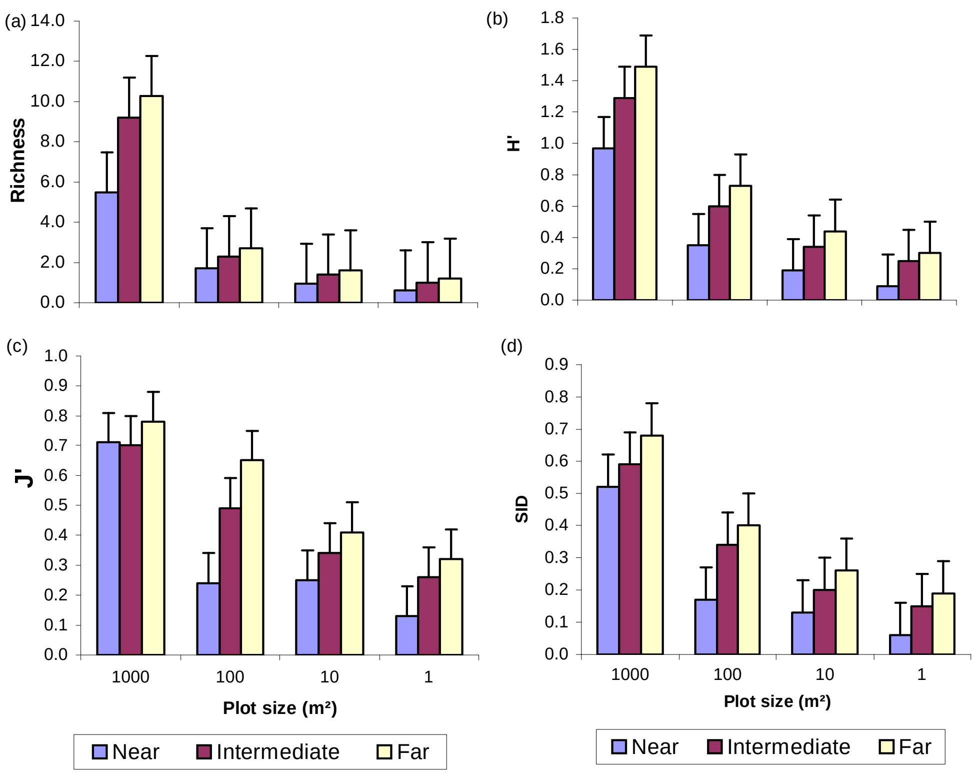

Figure 3a. The measure of (a) species richness, (b) *H'*, (c) *J'* and (d) SID, for different plot sizes in relation to the locations of the woody plant species across the combined sites.

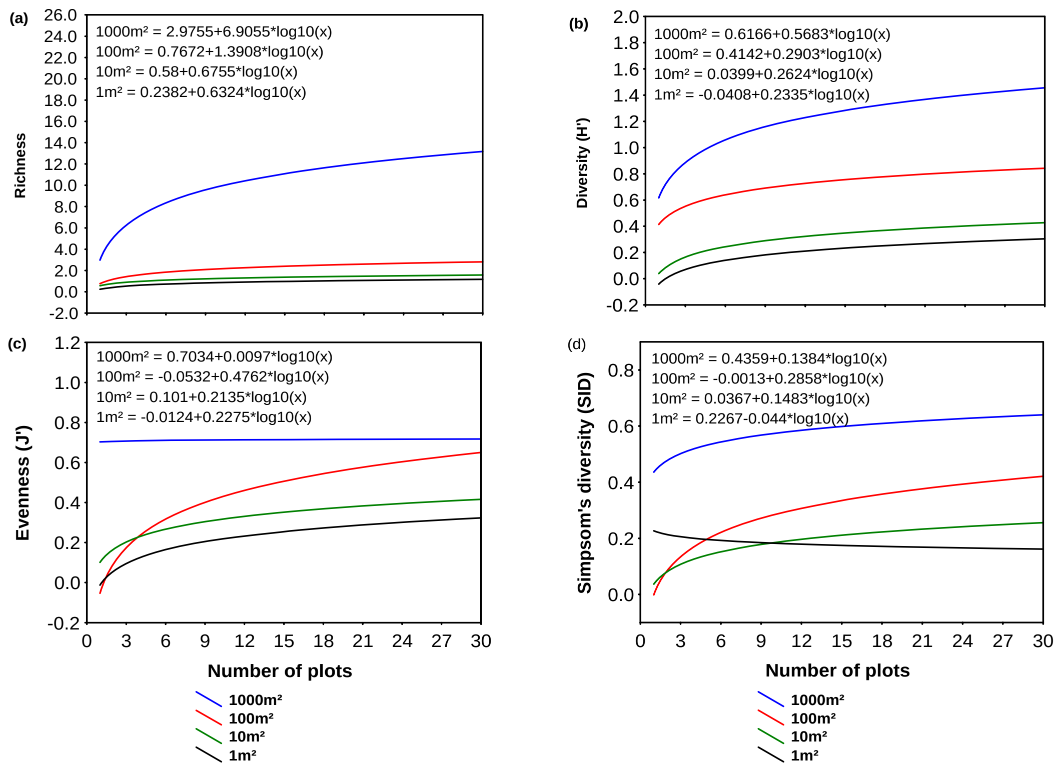

Figure 3b. The spatial scale of sampling plots in relation to (a) species richness, (b) *H'*, (c) *J'* and (d) SID, of the woody plant species across the combined sites based on the plot sizes.

4.1.3. Abundance, density and structure

The MWP sampling yielded 191 woody species, belonging to 42 plant families, having 33 species in the Fabaceae family (subfamilies; Mimosoideae – 17, Papilionoideae – 9, Caesalpinioideae – 7), 19 species in the Rubiaceae family, Celastraceae (16), Anacardiaceae (14), Ebenaceae (13), and the rest (96 species) between the remaining 37 families (General appendix). Generally across the combined sites of all woody plants (trees and seedlings combined), the far locations were denser (311.3 ± 37 plants/ha) than the intermediate (307.7 ± 49.7 plants/ha) and near locations (138.7 ± 24.8 plants/ha). The differences between the locations for plant density were significant $(F_{2,177} = 6.56,\ p < 0.01)$. The tree attributes (i.e., density, dbh and height) across the Eastern thorn bushveld generally increased from the near to far locations (Figure 4). The other vegetation types exhibited variable trends yet far locations were highest in density, dbh and height within the Natal lowveld bushveld (Figure 4). The intermediate locations in the Mixed lowveld bushveld had high tree density and height of trees compared to the other locations (Figure 4).

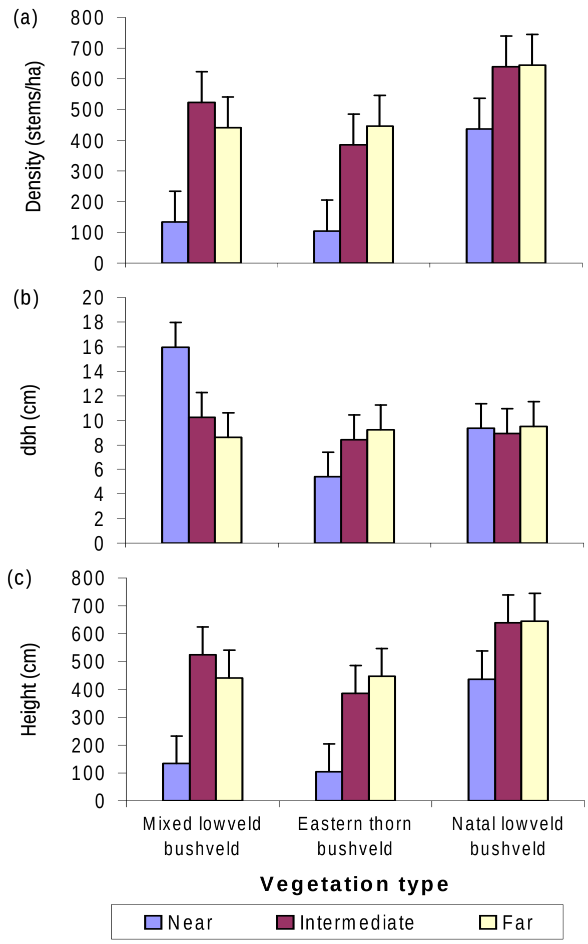

Figure 4. The mean (± SE) (a) density, (b) diameter at breast height (dbh), and (c) height, of trees in the MWPs within the three vegetation types.

The mean density of the trees for the combined sites was highest in the intermediate locations followed by the far and near locations, whilst mean stem diameter decreased from the near to the far locations (Table 4a). The mean height of the trees increased from the near to the far locations across the combined sites and in addition, inversely proportional to the dbh (Table 4a). For seedlings however, stem density increased from the near to the far locations, with dbh and height following the same trend across the combined sites (Table 5a). At the three broad geographical areas represented by the three vegetation types, density and height of trees were highest in the Natal lowveld bushveld, followed by the Mixed lowveld bushveld (Figure 5). The dbh was however highest amongst trees in the Mixed lowveld bushveld, and the least in the Eastern thorn bushveld (Figure 5). The highest density and height of the seedlings were consistent with the trend for the trees with the highest in the Natal lowveld bushveld followed by the Eastern thorn bushveld and the Mixed lowveld bushveld (Figure 5). Details of the density, dbh and height of plants for the ten individual sites are also presented (Table 4a and 5a). Tree density $(F_{2,85}= 5.5)$, dbh $(F_{2,85}= 6)$ and height $(F_{2,85}= 15)$, seedling density $(F_{2,85}= 5.9)$ and height $(F_{2,85}= 5)$ differed significantly (p <0.05) between the vegetation types whilst the dbh of seedlings did not. The effects of woody plant locations on density of trees $(F_{2,85}= 9.2)$ and seedlings $(F_{2,85}= 3.1)$ differed significantly (p <0.05) between the vegetation types. However, location did not affect the dbh and height of both trees, and also the height of seedlings.

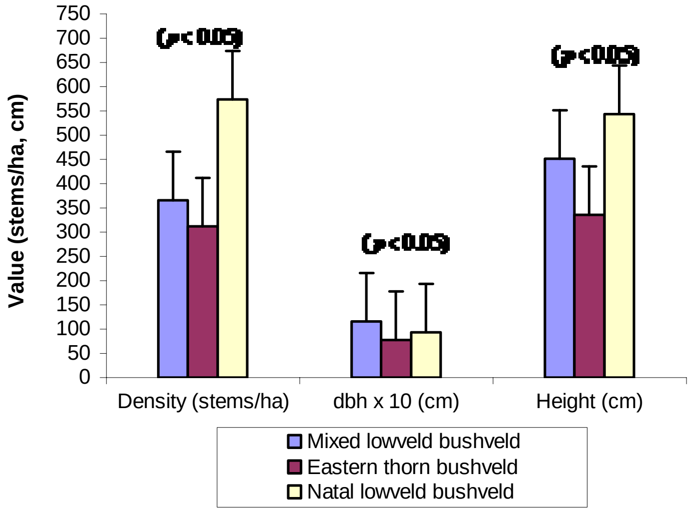

Figure 5. The density, dbh, and height of trees for the Mixed lowveld bushveld, Eastern thorn bushveld, and Natal lowveld bushveld vegetation types.

Trees were denser further away from the settlement towards the end of the woodland vegetation at the majority of the individual sites (Table 4a). These were often accompanied by increases in the height of trees within the locations. The dbh of the stems of trees in two of the villages (i.e., Tidbury and Fairbairn) both in the Eastern thorn bushveld followed an increasing trend in tree density and height from the near to the far locations relative to the settlement area (Table 4a). Generally therefore, the trends in the changes in tree density and tree height either increased or decreased in the majority of the sites, but highly variable, while no clear trend for the stem diameter of the trees was observed (Table 4a). Apart from Thorndale, Fairbairn, and Ntilini (Table 4b), the differences in stem density between the trees in the various locations from near to the far locations were not statistically significant in the remaining seven villages (Table 4b). Stem diameter significantly differed between the locations for trees in Thorndale and Tidbury, and tree heights significantly differed between the locations in Fairbairn only (Table 4b). Overall, there was a significant difference between locations for the density, stem diameter and height of trees for the combined sites (Table 4b).

Table 4a. The mean (± SE) density (stems/ha), dbh (cm) and height (cm) of trees with respect to locations at all ten sites for the 1000m² plots.

Villages (sites)	Density			dbh			Height		
	Near	Inter	Far	Near	Inter	Far	Near	Inter	Far
Thorndale[1]	133.3 (8.8)	1266.7 (307.8)	736.7 (158.8)	16.5 (0.5)	7.1 (0.2)	7.8 (0.2)	556.7 (47.5)	474.1 (12.7)	430.6 (36.6)
Finale A[1]	736.7 (158.8)	490.0 (173.5)	436.7 (68.9)	7.8 (0.2)	9.4 (1.6)	10.1 (1.2)	430.6 (36.6)	402.1 (54.5)	495.5 (13.0)
Mabins A[1]	66.7 (31.8)	203.3 (118.5)	196.7 (59.0)	12.2 (3.3)	9.6 (4.4)	7.6 (0.8)	392.7 (41.6)	482.7 (131.1)	407.3 (60.3)
Willows[1]	90.0 (34.6)	133.3 (103.5)	393.3 (78.4)	22.2 (7.1)	15.0 (4.1)	9.0 (1.6)	510.3 (104.5)	396.7 (25.5)	363.8 (13.3)
Tidbury[2]	150.0 (86.2)	416.7 (144.5)	450.0 (140.0)	4.1 (0.9)	10.1 (1.2)	9.6 (1.0)	342.9 (51.7)	397.2 (75.9)	487.4 (133.1)
Fairbairn[2]	56.7 (17.6)	390.0 (70.2)	450.0 (135.8)	5.2 (1.0)	7.2 (0.7)	8.7 (1.3)	198.8 (11.2)	338.6 (14.2)	343.0 (27.4)
Ntilini[2]	106.7 (37.1)	350.0 (66.6)	440.0 (85.4)	6.8 (0.9)	8.0 (0.4)	9.4 (2.6)	252.8 (55.8)	330.2 (53.7)	333.0 (58.0)
KwaNompondo[3]	83.3 (23.3)	186.7 (75.1)	360.0 (215.5)	12.0 (6.2)	8.4 (0.6)	9.1 (0.3)	317.9 (105.4)	348.2 (66.2)	352.9 (47.1)
KwaMduku[3]	723.3 (148.1)	690.0 (243.4)	843.3 (83.5)	7.3 (0.3)	10.5 (1.6)	9.3 (0.3)	560.1 (49.0)	709.5 (128.0)	670.7 (33.0)
KwaJobe[3]	503.3 (110.5)	1040.0 (201.3)	730.0 (20.8)	8.8 (0.6)	7.9 (0.1)	10.2 (1.5)	606.8 (78.9)	621.5 (24.0)	703.3 (87.0)
Across all the sites	215.7 (43.5)	516.7 (79.8)	503.7 (47.0)	10.8 (1.3)	9.3 (0.7)	9.1 (0.4)	423.8 (30.2)	450.1 (29.1)	458.7 (28.5)

[1]Mixed lowveld bushveld; [2]Eastern thorn bushveld; [3]Natal lowveld bushveld

Table 4b. ANOVA results showing the differences between locations for density, dbh and height of trees at all the individual sites (df = 2), and the combined sites with the effects of location (df = 2), and site x location (df = 18) for the 1000m² plots.

Villages (sites)	Density (stems / ha)		dbh (cm)		Height (cm)	
	F	*p*	F	*p*	F	*p*
Villages (sites)						
Thorndale	8.04	0.020	255.91	0.001	3.29	0.110
Finale A	1.24	0.350	1.29	0.340	2.08	0.210
Mabins A	0.96	0.430	0.50	0.630	0.31	0.740
Willows	4.47	0.060	1.89	0.230	1.51	0.290
Tidbury	1.69	0.260	10.65	0.010	0.61	0.570
Fairbairn	5.69	0.040	3.07	0.120	18.70	0.001
Ntilini	6.80	0.030	0.67	0.550	0.66	0.550
KwaNompondo	1.11	0.390	0.28	0.770	0.06	0.940
KwaMduku	0.22	0.810	2.90	0.130	0.91	0.450
KwaJobe	4.09	0.080	1.50	0.300	0.56	0.600

ANOVA (combined sites)						
Site	10.63	0.001	2.88	0.006	10.54	0.001
Location	18.25	0.001	1.58	0.215	0.78	0.473
Site x location	1.97	0.030	1.88	0.035	0.89	0.583

The trends in the status of young individual trees and seedlings were highly variable in density and height between the locations (Table 5a). With the exceptions of the villages of Willows, KwaNompondo and KwaJobe, no particularly distinct trend was observed in the density of seedlings in the remaining villages (Table 5a). Significant differences between locations were observed for density of seedlings in KwaNompondo, and height structure in Willows (Table 5b). A significant difference in density between locations was recorded across the combined sites, but non-significantly for height of seedlings (Table 5b).

Table 5a. The mean (± SE in parenthesis) density (stems/ha) and height of seedlings (cm), at all the study sites for the 1000m² plots.

Villages (sites)	Density			Height		
	Near	Inter	Far	Near	Inter	Far
Thorndale[1]	36.7	33.3	43.3	19.0	29.3	41.9
	(18.6)	(17.6)	(26.0)	(9.5)	(15.6)	(21.5)
Finale A[1]	13.3	83.3	83.3	10.4	62.4	23.5
	(13.3)	(56.1)	(60.1)	(10.4)	(48.3)	(13.2)
Mabins A[1]	86.7	13.3	146.7	62.9	39.3	49.0
	(51.8)	(8.8)	(111.7)	(26.8)	(22.7)	(21.2)
Willows[1]	3.3	16.7	16.7	11.2	24.7	111.0
	(3.3)	(6.7)	(6.7)	(11.2)	(3.3)	(20.7)
Tidbury[2]	16.7	30.0	216.7	51.3	41.0	100.7
	(12.0)	(20.8)	(98.2)	(37.8)	(22.3)	(26.1)
Fairbairn[2]	20.0	43.3	36.7	30.3	85.2	42.3
	(11.6)	(6.7)	(27.3)	(26.4)	(25.1)	(22.7)
Ntilini[2]	26.7	46.7	33.3	44.5	88.1	129.2
	(3.3)	(27.3)	(8.8)	(17.2)	(45.1)	(34.8)
KwaNompondo[3]	66.7	86.7	206.7	117.7	48.5	63.8
	(23.3)	(46.3)	(23.3)	(75.7)	(16.5)	(7.8)
KwaMduku[3]	176.7	183.3	90.0	67.8	61.7	72.0
	(34.8)	(69.4)	(50.3)	(20.0)	(16.2)	(27.7)
KwaJobe[3]	36.7	63.3	83.3	89.9	91.2	82.5
	(8.8)	(12.0)	(20.3)	(21.1)	(37.0)	(28.2)
Across all the sites	48.3	60.0	95.7	50.5	57.1	71.6
	(10.9)	(12.6)	(19.3)	(10.4)	(8.7)	(8.6)

[1]Mixed lowveld bushveld; [2]Eastern thorn bushveld; [3]Natal lowveld bushveld

Table 5b. ANOVA results for the differences between plots with respect to species attributes of seedlings at all the individual sites (df = 2), and the combined sites with effects of location (df = 2), and site x location (df = 18) for the 1000m² plots.

Villages (sites)	**Density (stems/ha)**		**Height (cm)**	
	F	**p**	**F**	**p**
Thorndale	0.06	0.940	0.50	0.630
Finale A	0.71	0.530	0.84	0.480
Mabins A	0.88	0.460	0.25	0.790
Willows	1.78	0.250	15.64	0.001
Tidbury	1.69	0.260	0.61	0.570
Fairbairn	0.47	0.650	1.36	0.330
Ntilini	0.37	0.700	1.52	0.290
KwaNompondo	5.32	0.040	0.65	0.550
KwaMduku	0.95	0.440	0.06	0.950
KwaJobe	2.60	0.150	0.03	0.970
ANOVA (combined sites)				
Site	3.42	0.002	1.61	0.134
Location	3.80	0.027	1.47	0.238
Site x Location	1.52	0.116	1.09	0.380

4.1.4. The gradient of woody stumps across the species locations relative to settlement areas

The stump and coppice counts decreased from the near to the intermediate locations and then increased in the far locations. Concurrently, species richness of stumps increased from the near to the intermediate locations and decreasing in the far locations. In spite of the trend that was observed, the mean numbers of stumps were not significantly different between the locations $(F_{2,87} = 2.8,\ p > 0.05)$. Additionally, the species richness of the stumps was not significantly different between the locations $(F_{2,87} = 0.1,\ p > 0.05)$. The relative proportion of the number of coppice shoots of harvested stumps in the 1000m² plots were 38.35%, 32.97, and 28.68% for the near, far and intermediate locations, respectively. The differences in mean numbers of the coppice shoots for the 1000m² across the combined sites were 117.5±18.3 shoots (near locations), 101 ± 33.2 (far) and 87.9 ± 23.2 (intermediate), were significant between the locations $(F_{2,87} = 3.4,\ p < 0.05)$. The significance was between the near against the intermediate and far locations (Tukey HSD).

The highest pH and clay values were associated with high K, Ca, exchangeable Mg and total N (Table 6). The two sites notably associated with this trend were Tidbury (Eastern thorn bushveld) and KwaNompondo (Natal lowveld bushveld). The Natal lowveld bushveld area was generally associated with high K, Ca, exchangeable Mg, total N, pH and clay as well as Zn and Mn (Table 6). The Eastern thorn bushveld was next highest in the Zn category whilst the Mixed lowveld bushveld had the least value. Copper levels were generally highest in the Mixed lowveld bushveld having a moderate pH from 4.8 – 5.1. Finale A in the Mixed lowveld bushveld generally had lowest nutrient values, with the highest observed in Tidbury (Eastern thorn bushveld) and KwaNompondo (Natal lowveld bushveld) (Table 6).

Table 6. The mean (± SE) values of analysed soil properties; PO_4, K, Ca, Mg, Zn, Mn, Cu, and N (in mg/L), pH (KCl), and Clay (%) at all the sites.

Sites	PO_4	K	Ca	Mg	Zn	Mn	Cu	N	pH	Clay
Thorndale	7.1	210.4	1182.9	455.1	0.9	41.8	4.4	113.4	4.8	22.8
	(0.4)	(26.8)	(161.2)	(41.0)	(0.1)	(5.6)	(0.5)	(6.3)	(0.1)	(1.6)
Finale A	5.1	151.7	735.8	168.9	0.5	22.7	2.3	77.7	4.8	14.3
	(0.8)	(20.6)	(128.8)	(25.1)	(0.1)	(2.7)	(0.5)	(5.4)	(0.1)	(0.8)
Mabins A	9.6	259.1	1293.7	367.6	1.1	29.3	3.8	143.6	5.3	22.4
	(1.4)	(27.6)	(132.5)	(49.9)	(0.1)	(3.2)	(0.8)	(23.3)	(0.0)	(2.3)
Willows	7.3	237.1	903.1	213.2	0.6	22.0	3.5	80.6	5.1	18.2
	(1.7)	(39.8)	(206.4)	(38.4)	(0.1)	(3.3)	(1.3)	(7.7)	(0.2)	(1.4)
Tidbury	17.2	433.4	3261.4	472.4	2.7	32.9	2.7	266.7	6.1	35.0
	(7.4)	(36.3)	(393.9)	(67.4)	(0.7)	(7.3)	(0.4)	(28.7)	(0.2)	(4.1)
Fairbairn	4.8	292.0	2491.1	417.9	1.2	28.6	2.0	178.9	5.9	30.3
	(1.2)	(27.5)	(495.2)	(50.3)	(0.2)	(2.8)	(0.3)	(14.1)	(0.2)	(3.5)
Ntilini	8.7	290.3	3166.3	440.6	1.3	41.6	2.1	219.0	5.9	29.4
	(1.5)	(41.0)	(445.8)	(28.7)	(0.2)	(6.4)	(0.3)	(11.4)	(0.2)	(4.1)
KwaNompondo	3.9	365.2	3574.7	980.7	1.8	67.9	16.5	348.8	5.2	53.3
	(0.8)	(44.4)	(389.4)	(127.6)	(0.2)	(8.4)	(2.2)	(27.9)	(0.1)	(3.7)
KwaMduku	5.2	237.3	677.7	274.1	6.8	52.0	0.9	121.4	4.8	13.3
	(0.7)	(31.8)	(187.1)	(62.6)	(6.1)	(5.1)	(0.1)	(13.5)	(0.2)	(1.4)
KwaJobe	9.0	196.6	270.8	187.0	1.8	38.7	0.5	83.6	4.4	9.3
	(2.9)	(12.8)	(46.5)	(27.2)	(1.1)	(6.5)	(0.0)	(6.9)	(0.1)	(0.5)

4.2. Constrained ordination (i.e., CCA) of woody plant composition, locations and environmental variables

4.2.1. Test of the significance of canonical axes in relation to environmental variables

The tests on the first three axes of the CCA location were highly significant (p <0.005) and implying that the first axis alone insufficiently explained the variation in the data. For the species data, the first axis (CCA1) explained 4.57% of the variance compared to the combined CCA1, CCA2 and CCA3 that explained 10.9% of the variance. For the species-environment relation, the CCA1 explained 17.2% of the variance with CCA1, CCA2 and CCA3 explaining 41.3% of the variance. All the first three CCA axes showed relatively close and very strong species-environment correlations. The marginal values of the independent effects of the environmental variables on the CCA1 showed that most of the variables were important (i.e., elevation, Ca, pH, total N, clay, K, Cu, slope, exchangeable Mg, rockiness and Mn, in decreasing order of importance), with Ca, pH, total N, Clay, K, and Cu closely correlated as was observed for exchangeable Mg, Rockiness and Mn (Table 7a). However the conditional effects of the variables showed that nine out of the fourteen variables i.e., elevation, total N, Cu, exchangeable Mg, clay, Mn, Ca, slope and K were significant to fit the model for predicting species composition (Table 7a, Figure 6a).

Table 7a. Marginal and conditional effects obtained from the summary of the forward selection for examining the importance of the environmental variables.

Marginal effects			**Conditional effects**				
Variable	Var.N	Lambda1	Variable	Var.N	LambdaA	*p*	F
Elevation	11	0.74	Elevation	11	0.74	0.006	3.76
Ca	3	0.62	N	9	0.55	0.014	2.84
pH	5	0.59	Cu	8	0.48	0.014	2.54
N	9	0.58	Mg	4	0.33	0.006	1.77
Clay	10	0.58	Clay	10	0.37	0.018	2.01
K	2	0.48	Zn	6	0.30	0.138	1.64
Cu	8	0.46	Mn	7	0.29	0.014	1.58
Slope	12	0.44	Ca	3	0.28	0.010	1.56
Mg	4	0.42	Slope	12	0.28	0.006	1.56
Rockiness	13	0.41	pH	5	0.24	0.130	1.29
Mn	7	0.40	PO_4	1	0.24	0.172	1.37
Soil depth	14	0.39	K	2	0.24	0.038	1.35
Zn	6	0.31	Soil depth	14	0.23	0.108	1.27
PO_4	1	0.21	Rockiness	13	0.18	0.432	1.02

4.2.3. Vegetation types, species composition, location and environmental variables

Generally, almost all the species were strongly responsive to some type of an environmental variable. The majority of the plants were distant from the origin and centre of the CCA triplot. Most species were along the first axis of the CCA (Figure 6a). The CCA1 correlated strongly with eight variables (pH, elevation, clay, rockiness, soil depth, potassium, calcium) (Table 7b). CCA2 correlated with elevation, potassium (negatively), manganese (negatively) and nitrogen (negatively). CCA3 correlated with clay, copper, nitrogen and slope. The majority of the species of the Fabaceae family (e.g., the *Acacia* spp.) appeared to be present in copper and zinc rich environments and having expected strong correlation with soil depth. More species particularly correlated with soil depth rather than rockiness. *Aloe thraskii, Rhus pentheri, Ozoroa sphaerocarpa, Euclea schimperi*, *Dombeya rotundifolia*, and

Acacia rogersii strongly correlated with intermediate and far locations and are found at the extreme ends of the CCA1 and CCA2 (Figure 6a). Most thorny woody species may be strongly correlated with elevation and having more than their average abundances in phosphate (PO_4) rich environments (Figure 6a). The *Rhus* and *Grewia* species mostly correlated with high pH, clayey conditions, calcium, potassium and nitrogen, and for which the majority of the intermediate locations were found. The near locations correlated with the presence of manganese and copper whilst far locations appeared to be highly correlated with a mix of nutrients (e.g., Ca, Zn, Cu). The correlations between the near and far locations were strong along CCA2, mostly towards the extreme ends of the CCA axes, having the highest probability of being associated with rare or less common species. Rockiness negatively correlated with soil depth but strongly with elevation and having fewer species associated with it (Figure 6a). The Eastern thorn bushveld vegetation correlated with CCA1 which is mostly associated with elevation and pH (Figure 6b). The Natal lowveld bushveld was also strong along the CCA1 and associated with soil depth and the presence of manganese. The Mixed lowveld bushveld was strong along the CCA2 and having the greater presence of phosphate (PO_4) (Figure 6b).

Table 7b. Correlations of environmental variables with the ordination axes (*r* = -ve / +ve). Correlated values of nutrients with respective CCA axis in bold.

Variable	Axis 1 (CCA1)	Axis 2 (CCA2)	Axis 3 (CCA3)
Phosphate	0.049	0.062	-0.081
Potassium	**0.458**	**-0.504**	0.097
Calcium	**0.689**	-0.290	0.292
Magnesium	0.221	-0.215	0.325
Acidity/alkalinity	**0.693**	-0.265	0.038
Zinc	-0.072	-0.125	-0.024
Exchangeable Manganese	-0.198	**-0.448**	0.267
Copper	-0.040	-0.049	**0.701**
Total Nitrogen	**0.445**	**-0.520**	**0.465**
Clay	**0.499**	-0.289	**0.587**
Elevation	**0.795**	**0.404**	0.215
Slope	0.337	-0.287	**0.419**
Rockiness	**0.537**	-0.044	0.184
Soil depth	-0.411	0.020	-0.363

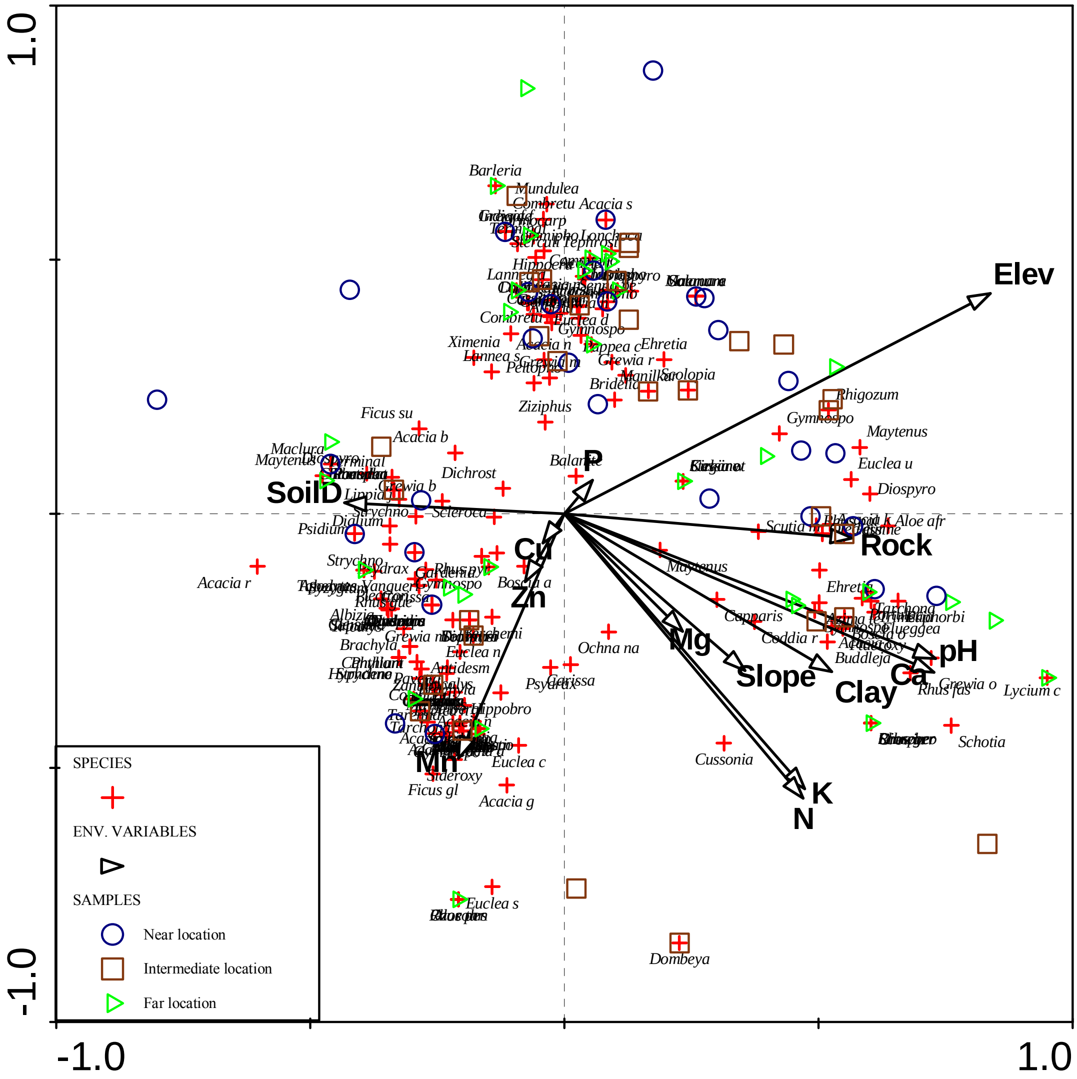

Figure 6a. A triplot (species, samples and environmental variables) from canonical correspondence analysis (CCA) of woody plants data in ten South African villages in communal areas located within savannas. The diagram represents a direct gradient analysis of ordination along axes 1 and 2 (i.e., CCA1 and CCA2).

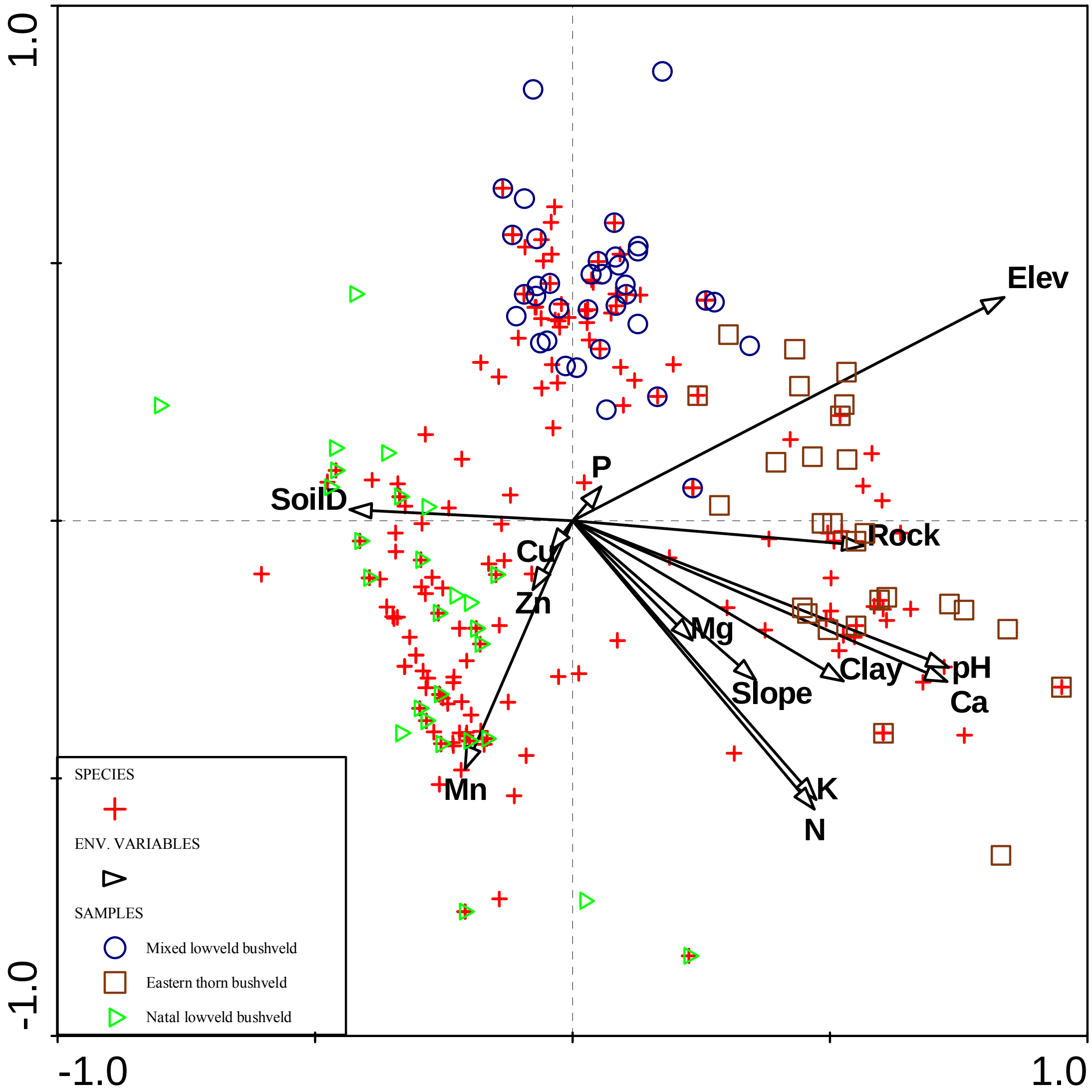

Figure 6b. A triplot derived from canonical correspondence analysis (CCA) of woody plants data along axes 1 and 2 across the villages for understanding the correlations and variations between species, environmental variables, and vegetation types in communal tenure areas.

5. DISCUSSION

5.1. Woody plant diversity along harvesting gradients

The high richness of the woody plant species in the far locations compared to the intermediate and near locations in the majority of the villages indicates that the farther locations of the vegetation of communal tenure areas were less impacted by the human harvesting disturbance, similarly reported for savannas (Shackleton et al., 1994; Sekhwela, 2003; Dembélé et al., 2006), and forest ecosystems (Sagar et al., 2003; Kumar and Ram, 2005). There were instances where the intermediate locations had high richness but too inadequate to be precisely described by the intermediate disturbance hypothesis (IDH) developed for forest ecosystems. The intermediate locations may be characterized by the overlaps between species assemblages, and that anthropogenic disturbance is possibly influencing the presence and abundance of less common species (Lyon and Gross, 2005). Local plant diversity has been found to be maximized under intermediate disturbance (Fédoroff et al., 2005). It is important to note that high species richness in highly disturbed areas can be influenced by the presence of colonizing species (e.g., through bush encroachment), that add to the species diversity and invalidating the IDH in savannas (Palmer et al., 2000). The absence of statistical significance between the intermediate and the far locations explains further the possibility that richness in these two locations will not be very different. As plant communities become less accessible due to distance from the settlement, human impacts become less. The high Shannon diversity for the species in the far locations is supported by the generally high richness, suggesting that the far locations were more species heterogeneous than the intermediate and the near locations (Waite, 2000). As a result, the possibility of having a set of woody plant species belonging to the same species will be less, compared to the intermediate and near locations (e.g., Waite, 2000; Sagar et al., 2003; Kumar and Ram, 2005). The evenness of the plant community will be critical for maintaining individuals of the same species and less frequently occurring species will be redundant in environments with intermediate disturbances. The highest evenness and the second highest richness for the intermediate location is partially the result of the reduction in competition as a result of heavy harvesting, allowing less competitive species to enter, while with low harvesting the opposite would tend to occur.

5.2. Plot sizes, scale and plant community composition

With the decreasing trend of woody plant species richness and diversity from the 1000m² plots to the 1m² plot sizes, the larger size plots of the modified Whittaker plots remain the most efficient of the four plots sizes (Shackleton 2000a; Campbell et al., 2002). In terms of detecting unique species, the 1m² plot size plots have also been found to be little useful compared to the other three plots (Barnett and Stohlgren, 2003). In spite of these results, several factors need to be considered when evaluating the efficiency of these plots (Stohlgren et al., 2000). Less ubiquitous species may contribute to the high richness in the smaller size plots as a result of their wider placement. Other contributing factors for the efficiency of the smaller sized plots may be due to the land use extent and levels of disturbance of large sized trees for the other scales. The analysis of Barnett and Stohlgren (2003) showed that the upper limit of the richness in the smaller size plot is in fact higher than for the 2m x 5m ($10m^2$) and 5m x 20m ($100m^2$) subplots. Bringing the findings of this study and that of Barnett and Stohlgren (2003) together will result in more useful information being collected if the smaller subplots (i.e., $1m^2$) are increased in number over the current ten placements in order to improve the success of detecting unique species and optimizing total richness in the smallest plots. The importance of more small plots is towards the finest understanding of species diversity at local scales (Barnett and Stohlgren, 2003). The overall increases of richness and the diversity indices from the near to the far locations explains the highest chance of finding individual plants belonging to different species in the far locations than in the intermediate and the near locations. This means that the identity or attributes of a randomly selected individual of woody species will be associated with a large degree of uncertainty about its contribution to community diversity (Waite, 2000). The study further showed that the richness and diversity of species in all the plot sizes will increase for any additional plot that is sampled. In spite of this overall observation, it was observed that the evenness of species in the $1000m^2$ plots will either stabilize or decrease with increasing number of sampled plots, explaining an ecological threshold that after a certain level of sampling or scale, species will become less equally abundant in the $1000m^2$ plots. Similarly, Simpson’s index of diversity decreased with increased number of the smallest plots ($1m^2$), providing an indication of having less individuals belonging to different species after a certain number of plots at a local scale has been sampled. The effects of plots sizes and scale may not largely influence highly specieos environments having well represented local harvesting pattern or disturbance gradients in this case. At individual sites, species richness and diversity were not significant between the plot sizes as the overall data was influenced by very strong indices at fewer sites and may not necessarily be influenced by plot sizes.

5.3. Trends in density, dbh, height and stumps of woody plant species

Generally across the combined sites for the overall trees and seedlings, the far locations were denser than the intermediate and near locations and attributed to a decreasing impact of harvesting at distances farther from the settlement. The Combretaceae family of plants were far denser than species in other families and characterized mainly by the *Combretum* and *Terminalia* species. However, the mean density of the trees for the combined sites increased from the near to the intermediate locations and decreasing in the far locations. This trend was similarly observed by Li et al. (2004) in their analysis of anthropogenic disturbance and possibly the result of other forms of disturbance other than plant extraction within the reach of far locations. The trends in density, and height of the seedlings for all the combined sites increased from the near to the far locations in response to the overall species composition and structural trend. On the individual villages / sites basis, the Mixed lowveld bushveld vegetation sites were comparatively denser than the other sites. The greater density of stems of trees in the far and intermediate locations compared to the near locations is inversely related to the gradient of disturbance, and greater numbers of plants encountered with distances far away from the settlement in the majority of the villages (Table 4a). The higher density will favour increased height as a result of greater competition for space. In the majority of the villages however, there was no statistical significant differences between the locations for density, dbh and height structure (Table 4b) and explaining an important attribute of savanna woodlands as not having distinct height canopy strata amongst the trees compared to forests (Scholes and Walker, 1993; Low and Rebelo, 1996; Shackleton, 2000b). Information on the seedlings showed significant differences between the various locations but the trend from the near to the far location was not distinct in the majority of the villages (Table 4a). Location is therefore expected to influence the density of young individual trees and seedlings (Figure 7), whilst their heights may not necessarily depend on the locations relative to settlements. In other studies however, the mean numbers of young individuals and seedlings have been found to increase from high to low disturbance in forest ecosystems (e.g., Kumar and Ham, 2005). The difference is possibly the result of the variation in the response patterns of young individual plants to harvesting disturbance in different ecosystems in addition to abiotic factors.

The coppice shoots of the harvested stumps decreased from the near locations to the intermediate before increasing in the far locations although the near location did not have the highest numbers of stumps (Luoga et al., 2002). This partly meant that a certain harvesting intensity will be required for regeneration of harvested parts of some woody plants to be favoured (Luoga et al., 2004; Martorell and Peters, 2005). Additionally, the less dense nature of the plants in the near locations provides sufficient open spaces between the harvested live stumps to enable the coppice shoots to sufficiently allocate resources (e.g., nutrients) for growth. The intermediate locations, noted to have minimum numbers of stumps produced the least coppice shoots. The numbers of the coppice shoots were significantly different between the locations and more importantly between the near and the other two locations. It was generally observed that both the numbers of stumps and the coppice shoots decreased from the near to intermediate locations against an increasing species richness, from the intermediate locations to the far locations with accompanied decrease in the species richness of the stumps. Increased coppicing of well-adapted species is expected to provide a source of stress to poor competitors.

Figure 7. The recruitment of young individuals of *Sclerocarya birrea* around adult trees (important fruit tree) in the intermediate location of the savanna vegetation relative to the settlement at Willows in the Mixed lowveld bushveld (Photo: DBK Dovie).

5.4. The relationship between vegetation and environmental variables

The majority of the environmental variables including elevation, total N, Cu, exchangeable Mg, clay, Mn, Ca, slope, and K were important and significant along the primary axis of the CCA (Table 7a), expected to most influence the assemblages of plant species (Lepš and Šmilauer, 2003). The addition of any other variable as shown in the CCA did not result in any significant changes in plant community (Lepš and Šmilauer, 2003). The edaphic variables in this study correlated with a number of species, a trend that has been reported in similar studies on forest ecosystems (e.g., Huerta-Martínez et al., 2004; Lyon and Gross, 2005). Three groups of assemblages of the majority of the woody species were obtained from the canonical drawing (Figure 6a) and explaining their extent of correlation with the environmental variables. Most thorny species (e.g., *Ziziphus mucronata*, *Ximenia americana*, *Acacia senegalensis*, *Acacia nilotica*, *Gymnosporia buxifolia*) were largely influenced by elevation. Soil depth correlated negatively with the first CCA axis (Table 7b) having many species, but may not influence plant community organization for the lack of significance showed with the first axis and contrary to the findings of Huerta-Martínez et al.

(2004). In that study soil depth had significant influences on species in forest ecosystems, which may not have the same influence in savanna ecosystems. Thus representing one of numerous differences between those two ecosystems in relation to the links between soil properties and diversity because forest species are more deep-rooted than for savannas. A few species (e.g., *A. thraskii*, *E. schimperi*, and *D. rotundifolia*) by the virtue of their placements on the CCA plot (Figure 6a) provide relevant information for predicting their locally available status in terms of possible threats, recruitment and competition among other factors towards the setting of appropriate criteria for management. At a broader vegetation type level a few nutrients could be said to have influenced the distribution of the species and elevation having a strong presence especially in the Eastern thorn bushveld with pH as a key correlate. The presence of soil nutrients such as high amounts of Zn and Mn with accompanied low pH levels in the Natal lowveld bushveld in general probably favoured the high densities and richness of the woody species. The Eastern thorn bushveld sites had high levels of the majority of the nutrients (e.g., K, Ca, exchangeable Mg, total N) associated with them yet the vegetation was the least species rich. Some of these nutrients in relation to other factors were possibly limiting or inhibiting other growth variables within the vegetation.

6. CONCLUSIONS

The study confirmed that harvesting as a form of vegetation disturbance decreases with increasing distance from human settlements. Woody plant communities in communal tenure areas experiencing low levels of human disturbance are thus likely to have more species than those areas with high levels of disturbances; the latter are invariably closer to the settlements. This disturbance gradient may arise directly through the harvesting of wood and other plant parts, which may ultimately result in the death of plants, or indirectly through subsequent livestock browsing and trampling. Individual young trees and seedlings with greater exposure to harvesting, grazing and trampling, will experience higher mortality than adult trees (Ramírez-Marcial et al., 2001; Neke, 2005; Shackleton et al., 2005). There is also a greater possibility that woody plant communities in less disturbed sites may exhibit higher diversity than in highly impacted environments. Individual seedlings and young plants were found to respond positively to the harvesting disturbance gradients across the 10 sites. The reduction in richness of woody plant species with increasing disturbance is influenced by the allocation of resources for growth, which is often moderated by the magnitude of disturbance (Sagar et al., 2003). For instance, unselective logging or harvesting may result in, for example, decreased total soil N and C and exchangeable Ca (Knoepp and Swank, 1997; Huerta-

Martínez et al., 2004). A complete removal of human disturbance from a system is likely to reduce the populations of some species (those that thrive on disturbance), whilst on the other hand, an extreme disturbance may threaten the long-term sustainability of other species, hence a balance needs to be maintained between these two extremes (Farina, 2000; Martorell and Peters, 2005). This is because although humans are considered to negatively affect many species, this threat may not hold within certain disturbance-intensity ranges or under some disturbance regimes, especially in systems with high natural disturbance, such as savannas (Li et al., 2004; Martorell and Peters, 2005; Kumar and Ram, 2005). This is why scale plays a major role for studying the status of plant biodiversity, with the goal of working towards understanding the dynamics of the factors of change and inherent conditions that are at play in influencing plant community assemblages. The choice of numbers of sampling plots, orientation and types of locations will influence the salient changes observed in plant communities at local scale levels. Plant biodiversity among other factors is the product of vegetation type, disturbance and environmental variables. As exhibited by this study, there are large variations and trends in local level plant biodiversity as a result of the heterogeneity that exists in resource use, availability and in response to various management actions. Landscape characteristics and soil properties are important determinants of the distribution of vegetation (Huerta-Martínez et al., 2004). The links between plant harvesting disturbance regimes, scale of sampling and plant community composition can be important drivers for setting disturbance indices to determine appropriate vegetation management criteria (e.g., enrichment planting). Information on the location of species will also complement other data (e.g. disturbance gradients, disturbance indices) for understanding which woody species need to be managed within specific vegetation formations as sources of biodiversity and NTFPs.

References

Austin, M.P., Pausas, J.G., Nicholls, A.O., 1996. Patterns of tree species richness in relation to environment in southeastern New South Wales, Australia. Australian Journal of Ecology 21, 154-164.

Barnett, D.T., Stohlgren, T.J., 2003. A nested-intensity design for surveying plant density. Biodiversity and Conservation 12(2), 255-278.

Campbell, B.M., Du Toit, R.F., 1994. Vegetation patterns and the influence of small scale farmers in a semi-arid savanna area in Zimbabwe. Kirkia 15, 10-32.

Campbell, P., Comiskey, J., Alonso, A., Dallmeier, F., Nuñez, P., Beltran, H., Baldeon, S., Nauray, W., De La Colina, R., Acurio, L., Udvardy, S., 2002. Modified Whittaker plots as an assessment and monitoring tool for vegetation in a lowland tropical rainforest. Environmental Monitoring and Assessment 76, 19 - 41.

Clinebell II, R.R., Phillips, O.L., Gentry, A.H., Stark, N., Zuring, H., 1995. Prediction of neotropical tree and liana species richness from soil and climatic data. Biodiversity and Conservation 4, 56-90.

Comiskey, J.A., Campbell, P., Alonso, A., Mistry, S., Dallmeier, F., Nuñez, P., Beltran, H., Baldeon, S., Nauray, W., De la Colina, R., Acurio, L., Udvardy, S., 2001. Vegetation Assessment of the Lower Urubamba Region, Peru. In: Dallmeier, F., Alonso, A., Campbell, P. (Eds.), Biodiversity of the Lower Urubamba Region, Peru. SIMAB Series 7, Smithsonian Institution/MAB Biodiversity Program, Washington, DC.

Connell, J.H., 1978. Diversity in tropical rainforests and coral reefs. Science 199, 1302-1310.

Dahlberg, A.C., 2000. Vegetation diversity and change in relation to land use, soil and rainfall – a case study from North-East District, Botswana. Journal of Arid Environments 44, 19-40.

Dai, A., Lamb, P.J., Trenberth, K.E., Hulme, M., Jones, P.D., Xie, P., 2004. The recent Sahel drought is real. International Journal of Climatology 24, 1323-1331.

Dembélé, F., Picard, N., Karembé, M., Birnbaum, P., 2006. Tree vegetation patterns along a gradient of human disturbance in the Sahelian area of Mali. Journal of Arid Environments 64, 284 - 297.

Dovie, D.B.K., 2003. Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa? International Journal of Sustainable Development and World Ecology 10, 247-262.

Dovie, D.B.K., Witkowski, E.T.F., Shackleton, C.M., 2004. The fuelwood crisis in southern Africa – relating fuelwood use to livelihoods in a rural village. GeoJournal 60(2), 123-133.

Dube, O.P., Pickup, G., 2001. Effects of rainfall variability and communal and semi-commercial grazing on land cover in southern African rangelands. Climate Research 17, 215-226.

Fabricius, C., Palmer, A.R., Burger, M., 2002. Landscape diversity in a conservation area and commercial and communal rangeland in Xeric Succulent Thicket, South Africa. Landscape Ecology 17, 531-537.

Farina, A., 2000. The cultural landscape as a model for the integration of ecology and economics. BioScience 50, 313-320.

Fédoroff, É., Ponge, J-F., Dubs, F., Fernández-González, F., Lavelle, P., 2005. Small-scale response of plant species to land use intensification. Agriculture, Ecosystems and Environment 105, 283-290.

Geist, H.J., Lambin, E.F., 2001. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52(2), 143-150.

Givnish, T.J., 1999. On the causes of gradients in tropical tree diversity. Journal of Ecology 87, 193-210.

Heywood, V.H., 1995. Global Biodiversity Assessment. Cambridge University Press, Cambridge.

Huerta-Martínez, F.M., Vázquez-García, J.A., García-Moya, E., López-Mata, L., Vaquera-Huerta, H., 2004. Vegetation ordination at the southern Chihuahuan Desert (San Luis Potosi, Mexico). Plant Ecology 174, 79-87.

Knoepp, J.D., Swank, W.T., 1997. Forest management effects on surface soil carbon and nitrogen. Soil Science Society of America Journal 61, 928-935.

Kumar, A., Ram, J., 2005. Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, central Himalaya. Biodiversity and Conservation 14, 309-331.

Lepš, J., Šmilauer, P., 2003. Multivariate analysis of ecological data using CANOCO. University Press, Cambridge.

Li, J., Loneragan, W.A., Duggin, J.A., Grant C.D., 2004. Issues affecting the measurement of disturbance response patterns in herbaceous vegetation – A test of the intermediate disturbance hypothesis. Plant Ecology 172, 11-26.

Low, A.B., Rebelo, A.G., 1996. Vegetation of South Africa, Lesotho and Swaziland. DEAT, Pretoria.

Luoga, E.J., Witkowski, E.T.F., Balkwill, K., 2002. Harvested and standing wood stocks in protected and communal miombo woodlands of eastern Tanzania. Forest Ecology and Management 164, 15-30.

Luoga, E.J., Witkowski, E.T.F., Balkwill, K., 2004. Regeneration by coppicing (resprouting) of miombo (African savanna) trees in relation to land use. Forest Ecology and Management 189, 23–35.

Lykke, M.A., Fog, B., Madsen, J.E., 1999. Woody vegetation changes in the Sahel of Burkina Faso assessed by means of local knowledge, aerial photos, and botanical investigations. Danish Journal of Geography (Special Issue) 2, 57-68.

Lyon, J., Gross, N.M., 2005. Patterns of plant diversity and plant-environmental relationships across three riparian corridors. Forest Ecology and Management 204, 267-278.

Magurran, A.E., 2004. Measuring biological diversity. Blackwell Publishing, Malden, Oxford, Carleton.

Martorell, C., Peters, E.M., 2005. The measurement of chronic disturbance and its effect on the threatened cactus *Mammillaria pectinifera*. Biological Conservation 124, 199-207.

MathSoft, 1999. S-PLUS 2000 Professional Release 1. MathSoft Inc., Washington DC.

Neke, S.K., 2005. The Regeneration Ecology of Savanna Woodlands in Relation to Human Utilisation. Unpublished PhD Thesis, University of the Witwatersrand, Johannesburg, pp. 244.

Palmer, M.W., McAlister, S.D., Arevalo, J.R., DeCoster, J.K., 2000. Changes in the understorey during 14 years following catastrophic wind throw in two Minnesota forests. Journal of Vegetation Science 11, 841-854.

Pickett, S.T.A., Parker, V.T., 1994. Avoiding the old pitfalls: opportunities in a new discipline. Restoration Ecology 2, 75-79.

Ramírez-Marcial, N., González-Espinosa, M., Williams-Linera, G., 2001. Anthropogenic disturbance and tree diversity in Montane Rain Forests in Chiapas, Mexico. Forest Ecology and Management 154, 311-326.

Sagar, R., Raghubanshi, A.S., Singh, J.S., 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest Ecology and Management 186, 61-71.

Schluter, D., Ricklefs, R.E., 1993. Species diversity: and introduction to the problem. In: Ricklefs, R.E., Schluter, D. (Eds.), Species diversities in ecological communities. Historical and geographical perspectives. University of Chicago Press, Chicago and London, pp. 1-10.

Scholes, R.J., Walker, B.H., 1993. An African savanna: synthesis of the Nylsvley study. Cambridge University Press, Cambridge.

Sekhwela, M.B.M., 2003. Woody vegetation resource changes around selected settlement along aridity gradient in the Kalahari, Botswana. Journal of Arid Environments 54, 469-482.

Shackleton C.M., Griffin N.J., Banks J.M., Mavrandonis J.M., Shackleton S.E., 1994. Community structure and species composition along a disturbance gradient in a communally managed South African savanna. Vegetatio 115, 157-167.

Shackleton, C.M., 2000a. Comparison of plant diversity in protected and communal lands in the Bushbuckridge lowveld savanna, South Africa. Biological Conservation 94, 273-285.

Shackleton, C.M., 2000b. Woodlands in South Africa and the National Forests Act. Southern African Forestry Journal 187, 19-28.
Shackleton, C.M., Guthrie, G., Main, R., 2005. Estimating the potential role of commercial over-harvesting in resource viability: A case study of five useful tree species in South Africa. Land Degradation and Development 16, 273-286.
Sheil, D., 1999. Tropical forest diversity, environmental change and species augmentation: after intermediate disturbance hypothesis. Journal of Vegetation Science 10, 851-860.
Silvertown, J.W., Lovett-Doust, J., 1993. Introduction to Plant Population Biology. Blackwell Scientific Publications, Cambridge.
Singh, S.P., 1998. Chronic disturbance, a principal cause of environmental degradation in developing countries. Environmental Conservation 25, 1-2.
Stohlgren, T.J., Falkner, M.B., Schell, L.D., 1995. A Modified-Whittaker nested vegetation sampling method. Vegetatio 115, 113-121.
Stohlgren, T.J., Owen, A., Lee, M., 2000. Monitoring shifts in plant diversity in response to climate change: a method for landscapes. Biodiversity and Conservation 9, 67-86.
Stuart, F., Chapin III, F.S., Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C., Díaz, S., 2000. Consequences of changing biodiversity. Nature 405, 234-242.
Sullivan, S., 1999. The impacts of people and livestock on topographically diverse open wood- and shrublands in arid north-west Namibia. Global Ecology and Biogeography Letters, Tropical Open Woodlands (Special Issue) 8, 257 - 277.
Tálamo, A., Caziani, S.M., 2003. Variation in woody vegetation among sites with different disturbance histories in the Argentine Chaco. Forest Ecology and Management 184, 79-92.
ter Braak, C.J.F., 2003. Program CANOCO version 4.5A. Centre for Biometry, Wageningen.
Turner, G.M., Romme, W.H., Gardener, R.H., O'Neill, R.V., Kurtz, T.K., 1993. A revised concept of landscape equilibrium: Disturbance and stability of scaled landscapes. Landscape Ecology 8, 213-227.
Waite, S., 2000. Statistical Ecology in Practice. A Guide to Analyzing Environmental and Ecological Field Data. Pearson Education Ltd., Essex.
White, P.S., Pickett, S.T.A., 1985. Natural disturbance and patch dynamics: an introduction. In: Pickett, S.T.A., White, P.S. (Eds.), The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, Orlando, pp. 3-13.
Worm, B., Lotze, H.K., Hillerbrand, H., Sommer, U., 2002. Consumer versus resource control of species diversity and ecosystem functioning. Nature 417, 848-851.

CHAPTER 3

Patterns of total and useful woody plant species richness and diversity along a disturbance gradient in South African savannas

Abstract

Biophysical factors are known to be significant correlates of patterns and processes in plant community structure and composition. It is however emerging that the selection and use of plants by local people fosters new patterns of local biodiversity. The uses come in various forms of non-timber forest products (NTFP). However, several gaps exist in our knowledge about their harvesting and the distribution patterns in locally available woody plant species, in relation to the magnitude and gradient of disturbance, particularly in savannas. Patterns in woody plant communities based on woody species that are used by the local people compared with those that are not used are investigated along harvesting disturbance gradients in South African communal land savannas. Sampling was by modified Whittaker plots to cover several locations and spatial scales of sampling. The species with local uses were identified with the help of local informants. Data were analysed using a combination of descriptive (e.g., means ± SE), univariate (e.g., ANOVA) and multivariate statistics (e.g., PCA). The difference between the mean numbers of useful and non-useful woody species across the 10 study sites was significant, with more useful (135 spp.) than non-useful (56 spp.). The number of woody plant species in total and the number with uses generally increased as one moved away from settlements. The proportion of locally available woody species useful to the local people ranged from over 81% to 100% of total species in individual villages. The eight broad use categories recorded were medicinal, wild edible fruits, fuelwood, housing poles, fencing poles, craft, local beverages and cultural. All the species sampled in Ntilini Village in the Eastern thorn bushveld had at least a single use while the lowest proportion of used species occurred in KwaMduku Village in the Natal lowveld bushveld (81%). The majority of the species used were not restricted to any particular location. Of the 48% of woody species that were identified to be restricted to specific locations, the majority had multiple uses. A relatively constant ratio of 1.0:1.1 was observed between useful species richness and total species richness, the two correlating strongly across the combined sites. The study further showed that the diversity of useful woody species in all locations (near, intermediate and far) from villages of the vegetation increased in locations with less total diversity. Comprehending the harvesting of plants as a function of total biodiversity is an important facet of the cultural landscape, which should help to guide models for managing vegetation that would otherwise be described as marginal or degraded.

Keywords: Biodiversity, communal areas, correlation, cultural landscape, harvesting, NTFPs, vegetation.

1. INTRODUCTION

1.1. The value of biodiversity

The products and services derived from biodiversity are highly diverse with benefits that accrue at the local, national and global levels (Daily, 1997; Salick et al., 1999; Farina, 2000; Scherrer et al., 2005). The benefits may be direct or indirect. People depend largely on plants and animals mostly in the form of non-timber forest products (NTFPs) as part of livelihood strategy and portfolio diversification. This includes the use of animal, plant, fungal, and microbial species for food, fuel, fibre, medicines, and raw materials. The majority of these resources are used directly by households as safety nets and in response to food insecurity and natural disasters (e.g., drought and floods). They are also often traded to supplement household income (e.g., Dovie et al., 2004; Shackleton et al., 2004; Dovie et al., 2005). Beyond such direct uses, biodiversity provides ecological services that are more difficult to precisely value. They are important parts of the processes that regulate the earth's atmospheric, climatic, hydrologic and biogeochemical cycles. Their optional and intrinsic values are considered bequest or legacy for the environment, humans or both (Kunin and Lawton, 1996; UNEP, 1999; Moore et al., 2002). Biodiversity is therefore a major source of natural resources to sustain life, providing a receptacle for unwanted products of human activity, as well as performing functions that maintain ecosystem integrity (UNEP, 1995, 1999; Daily, 1997; Bass et al., 2001). However, there is widespread agreement that environmentally destructive and exploitative practices destabilise biodiversity (Homma, 1992; BSP, 1996; Geist and Lambin, 2001; Ticktin et al., 2002; Shackleton et al., 2005).

1.2. The harvesting of woody plant species

Several studies (e.g., Cunningham and Mbenkum, 1993; Peters, 1996; Shackleton et al., 2004) have reported the extensive extraction and use of plant resources, with many showing negative impacts on individual species populations, although there are exceptions. The products harvested from woody plant species can be grouped into four broad categories (Peters, 1994; Ndangalasi et al., in press), (a) Fruits and seeds, with main plant parts harvested as fruits, nuts and oil seed, (b) Plant exudates, with latex, resin and floral nectar as the harvestable parts, (c) Vegetative structures, from which apical buds, bulbs, leaves, stems, bark and roots are harvested, and (d) Stems, from which poles and sticks are harvested for purposes such as housing, fencing, fuelwood, and wood for local craft materials. Although whole plants or different plant parts are harvested, the origin and use of these products are very different. Their harvests may either produce similar or different impacts that may be beneficial or detrimental to the individual species or the plant community. There are numerous examples of plant resources that are killed by the harvest of vegetative structures (e.g., Peluso, 1983; Peters, 1994, 1996). The actual impact of harvesting depends on the specific growth form or type of resource and amount that is removed. Some plants are typically multi-stemmed and can re-sprout after cutting if sufficient time is allowed between harvests. In contrast, intensive and uncontrolled harvesting can reduce the abundance of particular species especially the solitary ones (Conelly, 1985; Peters, 1990; Homma, 1992; Knoepp and Swank, 1997; Huerta-Martínez et al., 2004), whilst the harvesting of leaves may often have a negligible effect on the plant population being exploited (Kahn, 1988). The harvesting of roots, bulbs and bark usually kills or fatally weakens the exploited tree species and can become severe under high levels of exploitation. Nonetheless harvesting of NTFPs provides the disturbance required for a measurable positive or negative impact on the structure and dynamics of plant populations (Conell, 1978; Siebert and Belsky, 1985; Hall and Bawa, 1993; Ramírez-Marcial et al., 2001; Huerta-Martínez et al., 2004).

1.3. Local plant community composition and harvesting of woody plant species

Harvesting of plants may provide a major source of disturbance, in addition to factors such as livestock grazing, fires, cropping and drought within dryland savannas in the communal areas of South Africa (Cunningham and Mbenkum, 1993; Parsons et al., 1997; Fabricius et al., 2002). Such disturbances are major sources of both temporal and spatial heterogeneity in the structure and dynamics of natural communities, and are often the reasons for the mortality of some individual species (Mooney and Godron, 1983; Silvertown and Lovett-Doust, 1993; Shackleton et al., 2005). Harvesting may ultimately impact ecosystem characteristics such as species diversity and richness and the resultant changes may even reset succession (Mooney and Godron, 1983; White and Picket, 1985; Turner II et al., 1993; Clinebell II et al., 1995; Ramírez-Marcial et al., 2001). At the plant community level, the response patterns of plant species diversity to harvesting, use and disturbance are little studied and particular in dry savannas (e.g., Shackleton et al., 1994; Fabricius et al., 2002). Moreover, perceptions of local people about biodiversity are hardly factored into the understanding of plant community change as part of the cultural landscape (Parsons et al., 1997; Farina, 2000; Geist and Lambin, 2001), more particularly in South Africa. Thus patterns of useful species richness may well be different to that of total species richness. If so, this will have considerable consequences for conservation efforts involving rural communities (e.g., Fabricius et al., 2002). It also brings the debate of redundant species into the realm of local people's use of resources with respect to locally available species and is further complicated by the frequently high disturbance regimes one finds around rural settlements in communal areas of South Africa. This results in a gradient of disturbance radiating out from these settlements. Several studies have indicated that strong correlation exists between community structure and harvesting disturbance gradient. For example Shackleton et al. (1994) and Sekhwela (2003), noted that there is a general increase in species distribution and population size as one moves away from settlements in communal lands.

However, patterns of local species richness in relation to human usage have been little studied. Where they have, it is typically at a single spatial scale (e.g., Salick et al., 1999). But spatially, dynamics of diversity and resource use are crucial in developing sustainable management practices, at both the species and community levels. Therefore, this study sought to examine patterns of total and useful woody plant species richness along such disturbance gradients as a means of understanding the link between useful plants and local biodiversity at the plant community levels. This is important in developing models that recognise biodiversity and anthropogenic influences as interactive components of the cultural landscape (Salick et al., 1999; Farina, 2000; Moore et al., 2002, Scherrer et al., 2005). In pursuance of this objective and with the potential wider applicability of the results, ten different sites in three South African provinces were studied. These were selected to represent the large expected variation across the savanna biome due to differences in culture, language, history, resource availability and use (Cunningham and Davis, 1997).

2. METHODS

2.1. Study site description

The study was carried out in ten villages located mostly in communal areas of the former homelands and within the savanna biome of South Africa (Table 1), in three administrative provinces (Figure 1). The villages (i.e., study sites) were; Thorndale, Finale A, Mabins A and Willows (Limpopo province), Tidbury, Fairbairn and Ntilini (Eastern Cape), and KwaNompondo, KwaMduku and KwaJobe (KwaZulu-Natal).

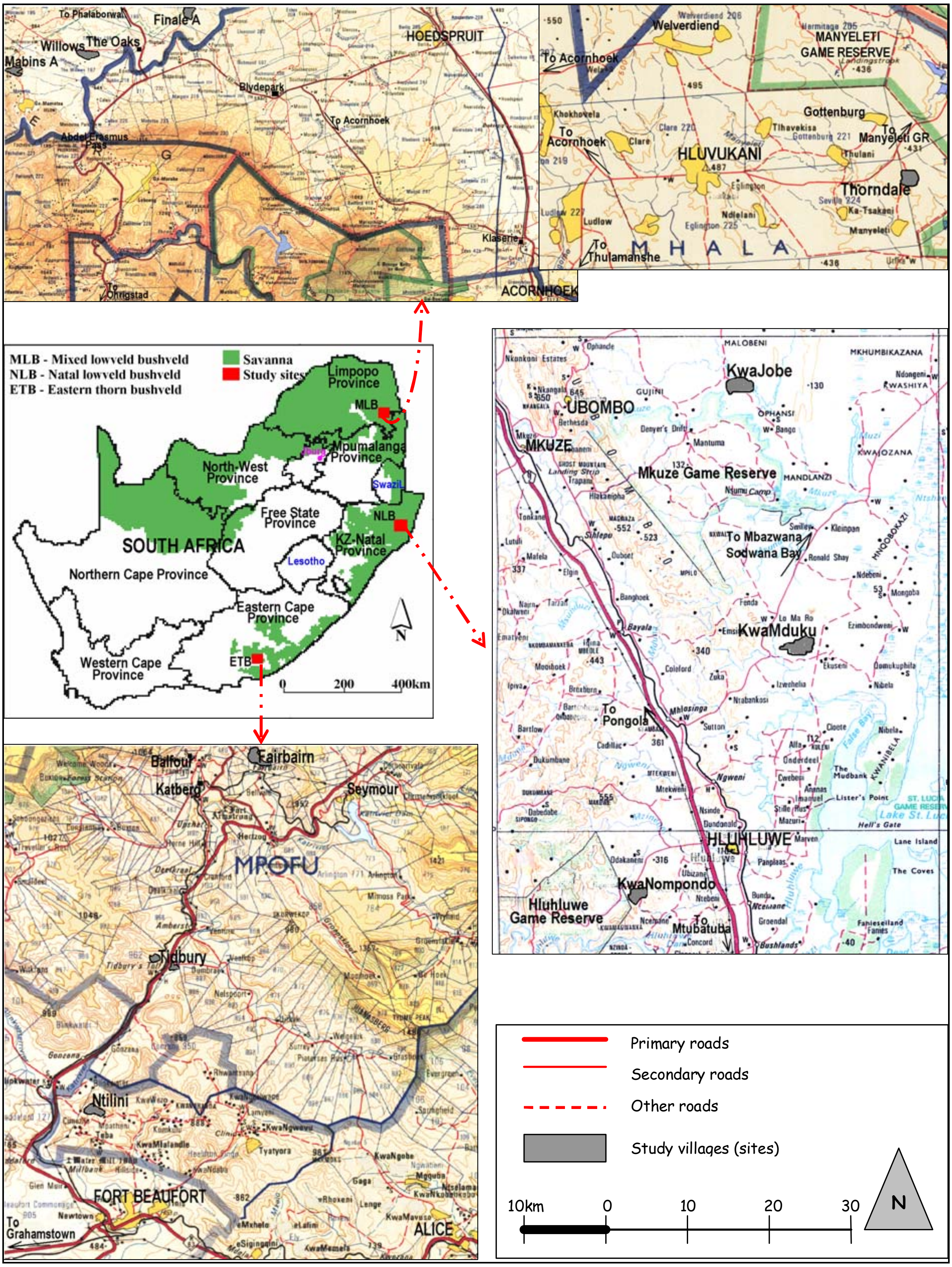

Figure 1. Map of study villages (sites).

Table 1. The summary of location, infrastructure, NTFP extraction and livelihoods, climate and vegetation of all ten study sites (Low and Rebelo, 1996; Shackleton et al., 2002; Twine et al., 2003; Dovie et al., 2005).

Villages (sites)	**Infrastructure**	**NTFP use and other livelihoods**	**Climate and vegetation**
Thorndale (24º39'S: 31º21'E) Finale A (24º19'S: 30º42'E) Mabins A (24º22'S: 30º32'E) Willows (24º21'S: 30º57'E)	The nearest town to Thorndale is Acornhoek (~48 km). Finale A, Mabins A and Willows are several distances away from the nearest urban centre (Hoedspruit, over 60 km). All four villages are characterized by unsealed roads and remote to major highways. The people of Mabins A and Willows do have access to electricity and some community pipe stands whilst Finale A had none of these and Thorndale, with stand pipes that draw water from boreholes by pump. The average residents per household are estimated at seven with Thorndale having the least at 6.3 persons per household. Thorndale and Finale A both have primary schools but not secondary schools whilst Mabins A and Willows have a secondary school each in addition to primary schools.	More households extract a number of resources from the surrounding vegetation than those that do not. All households utilized wooden utensils made of wood from the woodlands, and twig and grass hand brushes. Over 90% of households in all 3 communities of Finale A, Mabins A and Willows utilized fuelwood, wild edible herbs and wild edible fruits, and slightly lower for Thorndale, where some 83% of households that depend on poles from the woodlands for fencing. The proportion of households' ownership of livestock in all four villages ranged from 33.8% to 77.3%. Households in Thorndale embarked on crop production than any of the others.	Mixed lowveld bushveld vegetation with rainfall varying between 450 mm and 1000 mm annually and temperatures averaging 22°C. Dense bush on the uplands, open tree savanna in the bottomlands, dense riverine woodland on river banks, characterized by some *Combretum* spp., *T. sericea, S. madagascariensis,* and *Sclerocarya birrea*, some *Acacia* and *Albizia* spp. in the bottomland are prominent.

Tidbury (32º38'S: 26º39'E) Fairbairn (32º33'S: 26º42'E) Ntilini (32º42'S: 26º36'E)	The nearest urban centre to these villages is Fort Beaufort, which is 13 km from Ntilini, Tidbury (22 km) and Fairbairn (37 km). These villages are not too far away from the main tarred road linking Fort Beaufort but are unsealed. Unemployment is high and a few of the population work on commercial farms. Mean household number ranges between 4.2 – 7.7 persons per household. There is a primary school each in all 3 villages. No clinic in any of the villages. Ntilini has some private connections to electricity with the others having no electricity. There are communal stand pipes in Ntilini and none in the others. There is easy transport access to Ntilini and Tidbury than Fairbairn.	More than averages of eight woodland resources in the form of non-timber forest products are extracted by a single household from the surrounding vegetation for consumption and sale. Fairbairn had the highest mean number of resources utilized per household (9.6), Tidbury (9.5) and Ntilini (8.6). The resources used by the majority of households are fuelwood, wild edible herbs, wild edible fruits, wood for carving, grass hand brushes, poles for fencing and twig hand brushes. Over 90% of households, whether wealthy, poor or intermediate sold at least one type of NTFP. Majority of households owned livestock in all three villages with Tidbury having the least at 65%.	Eastern thorn bushveld vegetation with average annual rainfall under 450 to 900 mm per annum, and temperatures averaging 18°C. Vegetation is characterized by small (less than 3 m tall) *Acacia karroo* trees, *Rhus* spp., *Scutia myrtina, Maytenus polyacantha, and Ehretia rigida.* There is a corresponding change in vegetation along a rainfall gradient, dominated by *Acacia karroo* around Fairbairn (in the valley), to more succulent thicket in the south characterised by *A. karroo* and *Olea europaea*.

KwaJobe (27º36'S: 32º20'E) KwaMduku (27º51'S: 32º24'E) KwaNompondo (28º04'S: 32º10'E)	The Hluhluwe town is the closest urban area to KwaNompondo (12 km away) and KwaMduku (32 km). An estimated 1% of households of these two villages have electricity whilst households with piped water are between 1% and 2%. Majority of households rely on plant biomass for their fuel energy requirements. Primary schools abound in the area and 3 and 1 secondary schools each for KwaNompondo and KwaMduku, respectively. Both villages border nature reserves but residents are not allowed access. The mean numbers of persons per household stand at 7.2 and 7.3 for KwaNompondo and KwaMduku, respectively. KwaJobe, the third site is bordering the Mkuze game reserve and closer to the Jozini town (~40 km). There is no piped water and electricity in KwaJobe. The village has two primary schools and a secondary school.	Almost all the households in the villages of KwaNompondo, and KwaMduku utilized fuelwood, wood for household utensils, housing poles, wild edible fruits, wild edible herbs, twig and grass hand brushes, thatch grasses for roofing, and medicinal plants. About half the population rely on the sale of woodland products and traditional crops and livestock sales to raise cash income for their households. The use of NTFPs in KwaJobe had a similar trend as the other two villages, with over 90% of households depending on a myriad of resources. Additionally, 87% of households owned some livestock or poultry in KwaJobe with majority owning cattle and chicken. More than 70% of households had one member either in permanent or part-time employment.	Located in the Natal lowveld bushveld. Rainfall is 650 mm to 900 mm per year and mostly falling in summer and mean annual temperatures from 10°C to about 30°C. KwaJobe and KwaMduku mimic sub-tropical environments. The vegetation is a mix of scrub and woodlands. The most common tree species include *Acacia tortilis, A. karroo, Berchemia zeyheri, Boscia albitrunca, Euclea schimperi,* and *Spirostachys africana*.

2.2. Sampling

Field sampling was by means of the modified Whittaker plots (MWP) (Stohlgren et al., 1995; Barnett and Stohlgren, 2003). This was to for allow the local examination of woody plant composition and structure at different scales. Following the approach of Shackleton et al. (1994) three transects were located, radiating out from the periphery of each village (Figure 2). Three outer 1000m² MWPs were sampled along each transect. These locations were randomised using a Global Positioning System (GPS) that specified the distances between the plots based on the total distance from the periphery of the settlement to a representative area of the least impacted vegetation surrounding that settlement. Consequently, along each transect there was one MWP close to the village, one far away in relatively unimpacted vegetation, and one intermediate between these two extremes. This design was based on an assumption that harvesting and disturbance intensity decrease with distance away from the settlement and thus defining a disturbance gradient (Shackleton et al., 1994; Huerta-Martínez et al., 2004). The emphasis of the study was not on the autecology of any particular species. The near plot was at least 100m away from the last built area of village and the far locations within a representative stand of the most intact vegetation for that area, but avoiding edge effects due to infrastructure (e.g., roads) and farms.

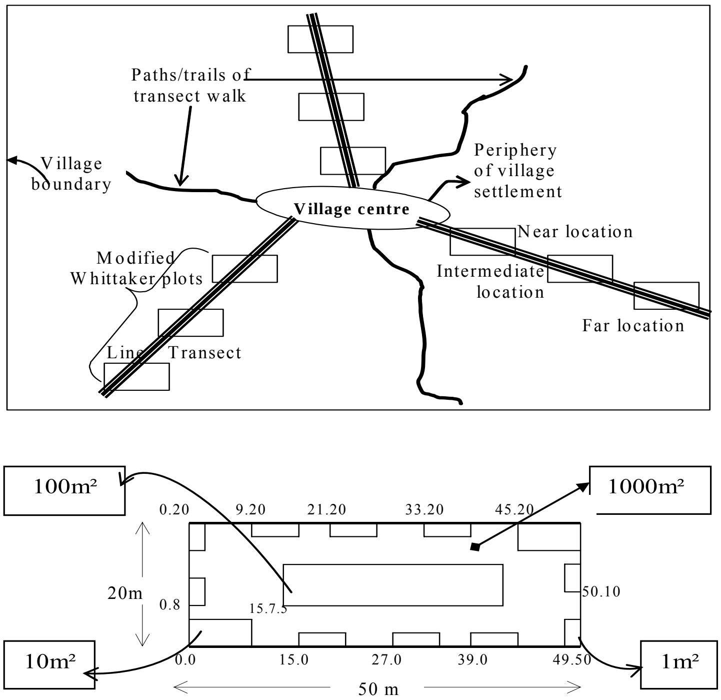

Figure 2. Sampling design showing the placement of modified Whittaker plots (MWP) and paths for transect walks relative to the settlement area (top), and detailed MWP with the placement of the subplots (bottom).

A total of nine plots were sampled in each of the 10 villages (n = 90). Sub-sampling was carried out within a layout involving an outer contiguous overlapping 0.1 ha (20m x 50m) plot (Figure 2; bottom). The three plots along each gradient represented plant community composition and structure and excluding areas that were used by neighbouring villages. Only woody plant species were sampled, and initially identified together with their uses if there was one, with the help of key informants. Voucher specimens were collected and prepared for post field identification and confirmation in the H.E. Moss Herbarium, Witwatersrand University. Village workshops in the form of focus group discussion were used to confirm the uses for the species. In this context, useful species were defined as those species with direct and cultural uses to the local people, and the non-useful species with no such uses. Indirect use values, option and non-use values were not considered.

2.3. Data analysis

Descriptive and univariate statistics were mostly used for analysing data. Species richness (N) represents the total number of species occurring per unit area of the MWPs. The diversity of total and useful species was calculated using the Shannon Wiener diversity index (*H'*). This is defined as $H' = -\sum p_i \ln p_i$ where, $p_i = n_i / N$ is the relative abundance of species, n_i = individual species number, and N = total number of individuals (Magurran, 2004). A Two-Way ANOVA was used to compare the group means of the numbers and diversity of species between the sites, as well as the occurrences of the useful species in relation to MWP locations. The Tukey honest significance difference post – hoc test (Tukey HSD) was used if there was a significant difference. The woody plant species data were first analysed for (i) homogeneity of variance (ii) normality, with a plot of raw residuals that showed a normal distribution, and (iii) the absence of outliers using a plot of the observed species numbers against the raw residual, and thus allowing ANOVA to be performed. No such test was performed on the diversity of non-useful species because the majority of plots had *H'* = 0. A *T* - test for independent samples was used to examine the difference between the overall mean number of useful and non-useful species across the combined sites. A 2 x 3 contingency table was used to test the association between the useful and non-useful species richness within the near, intermediate and far plots at each site. The total species richness (useful and non-useful), was plotted against the useful woody plant richness and diversity at each site, and across all the sites. The Spearman's Rank Correlation (Spearman *r*) was used for establishing the correlation between the total and useful woody plant species richness, and also between the diversity of total woody species versus the diversity of the useful woody plant species and presented in scatterplots. To ascertain the variances between woody species locations based on the presence of useful woody plants, the Principal Component Analysis (PCA) from the program CANOCO Version 4.5A package (ter Braak, 2003) was used. The PCA was selected because the lengths of the gradients of all axes were less than four standard deviations in a Detrended Correspondence Analysis (DCA) diagnostic test. Species that appeared in only one of the three locations were defined as 'rare'. Unless otherwise stated, S-PLUS 2000 program (MathSoft, 1999) was used for all statistics.

3. RESULTS

3.1. The local availability of woody plant species

The occurrence of woody plant species in MWPs relative to the built area of each of the ten villages varied in diversity and richness. Several species occurred more than once in a location and within combinations of locations across the woodlands (near, intermediate, far). There were species that occurred in all three locations as one moved away from the built area of villages. There were 191 woody plant species that were sampled across all the study sites from 42 woody plant families of which there were 33 species in the Fabaceae family, 19 species in the Rubiaceae family, Celastraceae (16), Anacardiaceae (14), Ebenaceae (13), and the rest between the remaining 37 families (Appendix I). Of the 191 species 135 had direct uses (within eight broad use - categories), to the local people (Appendix I). Of the 135 useful woody species, 24.4% had single use, 20.7% had four uses, 15.6% (5 uses), 14.1% (2 uses), 13.4% (6 uses), 9.6% (3 uses), 1.5% (8 uses), and 0.7% had seven uses. All the 17 species in the Mimosoideae subfamily had at least a single use, majority having over three uses. Eleven species from the Celastraceae family had at least a single use, followed by Rutaceae (10), Anacardiaceae (9) and Ebenaceae (8), all having at least a single use (Appendix I). Forty-eight per cent of the total woody species were found to occur in only one of the three locations and not in two or three across the study sites, and thus, were defined as "rare". They belonged mostly to the families Fabaceae (16 species), Ebenaceae (9), Celastraceae (8), Combretaceae (7), and Rubiaceae (7). The majority of the single occurring / plot species were recorded in the intermediate locations (60) followed by the far (56) and the near locations (25). Some of the "rare" species were found at more than one site (e.g., *Lannea schweinfurthii*, *Carissa bispinosa*, *Schotia brachypetala*, *Boscia albitrunca*, *Spirostachys africana*). Most large size diameter woody species had multiple uses. Considering that *Syzygium cordatum* has diameter at breast height (dbh) measuring over 70cm for some individual plants and having six uses. Similarly, *Terminalia sericea* and *Sclerocarya birrea* have dbh of some individuals measuring over 50cm and having five and eight uses, respectively. A number of species also had individuals with dbh of between 30cm and 50cm with uses of mostly four to six. Examples are *S. africana* and *Combretum apiculatum* (6 uses), Acacia *burkei* and *A. nigrescens*, and *Ficus glumosa* (4 uses), *Albizia adianthifolia* (3 uses) and *C. molle* (1 use). Other species that were noted to have moderate dbh from 24cm to 30cm were *Olea europaea*, *Euphorbia tetragona*, *Gymnosporia glaucophylla*, *Carissa bispinosa* and *Lannea schweinfurthii*. Smaller size woody species often occurred close to the human settlements and generally associated with sparse woody vegetation (Figure 3: top left) compared to the farther locations having large size woody species and mostly associated with dense vegetation (Figure 3: bottom). In some savannas with the sparse vegetation, large size trees may be found in what is typically referred to as parkland (Figure 3: top right).

Figure 3. Top left: The physical appearance of woody plants closer to settlements. Top right: Large size trees that can also be found close to settlements in what is typically called the parkland with very little undergrowth resulting from livestock grazing or clearing of vegetation. Bottom: The physiognomy of far locations in relation to size of woody plant species (Photos: DBK Dovie).

In the comparisons between the ten sites, the species richness and the Shannon diversity significantly differed between the sites at the inter-site level, thus $(F_{9,60} = 9.67\ p < 0.001)$ and $(F_{9,60} = 7.86,\ p < 0.001)$, respectively. There was a significant difference between mean useful and non-useful woody plant species richness $(t = 13.69,\ p < 0.0001;\ df = 178)$ with more useful species (17.3 ± 1.5) than non-useful (2.4 ± 0.6) for the 1000m² plot. Useful woody plant species richness significantly differed between the sites $(F_{9,60} = 3.38,\ p = 0.002;\ F_{critical} = 2.04)$ and non-significantly between locations $(F_{2,60} = 1.29,\ p = 0.281;\ F_{critical} = 3.15)$. Useful woody plant diversity was significantly different between the sites $(F_{9,60} = 6.89,\ p < 0.0001;\ F_{critical} = 2.04)$ and locations $(F_{2,60} = 8.69,\ p = 0.0005;\ F_{critical} = 3.15)$ with no significant interactive effects of sites and locations. A chi-square analysis showed that there was no association between the location of woody species in the MWPs and whether or not a species was useful.

3.2. Proportion of useful woody plant species

Of the total woody plant species sampled within the MWP irrespective of locations across all the sites, 70.7% had at least a single use with between 80% and 100% having up to eight uses. The generally noticeable use categories were medicinal, wild edible fruits/seeds, fuelwood, craft, housing pole, fencing pole, beverage, and cultural. All the species that were sampled in Ntilini in the Eastern thorn bushveld were useful to the local people (Table 2). The actual proportion of woody plant species based on the three woody plant species locations in each village that were useful (i.e., several species had overlapped across the locations and were hence counted twice or thrice) varied from over 80% to 100% of the total woody species available locally (Table 2). More than 90% of the total woody species in Thorndale, Willows, Fairbairn and KwaJobe were useful to the local population. The least proportion of the useful species of 80.5% was recorded in KwaMduku (Table 2). It was only in Tidbury (Eastern thorn bushveld) that the proportion of the useful woody plants was highest in the near locations, decreasing towards the far locations. All the woody species recorded in Ntilini were useful, and in Thorndale and Fairbairn, all the woody species in two of the three locations were useful. The highest proportion of useful species across all the sites occurred in the far locations and the least in the intermediate (Table 2).

Table 2. Proportion (%) of the combination of woody plant species used in specific locations relative to the total number of plants present in the locations (the used species may be repetitive in different locations and therefore do not represent single species count data).

Villages (sites)	**Near**	**Intermediate**	**Far**
Thorndale	100.0	95.8	100.0
Finale A	81.8	85.0	95.7
Mabins A	82.4	100.0	87.5
Willows	91.7	100.0	95.7
Tidbury	100.0	90.6	84.4
Fairbairn	100.0	100.0	95.0
Ntilini	100.0	100.0	100.0
KwaNompondo	94.1	80.0	90.6
KwaMduku	82.5	79.7	80.0
KwaJobe	93.1	84.2	100.0
All sites	89.9	89.5	91.4

3.3. Useful versus total woody plant species richness and diversity relative to location

3.3.1. Mixed lowveld bushveld

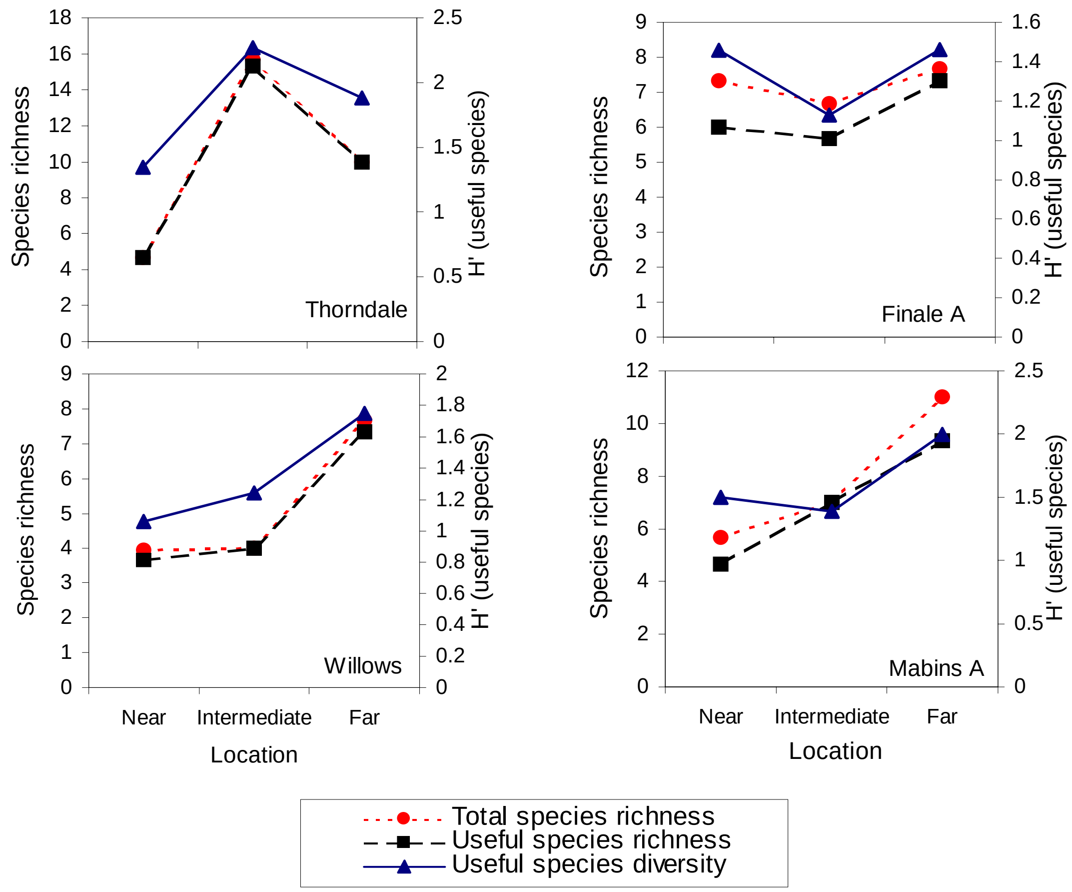

Figure 4a. Influence of location from settlement on mean total woody plant species richness in 1000m² plot, and diversity and useful woody plant species richness in Thorndale, Finale A, Mabins A and Willows.

In Thorndale, useful woody plant species richness and diversity followed the same trend as the total woody plant species richness, increasing from the near to the intermediate locations and decreasing in the far location (Figure 4a: Thorndale). At the other sites (i.e., Finale A, Mabins A, Willows) however the trend was distinct, the useful woody plant species richness and diversity increased with increasing total richness from the near to the far locations (Figure 4a: Finale A, Mabins A, Willows) although not very distinct for Finale A.

3.3.2. Eastern thorn bushveld

In Tidbury, useful woody plant species richness and diversity followed the same trend as the total woody species richness. Thus there was an increase from the near location to the intermediate location, where after it levelled off to the farthest location (Figure 4b: Tidbury). Mixed patterns were observed at Fairbairn. There, the total and useful woody plant species richness increased from the near location through to the farthest location. In contrast, the diversity of useful woody plant species increased from the near to intermediate location and then declined at the far location (Figure 4b: Fairbairn). In Ntilini, the diversity of the useful woody plant species was high in the near location, considerably less in the intermediate location and then high again in the far location. A pattern of total and useful woody plant species richness in Ntilini was similar to that at Tidbury within the same vegetation type (Figure 4b: Ntilini).

3.3.3. Natal lowveld bushveld

In KwaNompondo both useful woody plant species richness and diversity increased from the near to the far locations along with increasing total woody plant species richness (Figure 4b: KwaNompondo). In KwaMduku, all the indices were greatest at the intermediate location and lower at the near and far locations (Figure 4b: KwaMduku). KwaJobe revealed very mixed patterns for the three indices. The useful woody plant richness increased with distance away from human settlement. In comparison the diversity of useful woody plant species declined from the near to the intermediate location, and then increased markedly to the far location. Total richness displayed an inverse trend (Figure 4b: KwaJobe).

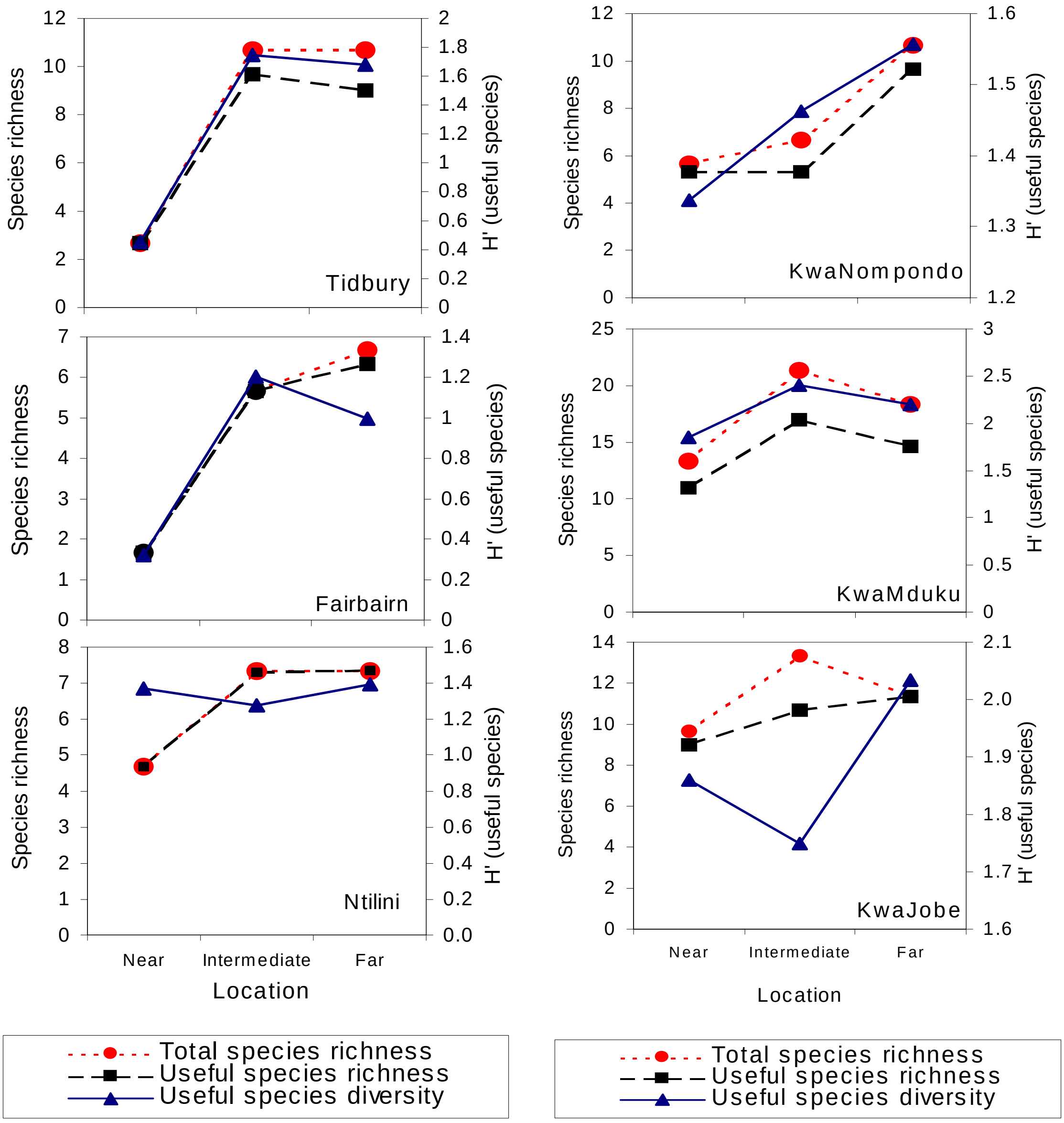

Figure 4b. Influence of distance from settlement on mean total and useful woody plant species richness, and useful diversity in the Eastern thorn and Natal lowveld bushveld vegetation types at the 1000m² plot level.

3.3.4. Combined sites levels

Overall, across all the study sites, the useful woody plant species richness and diversity increased from the near to the far locations, along increasing total species richness (Figure 4c). However, the degree of change between the intermediate and far locations was a lot less than between the near and intermediate locations. The ratio of useful species richness to total species richness remained relatively constant (Figure 4c).

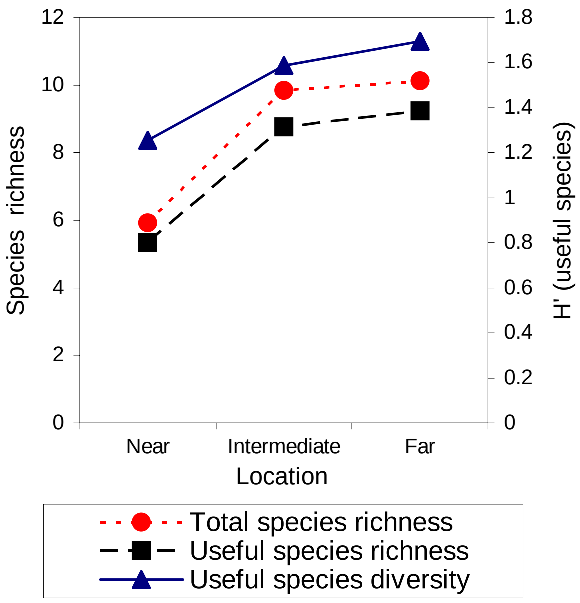

Figure 4c. Relating mean total woody plant species richness to the useful woody plant species richness and diversity across all sites at the 1000m² plot level.

3.4. Correlation between the total and useful woody plant species richness and diversity

3.4.1. Species correlations

The total woody plant species richness at each of the sites correlated positively and significantly with the useful woody plant species richness locally available (Table 3), with the least correlation, but still highly significant (Spearman $r = 0.83$, $p < 0.01$) observed in Finale A in the Mixed lowveld bushveld vegetation (Table 3). Similarly, the diversity of the total woody plant species present at all the individual sites correlated positively and significantly with the diversity of the useful woody plant species (Table 3). The least correlation in diversity was recorded for Finale A (Mixed lowveld bushveld) and KwaNompondo (Natal lowveld bushveld) (Table 3). The correlation that existed between the total and useful woody plant species richness was similar for the Eastern thorn bushveld ($r = 0.98$), Mixed lowveld bushveld ($r = 0.97$) and Natal lowveld bushveld ($r = 0.96$). The correlation was very strong across all the sites ($r = 0.97$, $p < 0.0001$). The correlation between the overall diversity and the useful woody plant species diversity followed the same trend as the woody plant richness in the Eastern thorn bushveld having the highest ($r = 0.99$), Mixed lowveld bushveld ($r = 0.97$) and Natal lowveld bushveld ($r = 0.92$). The correlation between the diversity of total and useful woody plant species across all the study sites was also very high ($r = 0.97$). The actual proportion of useful woody plant species for the pooled sites data negatively and significantly correlated (r = - 0.7, p <0.05) with the total woody plant species locally available (Figure 5).

Table 3. The relationship between (i) the total and useful woody plant species richness, and (ii) diversity of total woody and useful woody plant species at all 10 study sites (*p <0.05, **p <0.001, ***p <0.0001, [pc] perfect correlation with p = 1, with all locally available woody plant species having at least a single use).

Village (site)	**Spearman *r***	
	Species richness	**Diversity (*H'*)**
Thorndale	0.99***	0.99***
Finale A	0.83*	0.73*
Mabins A	0.98***	0.99***
Willows	0.98***	0.99***
Tidbury	0.98***	0.98**
Fairbairn	0.99***	0.99***
Ntilini	1.00 [pc]	1.00[pc]
KwaNompondo	0.96***	0.73*
KwaMduku	0.94**	0.91**
KwaJobe	0.89*	0.90**
Combined sites	0.97***	0.97***

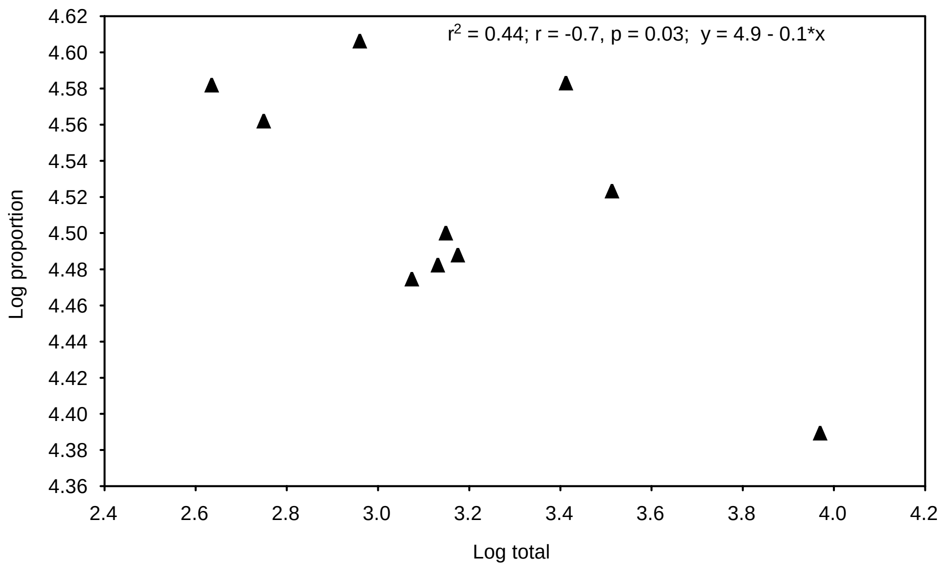

Figure 5. The scatter plot of the proportion of useful species against the mean total woody plant species.

3.4.2. Useful woody plant species variances within sampling plots

The PCA shows that the most important locations in terms of the diversity of the useful woody plant species were those located intermediately to the settlement whilst the near locations were the least important (Figure 6). Axis one (PCA1) explained 72.6% of the variation in woody plant species diversity with respect to locations, and the remaining 27.4% explained by PCA2 and PCA3 (Appendix II). The changes in useful woody plant species was lower for the far locations, compared to the intermediate and near locations (Figure 6). The majority of the useful woody plant species however appeared to be highly distributed concurrently between the three locations. The intermediate location which is much stronger than the others along the first axis has more irregularly distributed species associated with it compared to the near and far plots (Figure 6).

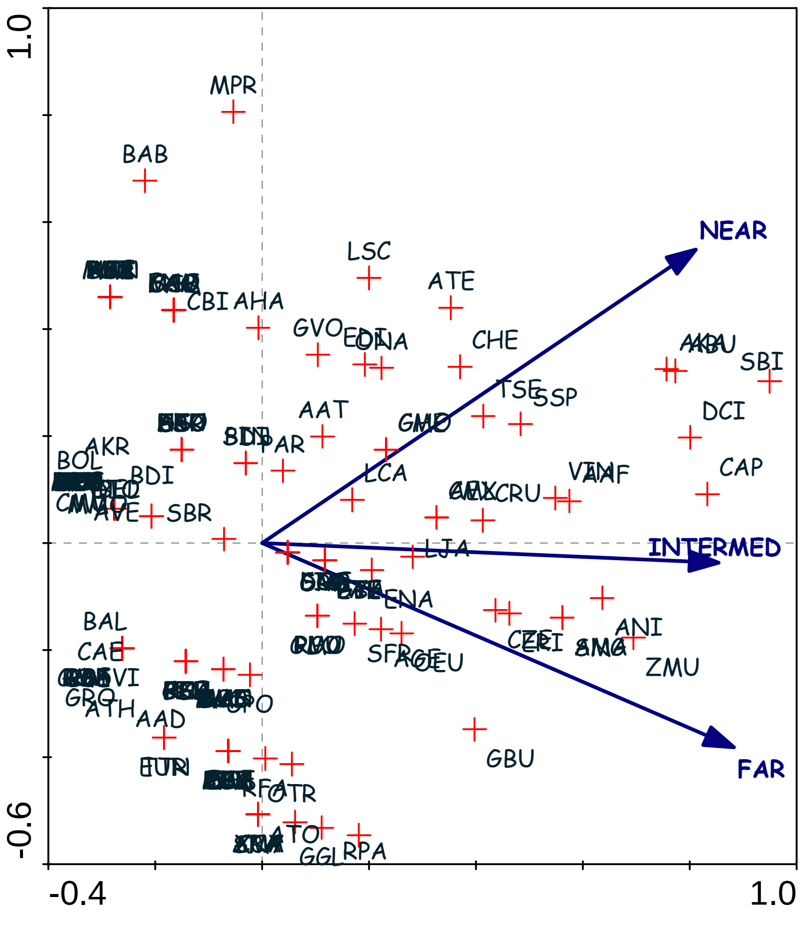

Figure 6. A principal component analysis (PCA) showing the variability among the useful woody plant species (++) with respect to locations from which the species were sampled relative to the human settlement of the villages.

4. DISCUSSION

4.1. Local availability of woody plant species

This chapter shows that marked differences exist in the locally available woody plant species richness and diversity between the villages or sites. The differences are a result of variations in factors of socioeconomic, environmental vegetation origins (Table 1), coupled with the differences in the culture of resource use. Such factors are often influenced by the human political economy through the distribution of socioeconomic resources that often impact plant biodiversity (i.e., negatively or positively). Several studies (e.g., Shackleton et al., 2002; Shackleton et al., 2004; Dovie et al., 2005) have shown that poor rural communities depend largely on the extraction of plant products from savannas. This is in response to the limited available economic options and marginalisation and as natural safety nets to fight hunger, unemployment and poverty. The eight broad categories of uses identified in the field, pertaining to the use of plant parts directly relate to the population, regeneration and recruitment dynamics of locally available woody species. These may have seasonal, short and long term effects on total biodiversity. This is because not all species are used and although over 70% of the 191 sampled were used and already being impacted on their own, other non-used species may also be impacted (Ticktin, 2005), for example uses of woody species as fuelwood will impact on the species themselves and others, becoming more severe when preferred species are depleted and others have to be used. The continuous and uncontrolled harvesting of NTFPs will possibly introduce ecological community disturbance and heterogeneity that is beneficial or detrimental to other species (Arnold and Ruiz Pérez, 2001; Hall et al., 2003; Nakazono et al., 2004). However, in extreme cases of resource use that involve the clearing of vegetation, patches and habitat fragmentation may result. Where the usefulness of the same woody species to humans coincides with its functional value to biodiversity (e.g., as indicator species) a conflict of benefits will possibly result in a major disturbance. The results further show that the patterns of the diversity of useful woody plant species were influenced by location. It is therefore possible to infer that there were still diverse species locally available within some communal areas of South Africa of which a number of such species will have human uses and yet important in plant community functioning. Shackleton et al. (2005) have similarly observed this for selected species based on population parameters of *C. collinum* and *S. birrea*. This however may not suggest that plant resource use in communal areas is sustainable but the culture of plant selection, the type of use, plant parts harvested, season and methods of harvesting are key determinants of sustainability (Peters, 1994; Arnold and Ruiz Pérez, 2001; Ticktin et al., 2002; Dovie, 2003).

4.2. Proximity, useful woody plant species richness and diversity

The woody plant species richness and diversity were greatest at distances furthest from human settlement compared to nearby locations. Immediate anthropogenic factors therefore will play major roles as drivers of change to plant community structure and composition based on the location of species. This has been previously observed within savannas (e.g., Shackleton et al., 1994; Sekhwela, 2003). The concurrent effects of combined "sites and locations" on species diversity, and not species richness, underscores the role of human impacts in altering patterns of species diversity. The resultant more plants with uses than without uses to the local people represent local people's attempts to optimise benefits from woody plant species having no implicit direct financial costs to them. As a result, diverse species were harvested from across the woodlands and not limited to any particular locations (Table 2). Thorndale and KwaMduku were more specieos than the other sites and may suggest low levels of disturbance possibly due to either low levels of harvesting and, or demographic factors.

The only site at which all species were useful to the local population was Ntilini (Figure 4b) within the Eastern thorn bushveld vegetation and was also one of the villages with the lowest species richness which could represent signs of over-harvesting. Useful woody plant species richness and diversity within three sites (i.e., Thorndale, Tidbury and KwaMduku) decreased with decreasing total richness (Figure 4a,b) that can be linked to generic correlates such as plant community assemblages, soil properties and competition, other than harvesting from the far locations with greatest useful species richness. In two other villages, mixed trends were recorded, whilst there was a decrease in the diversity of the useful woody plant species in the far locality in Fairbairn (Figure 4b). In KwaJobe, the diversity and richness of the useful woody plant species increased against a declining total species richness from the near to the far location (Figure 4b). Generally however, useful woody plant species richness and diversity increased with increasing total woody plants richness across all sites (Figure 4c). The actual proportions of the useful species relative to the total woody plant species locally available decreased from the near to the intermediate locations and then increased in the far location, also having the highest proportion of the useful species. The far locations were species rich and hence local people would have a wide variety of species to choose from for their uses, whilst the next highest proportion in the near plots will represent attempts to use whatever was present in addition to easy access. A correlation established between the total and useful woody plant species richness and useful diversity indicated that increased total woody plant richness will result in increased useful woody plant species richness and diversity (Table 3). The strong significant negative correlation between the proportion of the useful species and the mean total of the woody plant species across the combined sites (Figure 5), implies that in the environments with high total number of species, only a few proportion could be utilised. On the contrary, there will be more pressure put when small numbers of the total species are present. This is contrary to the study of Salick et al. (1999) for instance where high proportions were utilised. This might be due to the differences in the number of uses that a species may be subjected to as multiple use woody species may result in the fewer number of species used. Secondly, local knowledge and skill about resource use will contribute to high numbers of species used. Thirdly, the characteristics of resource users and livelihoods options such as shifting cultivation and slash and burn agriculture in forest ecosystems may differ for savannas hence the difference in the findings. Conservation wise, it will be important therefore to focus attention on the ecologically functional species and those useful to humans rather than putting all efforts into conserving all species within an environment. The principal component analysis (PCA, Figure 6) showed that there was little variation in the distribution of the useful species associated with the far and intermediate locations and both can be equally prone to overexploitation if left without any conscious management practices although they may be more specieos than the near locations.

4.3. Implications of the findings for communal area savanna management

The knowledge on useful and non-useful woody plant species will lead to informed decision about the productivity, threats to, and importance of ecological communities in defining appropriate criteria for management. The least and commonly occurring species exhibited differences in the levels at which vegetation types will have to respond to harvesting pressure that can suggest appropriate alternatives to managing the differences in response to harvesting. For example Neke (2005) suggests that woody species other than live resprouters show little harvesting impact and might be favourable as alternative fuelwood source. It implies that disturbances to woody plant communities need to be managed from different “harvesting-species attribute” scenarios to be able to optimise good results. The establishment of communal woodlands of endemic and indigenous species origin based on the principle of conservancies will provide different uses to the local people other than the traditional use for fuelwood that communal woodlots often target. At the individual household level, the planting of wild edible fruit trees may be encouraged but may however be considered as a new experience, requiring social adjustments by households. The extraction of woody plant species needs to be viewed as a function of total biodiversity, in turn as part of the cultural landscape and associated local scale information incorporated into vegetation and ecosystem-based management. The analysis on the proportion of woody plant species that are utilised and the overall woody species locally present could suggest relevant information on highly sought after species (i.e., species having multiple uses). It was noted that large sized woody species coincided with multiple NTFP uses (e.g., *S. cordatum, T. sericea*) with *S. birrea* having eight uses and worth exploring for the precise relationships and links. Hence there is the need to capture such dynamics when planning the management of woody plant species especially through communal conservancies that is currently absent in all the study sites. The culture of local people consciously managing local available useful species other than for medicinal purposes is still far from achieving.

5. CONCLUSIONS

The study shows that useful woody species richness and diversity are a direct function of total woody species richness. The numbers of useful woody plant species were directly related to the total woody species diversity of each savanna ecosystem. In addition, their diversity and species richness was higher in more distant areas from human settlements. The patterns of diversity and woody plant richness of useful species have strong and positive correlations with total woody species diversity and richness. The actual proportion of useful species was inversely related to the total woody plant species locally available. The occurrences of useful species were not restricted to any particular vegetation formation within the vegetation. Species that have multiple uses and yet were least prevalent across the vegetation types were possibly facing unknown threats that need to be understood and dealt with. Sampling scale is an important measure for determining the extent to which woody plant species respond to harvesting disturbance and the richness and diversity of species that are impacted positively or negatively. A better understanding of spatial scale will therefore provide specific clues, such as the limits for setting management criteria for communal rangelands, including the types of landscape and areas to cover, as well as operational costs that may be involved. The study further suggests that large sized species are likely to be more frequently targeted for selection for NTFP experimentation and use than those of small size and as a result, will provide a worthwhile guide for local management of woody species. Understanding the extraction of plant resources as a component of total biodiversity in savannas will result in more conscious and realistic conservation targets and aid in efforts to conserve them through the assessment and monitoring of all vegetation formations, structure and composition.

Appendix I. List of total woody plant species sampled across all the study sites with the three broad vegetation types using modified Whittaker plots, the family of plants they belong to and their uses locally within the study sites.

Species names	Family	Medicine	Fruit	Fuelwood	Craft	H-Poles	Fencing	Culture	Beverage	No. of uses
Barleria albostellata	Acanthaceae									0
Aloe africana	Aloaceae	√	√	√						3
Aloe thraskii	Aloaceae	√						√		2
Lannea discolor	Anacardiaceae	√	√							2
Lannea schweinfurthii	Anacardiaceae	√	√	√		√				4
Ozoroa sphaerocarpa	Anacardiaceae			√						1
Rhus fastigiata	Anacardiaceae	√	√	√			√			4
Rhus gueinzii	Anacardiaceae	√	√	√	√		√			5
Rhus leptodictya	Anacardiaceae		√	√						2
Rhus lucida	Anacardiaceae		√	√			√			3
Rhus pallens	Anacardiaceae			√						1
Sclerocarya birrea	Anacardiaceae	√	√	√	√	√	√	√	√	8
Oxyanthus latifolius	Anacardiaceae									0
Rhus gerrardii	Anacardiaceae									0
Rhus natalensis	Anacardiaceae									0
Rhus pentheri	Anacardiaceae									0
Rhus pyroides	Anacardiaceae									0
Monanthotaxis caffra	Annonaceae	√								1
Uvaria caffra	Annonaceae		√							1
Steganotaenia araliacea	Apiaceae									0
Carissa bispinosa	Apocynaceae		√				√			2
Carissa tetramera	Apocynaceae		√	√			√			3
Tabernaemontana ventricosa	Apocynaceae									0
Cussonia paniculata	Araliaceae	√	√	√	√					4
Cussonia arenicola	Araliaceae									0
Hyphaene coriacea	Arecaceae	√	√		√				√	4
Brachylaena discolor	Asteraceae	√								1
Brachylaena elliptica	Asteraceae			√						1
Tarchonanthus camphoratus	Asteraceae									0
Tarchonanthus trilobus	Asteraceae									0

Species names	Family	Medicine	Fruit	Fuelwood	Craft	H-Poles	Fencing	Culture	Beverage	No. of uses
Balanites maughamii	Balanitaceae	√		√	√	√	√			5
Rhigozum obovata	Bignoniaceae	√								1
Ehretia amoena	Boraginaceae		√	√						2
Ehretia rigida	Boraginaceae	√	√	√	√	√	√			6
Buddleja saligna	Buddlejaceae			√		√				2
Commiphora mollis	Burseraceae		√	√	√					3
Commiphora pyracanthoides	Burseraceae		√							1
Commiphora glandulosa	Burseraceae									0
Commiphora marlothii	Burseraceae									0
Boscia albitrunca	Capparaceae	√		√						2
Boscia oleoides	Capparaceae	√								1
Capparis tomentosa	Capparaceae	√								1
Maerua angolensis	Capparaceae	√								1
Cadaba natalensis	Capparaceae									0
Maerua caffra	Capparaceae									0
Cassine aethiopica	Celastraceae	√	√	√		√				4
Cassine peragua	Celastraceae	√	√	√			√			4
Cassine transvaalensis	Celastraceae	√	√	√		√				4
Gymnosporia buxifolia	Celastraceae	√	√	√			√			4
Gymnosporia glaucophylla	Celastraceae	√								1
Gymnosporia polyacantha	Celastraceae			√			√			2
Gymnosporia senegalensis	Celastraceae	√	√	√	√					4
Maytenus acuminata	Celastraceae	√								1
Maytenus heterophylla	Celastraceae	√		√	√		√			4
Maytenus procumbens	Celastraceae	√								1
Maytenus undata	Celastraceae		√	√	√					3
Elaeodendron transvaalense	Celastraceae									0
Gymnosporia maranguensis	Celastraceae									0
Gymnosporia mossambicensis	Celastraceae									0
Hippocratea longipetiolata	Celastraceae									0
Mystroxylon aethiopicum	Celastraceae									0
Combretum apiculatum	Combretaceae	√	√	√	√	√	√			6
Combretum collinum	Combretaceae	√		√	√	√				4

Species names	Family	Medicine	Fruit	Fuelwood	Craft	H-Poles	Fencing	Culture	Beverage	No. of uses
Combretum hereroense	Combretaceae	√	√	√	√	√			√	6
Combretum imberbe	Combretaceae	√	√	√	√	√	√			6
Combretum molle	Combretaceae	√								1
Combretum zeyheri	Combretaceae			√			√			2
Pteleopsis myrtifolia	Combretaceae			√		√	√			3
Terminalia sericea	Combretaceae	√		√	√	√	√			5
Terminalia prunioides	Combretaceae									0
Diospyros dichrophylla	Ebenaceae							√		1
Diospyros lycioides	Ebenaceae			√						1
Diospyros mespiliformis	Ebenaceae	√	√	√	√	√				5
Dombeya rotundifolia	Ebenaceae	√	√	√	√	√			√	6
Euclea crispa	Ebenaceae	√	√	√	√	√				5
Euclea divinorum	Ebenaceae	√	√	√	√		√			5
Euclea natalensis	Ebenaceae	√	√	√		√				4
Euclea schimperi	Ebenaceae		√							1
Euclea undulata	Ebenaceae	√								1
Diospyros alata	Ebenaceae									0
Diospyros simii	Ebenaceae									0
Diospyros villosa	Ebenaceae									0
Euclea natalensis var. obovata	Ebenaceae									0
Euclea natalensis var. rotundifolia	Ebenaceae									0
Antidesma venosum	Euphorbiaceae	√	√	√	√	√	√			6
Cleistanthus schlechteri	Euphorbiaceae			√	√					2
Euphorbia tetragona	Euphorbiaceae	√		√			√			3
Phyllanthus reticulatus	Euphorbiaceae	√		√	√	√				4
Sapium integerrimum	Euphorbiaceae	√								1
Spirostachys africana	Euphorbiaceae	√	√	√	√	√	√			6
Bridelia mollis	Euphorbiaceae									0
Jatropha zeyheri	Euphorbiaceae									0
Cassia abbreviata	Fabaceae	√		√						2
Dialium schlechteri	Fabaceae	√	√	√						3
Peltophorum africanum	Fabaceae	√	√	√	√	√	√	√	√	8
Schotia afra	Fabaceae	√	√	√			√	√		5

Species names	Family	Medicine	Fruit	Fuelwood	Craft	H-Poles	Fencing	Culture	Beverage	No. of uses
Schotia brachypetala	Fabaceae	√	√	√	√	√	√			6
Schrebera alata	Fabaceae									0
Senna petersiana	Fabaceae									0
Dalbergia melanoxylon	Fabaceae	√		√	√					3
Mundulea sericea	Fabaceae	√								1
Ormocarpum trichocarpum	Fabaceae	√		√	√	√				4
Philenoptera violacea	Fabaceae	√		√	√	√			√	5
Pterocarpus rotundifolius	Fabaceae	√	√	√	√	√	√			6
Tephrosia pondoensis	Fabaceae					√				1
Dalbergia obovata	Fabaceae									0
Indigofera sp.	Fabaceae									0
Tephrosia cordata	Fabaceae									0
Acacia ataxacantha	Fabaceae	√	√	√	√	√	√			6
Acacia borleae	Fabaceae	√		√	√	√	√	√		6
Acacia burkei	Fabaceae	√	√	√			√			4
Acacia caffra	Fabaceae	√	√	√	√	√	√			6
Acacia exuvialis	Fabaceae	√		√	√		√			4
Acacia gerrardii	Fabaceae	√	√	√			√		√	5
Acacia karroo	Fabaceae	√	√	√	√	√	√			6
Acacia kraussiana	Fabaceae	√		√						2
Acacia natalitia	Fabaceae			√			√			2
Acacia nigrescens	Fabaceae	√		√		√	√			4
Acacia nilotica	Fabaceae	√	√	√	√	√	√			6
Acacia robusta	Fabaceae	√		√		√	√			4
Acacia senegal	Fabaceae			√						1
Acacia tortilis	Fabaceae			√			√			2
Albizia adianthifolia	Fabaceae	√	√	√						3
Albizia harveyi	Fabaceae	√		√	√	√	√			5
Dichrostachys cinerea	Fabaceae	√		√	√	√	√			5
Dovyalis longispina	Flacourtiaceae		√							1
Dovyalis rotundifolia	Flacourtiaceae		√							1
Scolopia zeyheri	Flacourtiaceae		√	√						2
Trimeria trinervis	Flacourtiaceae		√							1

Species names	Family	Medicine	Fruit	Fuelwood	Craft	H-Poles	Fencing	Culture	Beverage	No. of uses
Flueggea verrucosa	Flacourtiaceae									0
Apodytes dimidiata	Icacinaceae									0
Kirkia wilmsii	Kirkiaceae									0
Hibiscus zeyheri	Malvaceae									0
Ficus glumosa	Moraceae	√	√	√		√				4
Ficus stuhlmannii	Moraceae	√	√	√	√	√				5
Ficus sur	Moraceae	√	√	√	√	√				5
Maclura africana	Moraceae									0
Psidium guajava	Myrtaceae	√	√	√		√				4
Syzygium cordatum	Myrtaceae	√	√	√	√	√	√			6
Ochna natalitia	Ochnaceae		√	√	√	√		√		5
Ximenia caffra	Olacaceae	√	√	√		√	√			5
Olea europaea	Oleaceae	√	√	√	√	√	√	√		7
Portulacaria afra	Portulacaceae	√	√							2
Portulaca africana	Portulacaceae									0
Ptaeroxylon obliquum	Ptaeroxylaceae	√		√		√	√			4
Berchemia discolor	Rhamnaceae	√	√	√	√		√			5
Berchemia zeyheri	Rhamnaceae	√	√	√	√	√			√	6
Scutia myrtina	Rhamnaceae	√	√	√						3
Ziziphus mucronata	Rhamnaceae	√	√	√		√	√	√		6
Canthium inerme	Rubiaceae	√	√	√	√	√				5
Canthium mundianum	Rubiaceae		√		√					2
Canthium spinosum	Rubiaceae	√								1
Coddia rudis	Rubiaceae	√		√	√		√			4
Gardenia volkensii	Rubiaceae	√		√	√	√				4
Plectroniella armata	Rubiaceae	√	√	√			√			4
Psydrax locuples	Rubiaceae		√							1
Psydrax obovata	Rubiaceae			√						1
Vangueria infausta	Rubiaceae	√	√	√	√	√			√	6
Canthium kuntzeanum	Rubiaceae									0
Canthium setiflorum	Rubiaceae									0
Catunaregam spinosa	Rubiaceae									0
Gardenia cornuta	Rubiaceae									0

Species names	Family	Medicine	Fruit	Fuelwood	Craft	H-Poles	Fencing	Culture	Beverage	No. of uses
Pachystigma macrocalyx	Rubiaceae									0
Pavetta gracilifolia	Rubiaceae									0
Pavetta lanceolata	Rubiaceae									0
Tarenna supra-axillaris	Rubiaceae									0
Tricalysia capensis	Rubiaceae									0
Tricalysia lanceolata	Rubiaceae									0
Zanthoxylum capense	Rutaceae	√		√	√	√				4
Azima tetracantha	Salvadoraceae	√		√	√		√	√		5
Pappea capensis	Sapindaceae	√		√	√					3
Hippobromus pauciflora	Sapindaceae									0
Manilkara mochisia	Sapotaceae	√	√	√		√				4
Sideroxylon inerme	Sapotaceae		√	√	√	√				4
Manilkara nicholsonii	Sapotaceae									0
Solanum incanum	Solanaceae	√								1
Lycium cinerea	Solanaceae									0
Solanum tomentosa	Solanaceae									0
Sterculia rogersii	Sterculiaceae	√	√	√	√					4
Strychnos gerrardii	Strychnaceae		√							1
Strychnos madagascariensis	Strychnaceae	√	√	√	√	√				5
Strychnos spinosa	Strychnaceae	√	√	√		√	√			5
Grewia bicolor	Tiliaceae	√	√			√				3
Grewia hexamita	Tiliaceae				√		√			2
Grewia monticola	Tiliaceae		√		√					2
Grewia occidentalis	Tiliaceae	√	√	√	√	√				5
Grewia robusta	Tiliaceae	√								1
Grewia flava	Tiliaceae									0
Grewia microthyrsa	Tiliaceae									0
Grewia retinervis	Tiliaceae									0
Lippia javanica	Verbenaceae	√								1

Appendix II. Summary of PCA loadings for log transformed data.

PCA	**Canonical axes:**	**0**	**Covariables:**	**0**	**Scaling:**	**2**	
Cent./stand.	by samples:	0	0	by species:	1	0	

Log-transformation
Spec: Species scores (adjusted for species variance)

N	NAME	AX1	AX2	AX3	AX4	WEIGHT	1
	EIG	0.7263	0.1477	0.126	0		
1	NEAR	0.8117	0.5491	-0.199	0	1	1
2	INTERMED	0.8539	-0.0361	0.5192	0	1	1
3	FAR	0.8825	-0.3819	-0.2745	0	1	1

PCA	**Canonical axes:**	**0**	**Covariables:**	**0**	**Scaling:**	**2**	
Cent./stand.	by samples:	0	0	by species:	1	0	

Log-transformation
CFit: Cumulative fit per species as fraction of variance of species

N	NAME	AX1	AX2	AX3	AX4	VAR(y)	% EXPL
	FR FITTED	0.7263	0.1477	0.126	0		
1	NEAR	0.6588	0.9604	1	0	0.92	0
2	INTERMED	0.7292	0.7305	1	0	0.95	0
3	FAR	0.7788	0.9247	1	0	1.13	0

References

Arnold, J.E.M., Ruiz Pérez, M., 2001. Can non-timber forest products match tropical forest conservation and development objectives? Ecological Economics 39, 437-447.

Barnett, D.T., Stohlgren, T.J., 2003. A nested-intensity design for surveying plant density. Biodiversity and Conservation 12(2), 255-278.

Bass, S., Hughes, C., Hawthorne, W., 2001. Forests, biodiversity and livelihoods: linking policy and practice. In: Koziell, I., Saunders, J. (Eds.), Living off Biodiversity: Exploring Livelihoods and Biodiversity Issues in Natural Resources Management. IIED, London, pp. 23-73.

BSP, 1996. Biodiversity: facts on the foundation of life. Biodiversity Support programme, Washington DC.

Clinebell II, R.R., Phillips, O.L., Gentry, A.H., Stark, N., Zuring, H., 1995. Prediction of neotropical tree and liana species richness from soil and climatic data. Biodiversity and Conservation 4, 56-90.

Conelly, W.T., 1985. Copal and rattan collecting in the Philippines. Economic Botany 39, 9-46.

Connell, J.H., 1978. Diversity in tropical rainforests and coral reefs. Science 199, 1302-1310.

Cunningham A.B., Davis G.W., 1997. Human Use of Plants. In: Cowling, R.M., Richardson, D.M., Pierce, S.M. (Eds.), Vegetation of Southern Africa. Cambridge University Press, Cambridge, pp. 474-506.

Cunningham, A.B., Mbenkum, F.T., 1993. Sustainability of harvesting *Prunus africana* bark in Cameroon. People and Plants working Paper. UNESCO, Paris.

Daily, G.C. (Ed.), 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington DC.

Dovie, D.B.K., 2003. Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa? International Journal of Sustainable Development and World Ecology 10, 247-262.

Dovie, D.B.K., Witkowski, E.T.F., Shackleton, C.M., 2004. The fuelwood crisis in southern Africa – relating fuelwood use to livelihoods in a rural village. GeoJournal 60(2), 123-133.

Dovie, D.B.K., Witkowski, E.T.F., Shackleton, C.M., 2005. Monetary valuation of livelihoods for understanding the composition and complexity of rural households. Agriculture and Human Values 22, 87-103.

Fabricius, C., Palmer, A.R., Burger, M., 2002. Landscape diversity in a conservation area and commercial and communal rangeland in Xeric Succulent Thicket, South Africa. Landscape Ecology 17, 531-537.

Farina, A., 2000. The cultural landscape as a model for integration of ecology and economics. Bioscience 50(4), 313-320.

Geist, H.J., Lambin, E.F., 2001. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52(2), 143-150.

Hall, J.S. Harris, D.J., Medjibe, V., Ashton, P.M.S., 2003. The effects of selective logging on forest structure and tree species composition in a Central African forest: implications for management of conservation areas. Forest Ecology and Management 183, 249-264.

Hall, P., Bawa, K., 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. Economic Botany 47(3), 234-247.

Homma, A.K.O., 1992. The dynamics of extraction in Amazonia: a historical perspective. Advances in Economic Botany 9, 23-31.

Huerta-Martínez, F.M., Vázquez-García, J.A., García-Moya, E., López-Mata, L., Vaquera-Huerta, H., 2004. Vegetation ordination at the southern Chihuahuan Desert (San Luis Potosi, Mexico). Plant Ecology 174, 79-87.

Kahn, F., 1988. Ecology of economically important palms in Peruvian Amazonia. Advances in Economic Botany 6, 42-49.

Knoepp, J.D., Swank, W.T., 1997. Forest management effects on surface soil carbon and nitrogen. Soil Science Society of America Journal 61, 928-935.

Kunin, W.E., Lawton, J.H., 1996. Does biodiversity matter? Evaluating the case for conserving species. In: Gaston, J.K. (Ed.), Biodiversity: A biology of numbers and difference. Blackwell Science Ltd. London, pp. 283-308.

Low, A.B., Rebelo, A.G., 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Magurran, A.E., 2004. Measuring biological diversity. Blackwell Publishing, Malden, Oxford, Carleton.

MathSoft, 1999. S-PLUS 2000 Professional Release 1. MathSoft Inc., Washington DC.

Mooney, H.A., Godron, M., 1983. Disturbance and Ecosystems: Components of response. Springer-Verlag, New York.

Moore, J.L., Manne, L., Brooks, T., Burgess, N.D., Davies, R., Rahbek, C., Williams, P., Balmford, A., 2002. The distribution of cultural and biological diversity in Africa. Proceedings of the Royal Society of London 265, 1645-1653.

Nakazono, E.M., Bruna, E.M., Mesquita R.C.G., 2004. Experimental harvesting of the non-timber forest product *Ischnosiphon polyphyllus* in central Amazonia. Forest Ecology and Management 190, 219-225.

Ndangalasi, H.J., Bitariho, R., Dovie D.B.K., in press. Harvesting of plant parts and implications for conservation in two montane forests of East Africa. Biological Conservation XX.

Neke, S.K., 2005. The Regeneration Ecology of Savanna Woodlands in Relation to Human Utilisation. Unpublished PhD Thesis, University of the Witwatersrand, Johannesburg, pp. 244.

Parsons, D.A.B., Shackleton, C.M., Scholes, R.J., 1997. Changes in herbaceous layer condition under contrasting land use systems in the semi-arid lowveld, South Africa. Journal of Arid Environment 37, 319-329.

Peluso, N.L., 1983. Networking in the commons: a tragedy for rattan? Indonesia 35, 95-100.

Peters, C.M., 1990. Plenty of fruit but no free lunch. Garden 14, 8-13.

Peters, C.M., 1994. Sustainable harvest of non-timber plant resources in tropical moist forest: an ecological primer. Biodiversity Support Program-WWF, Washington, DC.

Peters, C.M., 1996. Beyond nomenclature and use: a review of ecological methods for ethnobotanists. In: Alexiades, M.N. (Ed.), Selected guidelines for ethnobotanical research. The New York Botanical Garden, pp. 241-276.

Ramírez-Marcial, N., González-Espinosa, M., Williams-Linera, G., 2001. Anthropogenic disturbance and tree diversity in Montane Rain Forests in Chiapas, Mexico. Forest Ecology and Management 154, 311-326.

Salick, J., Bium, A., Martin, G., Apin, L., Beaman, R., 1999. Whence useful plants? A direct relationship between biodiversity and useful plants among the Dusun of Mt. Kinabalu. Biodiversity and Conservation 8, 797-818.

Scherrer, A.M., Motti, R., Weckerle, C.S., 2005. Traditional plant use in the areas of Monte Vesole and Ascea, Cilento National Park (Campania, Southern Italy). Journal of Ethnopharmacology 97, 129-143.

Sekhwela, M.B.M., 2003. Woody vegetation resource changes around selected settlement along aridity gradient in the Kalahari, Botswana. Journal of Arid Environments 54, 469-482.

Shackleton C.M., Griffin N.J., Banks J.M., Mavrandonis J.M., Shackleton S.E., 1994. Community structure and species composition along a disturbance gradient in a communally managed South African savanna. Vegetatio 115, 157-167.

Shackleton, C.M., Grundy, I.M., Williams, A., 2004. Use of South Africa's woodlands for energy and construction. In: Lawes, M.J., Eeley, H.C., Shackleton, C.M., Geach, B.S. (Eds.), Indigenous Forests and Woodlands in South Africa: Policy, People and Practice. University of Natal Press, Durban, pp. 337-363.

Shackleton, C.M., Guthrie, G., Main, R., 2005. Estimating the potential role of commercial over-harvesting in resource viability: A case study of five useful tree species in South Africa. Land Degradation and Development 16, 273-286.

Shackleton, C.M., Shackleton, S.E., Ntsudu, M., Ntzebeza, J., 2002. The role and value of savanna non-timber forest products to rural households in the Kat River Valley, South Africa. Journal of Tropical Forest Products 8(1), 45-65.

Siebert, S.F., Belsky, J.M., 1985. Forest product trade in a lowland Filipino village. Economic Botany 39, 522-533.

Silvertown, J.W., Lovett-Doust, J., 1993. Introduction to Plant Population Biology. Blackwell Scientific Publications, Cambridge.

Stohlgren, T.J., Falkner, M.B., Schell, L.D., 1995. A Modified-Whittaker nested vegetation sampling method. Vegetatio 115, 113-121.

ter Braak, C.J.F., 2003. Program CANOCO version 4.5. Centre for Biometry, Wageningen.

Ticktin, T., 2005. Applying a metapopulation framework to the management and conservation of a non-timber forest species. Forest Ecology and Management 206, 249-261.

Ticktin, T., Nantel, P., Ramírez, F., Johns, T., 2002. Effects of variation on harvest limits for non-timber forest species in Mexico. Conservation Biology 16, 691-705.

Turner, G.M., Romme, W.H., Gardener, R.H., O'Neill, R.V., Kurtz, T.K., 1993. A revised concept of landscape equilibrium: Disturbance and stability of scaled landscapes. Landscape Ecology 8, 213-227.

Twine, W.C., Moshe, D., Netshiluvhi, T.R., Shipugu, V., 2003. Consumption and direct-use values of savanna bio-resources used by rural households in Mametja, a semi-arid area of Limpopo province, South Africa. South African Journal of Science 99, 467-473.

UNEP, 1995. Global Biodiversity Assessment. United Nations Environment Programme Cambridge University Press, Cambridge.

UNEP, 1999. Global Environment Outlook 2000. United Nations Environment Programme, Earthscan Publications Ltd, London.

White, P.S., Pickett, S.T.A., 1985. Natural disturbance and patch dynamics: an introduction. In: Pickett, S.T.A., White, P.S. (Eds.), The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, Orlando, pp. 3-13.

CHAPTER 4

Conservation and ecological implications of age and gender based knowledge of useful woody plant species in South African savannas

Abstract

The precise relationships between social attributes and indigenous knowledge of people's use of biological resources are often unclear, yet these could provide relevant information for biological work. This study was undertaken in selected savanna biome villages within South Africa to investigate age and gender differences in local knowledge about the consumption of locally available woody plant species. Focus group discussions, comprising six groups based on gender and age were used for the data collection. The results were analysed using multivariate (e.g., DCA ordination) and univariate statistics (e.g., Chi-square). Knowledge on diversity and numbers of useful woody plant species varied between age groups and with gender, yet the differences was not statistically significant. Although young and middle aged females listed more woody species than the other groups across the combined sites, males generally listed more species. A total of 267 woody plant species, belonging to 69 families, were recorded (15 protected by law in South Africa). Some species (e.g., *Alberta magna, Catha edulis* and *Ocotea bullata*) qualified as threatened species based on local and Regional Red Data Lists. *Trichilia emetica, Peltophorum africanum* and *Sclerocarya birrea* had many uses, seven and eight for the latter two, respectively. Of the total woody species, the 17.9% belonging to the Fabaceae family had the highest numbers of uses. Over half (53.9%) of the total woody species had multiple uses that are likely to be of great proximate concern for over utilization. From this study emerges the importance of traditional nomenclature and indigenous knowledge for enhancing the information base of locally available species conservation assessments, sustainability parameters, methodological inclusiveness and decision-making. It is proposed that a threatened species list at the local (village) level, herein referred to as the "Locally Brown List", based on an indigenous knowledge categorization be developed and promoted (e.g., DD KA1, implying a species under threat based on local knowledge but data deficient biologically). This categorization will provide pertinent information on current and future threats to species at the local level as a means of drawing attention to biological assessments whilst facilitating the understanding of several unstudied species that are of use to humans.

Keywords: Ethnobotany, indigenous knowledge, Locally Brown List, NTFPs, savanna biome, protected tree species.

1. INTRODUCTION

1.1. Indigenous knowledge and the use of biodiversity

Indigenous peoples have interacted with their environment since the start of human evolution, from which the utilisation of wild plants and animals continues to greatly benefit society to this day (Berlin, 1992; Rhoades and Bebbington, 1995; Johnson, 2000; Scherrer et al., 2005). These interactions were made possible through people's development of broad-base understanding and knowledge of their environment (Hunn, 1993; Rhoades and Bebbington, 1995; Hansen, 1998; Scherrer et al., 2005). The immense genetic diversity within traditional farming systems is mostly the product of human innovation and experimentation of biodiversity (WWF, 1994; Wickramasinghe et al., 1996). Indigenous knowledge of useful organisms is often not documented and is largely based on many years of close association with the natural and biophysical environment (Posey, 1993; Johnson, 2000). Key bioprospecting activities have benefited from indigenous knowledge, yet it has not been well exploited to supply appropriate intellectual resources for biodiversity conservation. The perceptions of indigenous and rural people about biological resources have been documented in important biodiversity management-oriented studies (e.g., Cunningham and Mbenkum, 1993; Elisabetsky, 1996; Cunningham, 1996; Wild and Mutebi, 1996). The perceptions are often translated into belief systems to protect key natural resources such as in extractive reserves and sacred groves (McNeely, 1992; Kleymeyer, 1994). However, very little is documented about the understanding of this knowledge within the communal area savannas of South Africa. Here, resource extraction is poorly regulate and are at risk of depletion, together with the associated indigenous knowledge and nomenclature. The need to fully tap this knowledge to benefit formal science is long overdue because it can contribute to information required for setting priorities for scientific studies and conservation.

1.2. Ethnobotany and the state of woody plant species

Research has demonstrated the importance of plants in savannas to secure livelihoods through the increasing extraction of non-timber forest products (NTFPs) (Cunningham and Davis, 1997; Campbell et al., 2000; Dovie et al., 2002; Cocks and Wiersum, 2003; Lawes et al., 2004). NTFPs have been recognised in the supply of food, fibres, medicine, household incomes, energy, construction materials, and craft resources and for cultural purposes (Scoones et al., 1992; Dzerefos et al., 1999; Letsela et al., 2002; Shackleton et al., 2002; Cocks and Wiersum, 2003; Dovie, 2003; Dovie et al., 2005; Romero et al. in press).

Ethnobotanical studies have added value to the understanding of the ecology and conservation biology of a number of species (e.g., Salick, 1995; Ladio and Lozada, 2004). The local perceptions of historical changes to vegetation and associated trajectories have also provided key indicators for mainstreaming conservation planning (e.g., Lykke et al., 1999; Chazdon and Coe, 2001). For example in a Burkina Faso study, females identified significant declines in the availability of useful species in a vegetation change study (Lykke et al., 1999). Clues for taxonomic diversity of plants among several tribes in eastern Nicaragua have also been documented (Coe and Anderson 1997, 1999). In Cameroon, the ecology and biogeography of selected plant resources have been studied using indigenous knowledge (Djik, 1999). Similarly in South Africa, several checklists of a number of plants that are used for craftwork and medicinal purposes have been documented (e.g., Cunningham, 1987; Williams et al., 2001). The deployment of tribal people, with excellent local knowledge in botanical projects has become popular. Seed producing trees and medicinal properties of plants have been studied for their modifications resulting from human utilisation in Nepal and the implications for management based on information from the local population (Manandhar, 1995).

However, all the above examples and several other studies have yet to provide detailed information on the precise synergy/relationships between locally available species numbers and diversity, in relation to societal uses. This synergy could provide much needed information on the state of plant resources towards informed conservation planning (e.g., biodiversity assessment and monitoring and Threatened Lists). Existing guides for setting conservation priorities have not included indigenous knowledge and applicable only at Taxa level. However, the variance and the mismatch between indigenous knowledge and formal science can bring about improved understanding and practice to conserving biodiversity.

The objective of this analysis was to determine from indigenous knowledge the differences in the diversity and number of woody plant species available and used locally, within and between different sites in three South African provinces located in the savanna biome, based on age and gender of the local people. Nine sites were selected to represent the large expected variation across the biome due to differences in culture, language, history and resource availability (Cunningham and Davis, 1997). The following hypotheses were tested: (a) the perception of the diversity and numbers of woody plants available and used locally increases with the age of users, and (b) the diversity and numbers of woody species available and used locally is perceived to be higher by females. The first hypothesis is based on older people having had more interactions with and used woody plant species for longer periods of time than younger people (Hansen, 1998; Kristensen and Balslev, 2003). The second hypothesis stems from the widespread greater involvement of women rather than men in the interaction with and utilisation of NTFP resources which involves extraction and processing (e.g., Hansen, 1998; Mies and Shiva, 1993; Stratford and Davidson, 2002; Lado, 2004; Dovie et al., 2005) and hence they are expected to be more knowledgeable (e.g., Figueiredo et al., 1993). However, several other studies have also identified men as more knowledgeable in their perceptions about useful woody plants (e.g., Styger et al., 1999; Luoga et al., 2000; Stagegaard et al., 2002; Letsela et al., 2002). It is noteworthy however that, women are often less well represented and interviewed less in most studies. Hence the use of focus group discussions in this study will provide equal gender opportunities. The division of labour, expertise and resource control at intra and inter-household and community levels does indeed contribute largely to differences in knowledge (Kajembe, 1994; Rocheleau and Edmunds, 1997; Hansen, 1998; Styger et al., 1999; Lado, 2004).

2. STUDY SITES DESCRIPTION

All nine study villages (sites) were located within the savanna biome and former homelands of South Africa within the Limpopo, KwaZulu-Natal and Eastern Cape provinces. These areas are often zoned into land use areas comprising arable agriculture, residential and common grazing areas. The extraction of woodland resources, livestock and crop production, migrant labour and poverty are some livelihood features common to these areas (e.g., Dovie et al., 2005). Key information about the location and vegetation of the sites is presented (Table 1).

Table 1. Summary of bio-geographical and cultural attributes of the study sites.

Village (site)	Cardinal points	Location description and vegetation type	Ethnic group
Tidbury Fairbairn Ntilini	32º38.6'S: 26º39.5'E 32º33.6'S: 26º42.5'E 32º42.4'S: 26º36.0'E	Kat River valley of the Mpofu district of the *Eastern Cape* province and between the urban settlements of Seymour in the north, and Fort Beaufort in the south. Vegetation type is the Eastern thorn bushveld.	Xhosa speaking in former Ciskei homeland
KwaJobe KwaNompondo	27º36'S: 32º20'E 28º04'S: 32º10'E	Located in the north-eastern *KwaZulu-Natal* province (Maputaland coastal plain) in the Ubombo District. Lies adjacent to the Mkuze Game Reserve, whilst KwaNompondo shares a common boundary with the Hluhluwe Umfolodzi Game Reserve and vegetation mixed with scrub, all in the Natal lowveld bushveld.	Zulu speaking within the Zululand.
Thorndale	24º39'S: 31º21'E	Thorndale shares a common boundary with the Manyeleti Game Reserve, and within the Bushbuckridge Region, in *Limpopo* province. Vegetation type is Sour and Mixed lowveld bushveld.	Tsonga speaking in Thorndale and mostly Northern Sotho in Finale A, Mabins A & Willows.
Finale A Mabins A Willows	24º19'S: 30º42'E 24º22'S: 30º32'E 24º21'S: 30º57'E	The three villages lie north of the Hoedspruit town and markedly and located far off the main highway to the Pharlabowa town in the *Limpopo* province, within the Mixed lowveld bushveld vegetation.	

3. METHODOLOGY

3.1. Data collection

Participatory focus group discussion (FGD) (Krueger, 1988; Lykke et al., 1999) was used to independently obtain lists of woody species useful as NTFPs, their local availability and local conservation status. The FGD was conducted in nine villages (sites) which are culturally and biogeographically diverse at each site. Within each village, six focus groups were formed for the discussions, based on age and gender. Thus individuals (a) below 31 years old, (b) from 31 – 50 years, and (c) 51 years and above, replicated for both males and females (Figure 1). Between 15 and 20 individuals constituted each of the six focus groups within each village. Participants were asked to list all useful woody plant species known to them and their local availability. Each of the groups had their own facilitator, a reporter and key informants that guided and ensured the authenticity of the discussion and not influenced the outcome of the discussion. The responses were compiled as numbers of species scored for nine broad use categories, by the age and gender groupings (Figure 1).

Figure 1. Left: One of the groups (seated) visited by the project team to enhance further discussion at Finale A within the Mixed lowveld bushveld vegetation type (Photo: Community member, Finale A). Right: Young males at Ntilini (Eastern thorn bushveld) had their share of the discussion (Photo: DBK Dovie).

3.2. Data analysis

A list of the woody plant species was generated at each site and for each corresponding NTFP use category. The perception of the local people (groups) about the state of the woody plant species represented the extent of their knowledge. The group with the highest numbers of species listed was rated the most knowledgeable. All species with three and more uses were defined as having 'multiple uses' within the confines of this study. Species numbers were represented by means and standard errors based on the numbers for each of the six groups, within each site. Species that were no longer known to be readily available for use by the local people because they were difficult to find or encounter compared to previous times (≥10 years in the past) were also noted. Various Red Data Lists were used for identifying the conservation status of the species (e.g., Hilton-Taylor, 1996; Scott-Shaw, 1999; IUCN, 2001). The IUCN Red Data List (IUCN, 2001) was used as a template for proposing a localised indigenous knowledge level categorization of threats to species locally rather than at the taxa level. To ascertain the relationships between the species and their similarities of use under the nine use categories, Detrended Correspondence Analysis (DCA) (CANOCO Version 4.5; ter Braak, 2003) was used. DCA was selected because the length of the longest gradient of axes 1 and 2 were more than four standard deviations within the standard number of segments. The number of times that a species was recorded as useful under any of the use categories based on different gender and age groups represented the abundance of the species. Based on this therefore, the diversity of the species corresponding to each of the groups at the village, provincial and across all sites was calculated using the Shannon Wiener Diversity Index (*H'*). This was defined as $H' = -\sum p_i \ln p_i$ where, $p_i = n_i / N$ is the relative abundance of species, n_i = individual species number, and N = total number of species (Magurran, 2004).

A General Linear Model (GLM) with a Two-Way ANOVA (age class, gender) and *a posteriori* test, the Tukey Honest Significance Difference (HSD), was used to compare the group means of the numbers and diversities of species between and across the sites, as well as the differences in the age and gender groupings based on the computed Shannon Diversity Index. The woody plant species data were first analysed for (i) homogeneity of variance (i.e., Hartley, $F_{\max} = 18.12$; Cochran, $C = 0.134$; Bartlett, $\chi^2 = 8.289$: df = 17, p >0.05), (ii) normality, with a plot of raw residuals that showed a normal distribution, and (iii) the absence of outliers, with a plot of the observed species numbers against the raw residual (normal distribution: $\chi^2 = 0.673, df = 4, p = 0.955$, Kolmogorov-Smirnov $d = 0.0739$), and thus allowing ANOVA to be performed. Contingency tables were used to examine the associations between the responses of age groups and genders within and across the sites. Unless otherwise stated, all statistics were performed using the program STATISTICA Version 6 (StatSoft Inc, 2002).

4. RESULTS

4.1. Overall knowledge of locally available useful woody plant species

A total 267 woody plant species were listed by the local people, which belong to 69 plant families. Over half of the species were accounted for by only nine families as follows: Fabaceae – 17.9% (sub-families: Mimosoideae – 9%, Papilionoideae – 5.2%, Caesalpinoideae – 3.7%), Euphorbiaceae (6.7%), Celastraceae (5.6%), Anacardiaceae (5.6%), and Ebenaceae (4.1%), Rubiaceae (3.7%), Moraceae (3.4%), Apocynaceae (3.0%) and Flacourtiaceae (3.0%), with 60 families accounting for the remaining species. Nine different use categories of woody plant species (i.e., medicine, edible fruit/seed, fuelwood, craft, housing poles, fencing, furniture, cultural, and beverage including traditional liquor were recorded. Most species had more than a single use, and in some cases, up to eight uses per species. Of the 267 species, the species with multiple uses (3–8) had the highest proportion of 53.9% compared to fewer use (1–2) species of 46.1% (Figure 2a). However, single use species were the highest in proportion across all uses (29.6%) followed by double-use species (16.5%) and the least being species having seven uses (0.4%) (Figure 2a). Only *Trichilia* *emetica* had seven uses whilst *Peltophorum africanum* and *Sclerocarya birrea* had eight uses each.

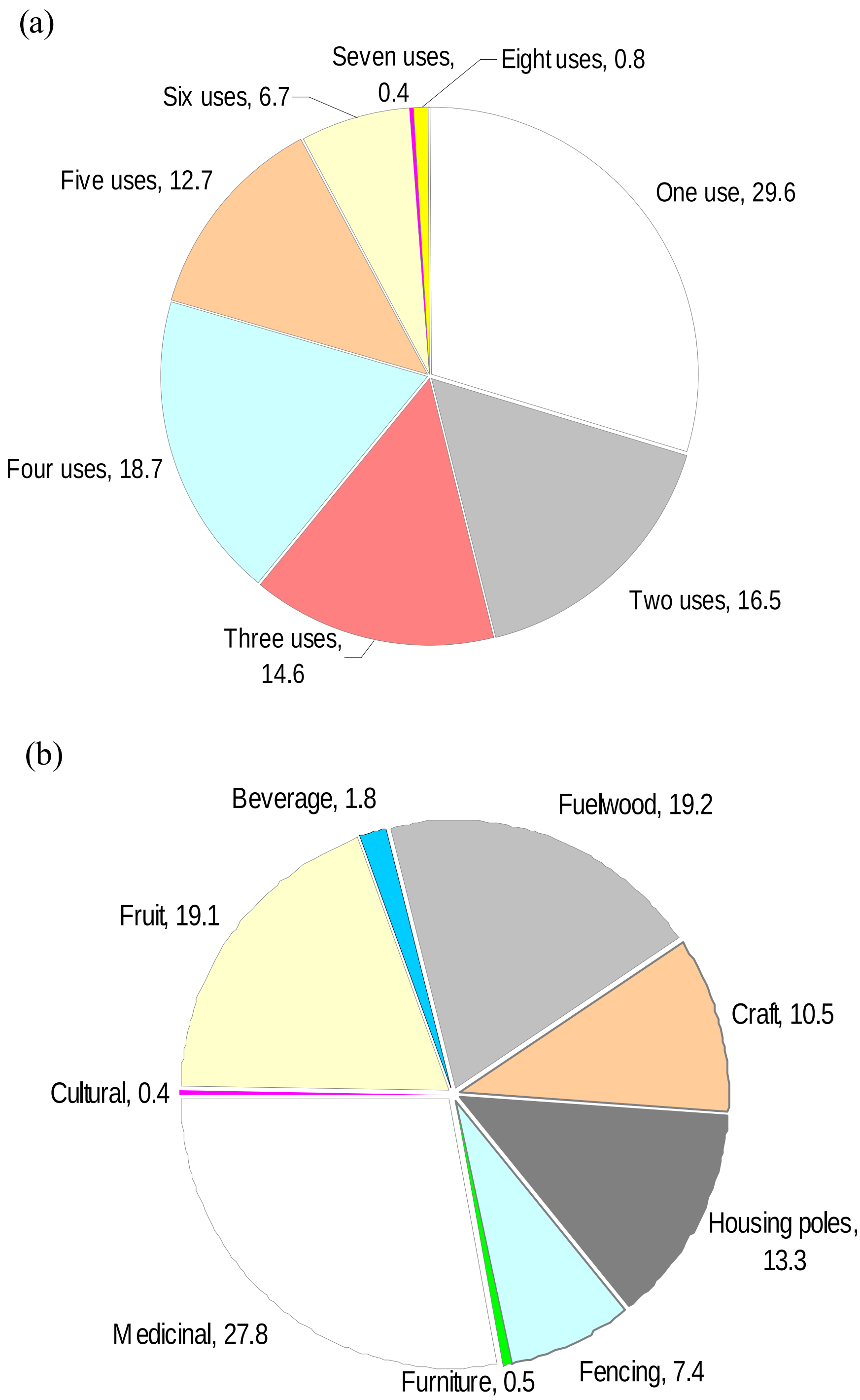

Figure 2. The proportion (%) of the useful woody plant species for (a) the number of uses, and (b) the categories of uses across the combined sites.

Of the overall uses, the majority of the species (i.e., 27.8%) were for medicinal purposes (Figure 2b) followed by species for fuelwood (19.2%) and wild edible fruits (19.1%), and the least being indigenous furniture (0.4%) although there is a strong cultural dimension to use of medicinal plants (e.g., Cocks and Dold, 2004). Most of the species therefore had shared uses. The top three frequently named species for the various uses are shown in Table 2a. The DCA analysis revealed close similarities in the species used for (a) medicine and culture, (b) fruits and beverages, (c) housing poles and craft, (d) fuelwood and fencing, and (e) fencing and furniture (Figure 3).

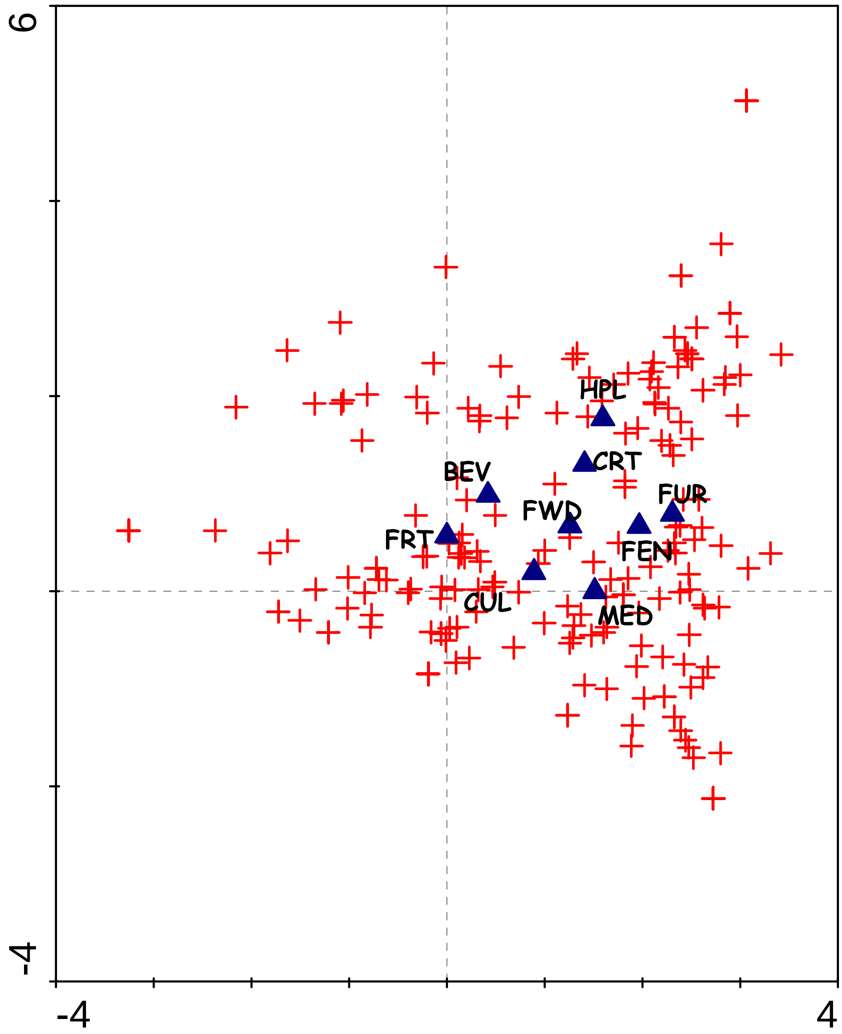

Figure 3. DCA ordination biplot showing the similarities and dissimilarities between woody plants species (++) for the various use categories (MED-medicine, FRT-edible fruits, FWD-fuelwood, CRT-craft materials, HPL-housing pole, FEN-fencing materials, FUR-indigenous furniture, CUL-cultural uses, BEV-local beverages).

Table 2a. The top three woody species (with families and vegetation type) that were frequently cited in the various use categories except for cultural uses where only three species were listed (but could have been cited under medicinal use).

Use categories with species	Family	Vegetation type	Use categories with species	Family	Vegetation type
Medicinal			Fencing poles		
Schotia brachypetala	Fabaceae	NLB, MLB, ETB	*Acacia karroo*	Fabaceae	NLB, ETB
Trichilia emetica	Meliaceae	NLB, MLB	*Coddia rudis*	Rubiaceae	ETB
Aloe africana	Aloaceae	MLB, ETB	*Combretum apiculatum*	Combretaceae	NLB, MLB
Edible fruits			Furniture		
Vangueria infausta	Rubiaceae	NLB, MLB	*Pterocarpus angolensis*	Fabaceae	MLB
Berchemia zeyheri	Rhamnaceae	NLB, MLB	*Trichilia emetica*	Meliaceae	NLB, MLB
Trichilia emetica	Meliaceae	NLB, MLB	*Podocarpus latifolius*	Podocarpaceae	ETB, MLB, ETB
Fuelwood			Cultural		
Combretum apiculatum	Combretaceae	NLB, MLB	*Ziziphus mucronata*	Rhamnaceae	NLB, MLB
Vangueria infausta	Rubiaceae	NLB, MLB	*Sclerocarya birrea*	Anacardiaceae	NLB, MLB
Berchemia zeyheri	Rhamnaceae	NLB, MLB	*Peltophorum africanum*	Fabaceae	NLB, MLB
Craft			Beverage		
Acacia caffra	Fabaceae	NLB, MLB, ETB	*Sclerocarya birrea*	Anacardiaceae	NLB, MLB
Berchemia zeyheri	Rhamnaceae	NLB, MLB	*Combretum hereroense*	Combretaceae	MLB
Pterocarpus angolensis	Fabaceae	NLB, MLB	*Trichilia emetica*	Meliaceae	NLB, MLB
Housing pole					
Combretum erythrophyllum	Combretaceae	ETB			
Ptaeroxylon obliquum	Ptaeroxylaceae	NLB, ETB			
Faurea saligna	Proteaceae	MLB, ETB			

NLB - Natal Lowveld bushveld (KwaZulu-Natal province), MLB - Mixed Lowveld bushveld (Limpopo province), ETB - Eastern thorn bushveld (Eastern Cape province)

The woody plant species that were listed and defined as currently 'rare' by the local people, were *Cassipourea gerrardii, Trichocladus ellipticus, Dovyalis caffra*, *Ekebergia capensis, Acacia caffra, Canthium mundianum*, and *Cussonia paniculata,* from the Eastern thorn bushveld; *Adenia gummifera, Smodingium argutum* and *Erythroxylum pictum* in the Natal lowveld bushveld; and *Englerophytum magalismontanum* in the Mixed lowveld bushveld. Many were listed as threatened (Table 2b). Additionally, over 5% (15) of the 267 useful woody plant species that were listed by the local people are part of the list of the 47 protected tree species in South Africa (DWAF, 2002). They are *Adansonia digitata, Boscia albitrunca, Breonadia salicina, Pittosporum viridiflorum, Podocarpus latifolius, Pterocarpus angolensis, Sclerocarya birrea, Sideroxylon inerme, Catha edulis*, *Cleistanthus schlechteri, Combretum imberbe, Mimusops caffra, Ocotea bullata, Philenoptera violacea*, and *Rhizophora mucronata*. However, some of the species listed in Table 2b are abundant in protected areas (e.g., *Combretum collinum*). The Mixed lowveld bushveld (Limpopo province) had more individual species (120) compared to the Natal lowveld bushveld in the KwaZulu-Natal province (118) and Eastern thorn bushveld in the Eastern Cape province (100), belonging to 41, 42 and 44 plant families, respectively.

Table 2b. The conservation status of woody plant species that were named by local people and falling within threatened species lists.

Species	Red list category / criteria		Uses identified in this study only
	South Africa [a]	Global [b]	
Alberta magna	Rare, lower risk, conservation dependent	Near threatened	Medicinal
Aloe thraskii	Near threatened, lower risk	Data deficient	Medicinal
Catha edulis	Rare, lower risk, least concern	Near threatened	Medicinal
Combretum collinum	Rare, lower risk, least concern	Data deficient	Medicinal, fuelwood, craft, housing pole
Cyathea capensis	Near threatened, lower risk	Data deficient	Medicinal, fruit
Ensete ventricosum	Indeterminate	Not evaluated	Medicinal
Ocotea bullata	Vulnerable, lower risk, conservation dependent	Vulnerable	Medicinal
Olinia radiata	Rare, lower risk	Data deficient	Medicinal
Raphia australis	Vulnerable, lower risk	Vulnerable	Medicinal
Smodingium argutum	Rare, lower risk	Near threatened	Medicinal
Trichocladus ellipticus	Insufficiently known	Near threatened	Medicinal, furniture, fruit, fuelwood, craft

[a] (Hilton-Taylor 1996, Scott-Shaw 1999) and [b] IUCN (2001).

4.2. Differences in knowledge about the diversity and numbers of woody plant species

A two - factor ANOVA showed no significant difference between age and gender knowledge in listing the numbers of locally available useful woody plant species across the combined sites $\left(F_{(8,35)} = 2.266,\ p > 0.05\right)$. There was a significant difference between the age and gender knowledge between individual sites $\left(F_{(8,35)} = 2.266,\ p < 0.001\right)$, similarly observed for the species diversity $\left(F_{(8,35)} = 2.266,\ p < 0.01\right)$. A Tukey HSD test confirmed eleven significant differences between paired combinations of sites for species numbers, and three for the species diversity.

4.2.1. Influence of age of users on *H'*

The highest *H'* was recorded by the different age groups as follows; age groups less than 31 years in Mabins A, Fairbairn and KwaNompondo; 31 – 50 years in Finale A, Ntilini and KwaJobe; and over 50 years in Willows and Tidbury whilst the diversity was the same (*H'* = 3.6) for all three groups in Thorndale (Table 3a). All three age groups had one each of the highest diversity in each of the three Eastern Cape villages. The age groups <31 years, and 31 – 50 years each had a highest index in the two KwaZulu-Natal villages (Table 3a). The age group <31 years and >50 years both had the highest species diversity (*H'* = 3.3 ± 0.1), across the combined sites (Table 3a). In all cases of the highest diversity indices, the corresponding mean number of species was also high for the same sites. The highest mean number of species across the combined sites (61.0 ± 6.1) was highest for the age group over 50 years (Table 3a). The differences in the species number between the age groups in the villages within each province at the provincial levels were not significant in all three provinces. Similarly, the differences in the species number were not significant based on the age groups between the nine individual villages $(F_{(1,35)} > 4.17,\ p > 0.05)$. Species diversity followed a similar trend just as the numbers of species, having no significant differences between any of the sites with respect to age groups.

Table 3a. The Shannon Diversity Index (*H'*) and the number of species (mean ± SE) recorded for the various use categories by three age groups at the individual village level and across all the nine sites.

Village (site)	Diversity (*H'*)			Species number		
	< 31	31-50	> 50	< 31	31-50	> 50
Thorndale[1]	3.6 (0.1)	3.6 (0.1)	3.6 (0.3)	41.5 (4.5)	40.5 (3.5)	39.5 (10.5)
Finale A[1]	3.3 (0.1)	3.5 (0.0)	3.3 (0.0)	30.5 (4.5)	35.5 (0.5)	31.0 (1.0)
Mabins A[1]	3.1 (0.4)	2.7 (0.3)	2.9 (0.6)	25.0 (9.0)	18.0 (6.0)	23.0 (12.0)
Willows [1]	2.9 (0.1)	2.5 (0.1)	3.2 (0.2)	19.0 (1.0)	14.0 (1.0)	29.0 (6.0)
Tidbury [2]	3.2 (0.1)	3.4 (0.2)	3.6 (0.0)	25.0 (3.0)	31.5 (4.5)	35.5 (0.5)
Ntilini[2]	3.1 (0.2)	3.3 (0.0)	3.0 (0.2)	23.5 (5.5)	27.0 (0.0)	20.5 (3.5)
Fairbairn[2]	3.5 (0.2)	2.7 (0.3)	3.3 (0.5)	34.0 (6.0)	16.5 (4.5)	30.0 (13.0)
KwaJobe[3]	3.8 (0.0)	3.9 (0.1)	3.7 (0.2)	46.5 (2.5)	50.5 (2.5)	47.0 (10.0)
KwaNompondo[3]	3.2 (0.2)	2.9 (0.3)	2.8 (0.3)	26.5 (4.5)	20.0 (5.0)	19.0 (6.0)
Combined sites	3.3 (0.1)	3.2 (0.1)	3.3 (0.1)	60.1 (5.9)	56.3 (8.3)	61.0 (6.1)

[1]Limpopo, [2]Eastern Cape, and [3]KwaZulu-Natal province villages (sites)

4.2.2. Influence of gender of users on *H'*

At the village level and based on the Shannon Index, both males and females recorded the same highest species diversity in three villages each, with the highest diversity recorded for both genders in KwaJobe (Table 3b). Diversity was generally similar or slightly higher for males (*H'* = 3.3) than females (*H'* = 3.2) across the combined sites. The differences in the numbers of species listed based on gender were non-significant, between (a) the nine individual villages $(F_{(1,35)} = 4.17, p > 0.05)$ and (b) the pooled numbers across the combined sites $(F_{(1,51)} = 4.17,\ p > 0.05)$.

Table 3b. The Shannon Diversity Index (*H'*) and number of species (mean ± SE) by gender listing at the individual village levels and across all the nine sites.

Villages (sites)	**Species diversity**		**Mean species number**	
	Male	Female	Male	Female
Thorndale	3.7(0. 1)	3.5 (0.1)	43.3 (4.1)	37.0 (4.6)
Finale A	3.4 (0.1)	3.4 (0.1)	31.3 (2.9)	33.3 (1.7)
Mabins A	2.9 (0.3)	3.0 (0.3)	21.0 (7.1)	23.0 (6.7)
Willows	3.0 (0.3)	2.8 (0.2)	22.7 (6.2)	18.7 (2.9)
Tidbury	3.4 (0.1)	3.4 (0.2)	30.3 (2.9)	31.0 (4.5)
Ntilini	3.1 (0.2)	3.1 (0.1)	24.3 (3.7)	23.0 (2.6)
Fairbairn	3.5 (0.2)	2.9 (0.2)	34.7 (6.9)	19.0 (4.7)
KwaJobe	3.9 (0.0)	3.7 (0.1)	51.3 (2.8)	44.7 (4.6)
KwaNompondo	2.9 (0.2)	3.0 (0.3)	20.7 (3.0)	23.0 (5.3)
Across all sites	3.3 (0.1)	3.2 (0.1)	31.1 (2.4)	28.1 (2.1)

4.3. Relationships in knowledge about woody plant species based on age and gender

Males >50 years were more knowledgeable in six out of the nine sites and their female counterparts least knowledgeable at four sites (Figure 4). Females <31 years were more knowledgeable compared to their male counterparts across the combined sites, and in six out of the nine sites. Similarly, females aged 31–50 years were also more knowledgeable than their male counterparts across all the combined sites, and in five villages (Figure 4). Overall, age groups and gender were significantly associated in the Mabins A village in Limpopo and KwaNompondo in KwaZulu-Natal (Table 4). In Mabins A, a significant association existed between age groups <31 years and >50 years for the number of useful woody plant species $\left(\chi^2 = 16.97, df = 1, p < 0.0001\right)$, and also a significant association between those aged 31–50 years and >50 years $\left(\chi^2 = 13.39, df = 1, p < 0.001\right)$. No association between age groups <31 years and 31-50 years was observed for the number of useful woody plant species $\left(\chi^2 = 0.01, df = 1, p > 0.05\right)$. Similar results were observed for KwaNompondo. There were no significant associations between age and gender in the numbers of woody plant species across the combined sites (Table 4).

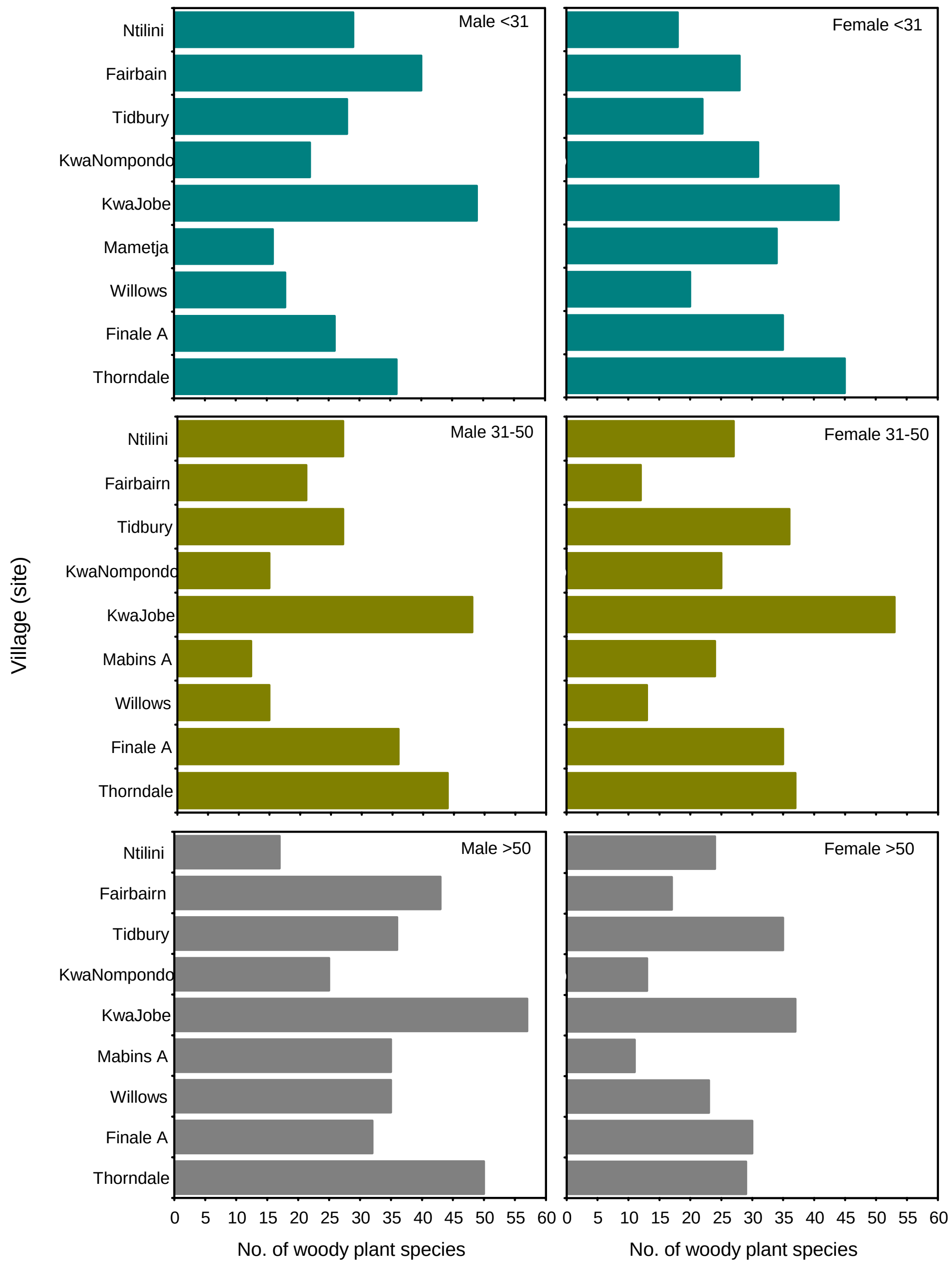

Figure 4. The total numbers of species at each of the nine villages listed according to age groups and gender.

Table 4. Chi-square tests (df = 2, p <0.05) of the relationship between age and gender for the numbers of useful woody plants at the village and provincial levels, and across all the sites. There are three age groups (i.e., <31, 31–50 and >50 years).

Village	χ^2 - value	Cramer's V	p
Thorndale	5.72	0.1541	0.0573 [ns]
Finale A	1.22	0.0793	0.5434 [ns]
Mabins A	22.78	0.4154	< 0.0001***
Willows	1.58	0.1129	0.4538 [ns]
Tidbury	2.00	0.1043	0.3679 [ns]
Ntilini	3.66	0.1605	0.1604 [ns]
Fairbairn	2.32	0.1200	0.3135 [ns]
KwaJobe	3.43	0.1093	0.1800 [ns]
KwaNompondo	7.47	0.2388	0.0239*
Across all the sites (villages)	5.42	0.0778	0.0665 [ns]

4.4. Differences in species numbers for specific use categories

The numbers of species listed by the age and gender groups for the corresponding uses were directly compared for seven use categories that had the highest numbers of species. Generally at the village level, males listed more species for medicine, fruits, craft wood, housing and fencing poles, whilst females dominated in the categories of fuelwood and beverages (Table 5a). For the combined sites, males dominated in the species numbers for medicine, fruits, craft, and fencing, whilst females scored the highest for fuelwood and beverages (Table 5a). On the age basis, the older generation listed more species for four specific use categories (i.e., medicine, craft, fencing and housing poles), the middle-aged group dominated the beverage category whilst the younger generation excelled in the species for fuelwood (Table 5b). The data for the numbers of species at the provincial level for the use categories by the age groups were highly variable (Table 5b). However, with the combined sites, the older generation scored the highest numbers of species for medicine and craft, and the middle aged group for fruits/seeds, and the younger generation for fuelwood and housing poles (Table 5b).

Table 5a. Differences in the numbers of species that were listed by males and females for seven specific use categories at the village, provincial and all combined sites levels.

Villages	Gender	Medicinal	Fruit	Fuelwood	Craft	Housing	Fencing	Beverage
Thorndale	Male	■	■		■		■	■
	Female			■		■		
Finale A	Male		■		■			
	Female	■	■	■		■	■	■
Willows	Male	■	■		■	■	■	
	Female			■				■
Mabins A	Male	■	■		■		■	
	Female		■	■		■	▒	■
KwaJobe	Male	■			■	■		■
	Female		■	■	■		■	■
KwaNompodo	Male		■	■	■	■	■	
	Female	■	■					■
Tidbury	Male		■	■			■	▒
	Female	■		■	■	■		▒
Fairbairn	Male	■	■	■	■	■	■	▒
	Female			■			▒	▒
Ntilini	Male	■	■	■	■	■		▒
	Female		■	■			■	▒
Limpopo Province	Male	■	■		■		■	
	Female			■		■		■
KwaZulu-Natal	Male	■			■	■	■	■
	Female		■	■				■
Eastern Cape	Male	■	■	■	■	■	■	▒
	Female						■	▒
All Sites	Male	■	■		■	■	■	
	Female			■		■		■

■ Group with the highest numbers of woody plants for a corresponding use category
▒ There was no plant for particular group and use category

Table 5b. Differences in the numbers of species based on age groups for seven specific use categories at the village, provincial and all combined sites levels.

Villages	Age group	Medicinal	Fruit	Fuelwood	Craft	Housing	Fencing	Beverage
Thorndale	< 31 yrs	2nd highest	Highest	Highest	2nd highest	Highest	Least	2nd highest
	31 - 50 yrs	Least	2nd highest	2nd highest	Least	Least	2nd highest	Highest
	> 50 yrs	Highest	Least	Least	Highest	2nd highest	Highest	Least
Finale A	< 31 yrs	Highest	2nd highest	2nd highest	Least	Highest	Highest	2nd highest
	31 - 50 yrs	2nd highest	Highest	Highest	2nd highest	2nd highest		Highest
	> 50 yrs	Least	Least	Least	Highest	Least	2nd highest	Highest
Willows	< 31 yrs	2nd highest	Highest	Highest	2nd highest	2nd highest		Least
	31 - 50 yrs	Least	2nd highest	2nd highest	Least		Highest	2nd highest
	> 50 yrs	Highest	Highest	Highest	Highest	Highest	2nd highest	Highest
Mabins A	< 31 yrs	2nd highest	2nd highest	Highest	2nd highest	2nd highest	Highest	2nd highest
	31 - 50 yrs	Least	Least	Least	Least	Highest		Highest
	> 50 yrs	Highest	Highest	2nd highest	Highest	Least	Highest	Least
KwaJobe	< 31 yrs	Least	2nd highest	2nd highest	2nd highest	2nd highest	2nd highest	2nd highest
	31 - 50 yrs	Highest	Highest	Highest		Highest	Least	2nd highest
	> 50 yrs	2nd highest	Least	Least	Highest	Highest	Highest	Highest
KwaNompodo	< 31 yrs	Least	2nd highest	Highest	2nd highest	Highest	2nd highest	
	31 - 50 yrs	Highest	2nd highest	Highest	2nd highest	Least	Highest	Highest
	> 50 yrs	2nd highest	Highest	2nd highest	Highest	2nd highest	Least	2nd highest
Tidbury	< 31 yrs	Least	Least	2nd highest	Highest	Least	2nd highest	
	31 - 50 yrs	2nd highest	2nd highest	Highest	2nd highest	Highest	Highest	
	> 50 yrs	Highest	Highest	Highest		2nd highest	2nd highest	
Fairbairn	< 31 yrs	Highest	Highest	Highest	Highest	Least	Highest	
	31 - 50 yrs	Least	2nd highest	Least	Least	2nd highest		
	> 50 yrs	2nd highest	Least	2nd highest	2nd highest	Highest	Highest	
Ntilini	< 31 yrs	Highest	2nd highest	Highest	Highest	Least	Least	
	31 - 50 yrs	Least	Highest	2nd highest	2nd highest	2nd highest	2nd highest	
	> 50 yrs	2nd highest	Least	2nd highest	2nd highest	Highest	Highest	
Limpopo Province	< 31 yrs	Highest	Highest	Highest	2nd highest	Highest	2nd highest	2nd highest
	31 - 50 yrs	Least	Least	2nd highest	Least	2nd highest	Least	Highest
	> 50 yrs	2nd highest	2nd highest	2nd highest	Highest	Least	Highest	Highest
KwaZulu-Natal	< 31 yrs	2nd highest	2nd highest	2nd highest	2nd highest	Highest	2nd highest	Least
	31 - 50 yrs	Highest	Highest	Highest	Least	Least	Highest	2nd highest
	> 50 yrs	Highest	Least	Least	Highest	2nd highest	Least	Highest
Eastern Cape	< 31 yrs	2nd highest	2nd highest	Highest	Highest	Least	Least	
	31 - 50 yrs	Least	2nd highest	Least	Least	2nd highest	Highest	
	> 50 yrs	Highest	Highest	2nd highest	2nd highest	Highest	2nd highest	
All Sites	< 31 yrs	2nd highest	2nd highest	Highest	2nd highest	Highest	2nd highest	2nd highest
	31 - 50 yrs	Least	Highest	2nd highest	Least	2nd highest	Highest	Highest
	> 50 yrs	Highest	Least	Least	Highest	Least	Highest	Highest

Highest: Group with highest numbers of woody plants for a corresponding use category
2nd highest: Group with 2nd highest numbers of woody plants for use category
Least: Group with least numbers of woody plants for a corresponding use category
Empty cells denote no species was recorded for use category

5. DISCUSSION AND CONCLUSIONS

5.1. Diversity and numbers of woody plant species

Many indigenous and local communities possess unique experiences in the harvesting and use of woody plants (Figueiredo et al., 1993; Salick, 1995; Stagegaard et al., 2002; Kristensen and Balslev, 2003; Scherrer et al., 2005). As a result, indigenous communities have been able to manage genetic resources, majority of which often form the selection basis of land races in agriculture. Some of the managerial knowledge of local people may be administered through cultural factors such as taboos that placed limitation on resource use and mediated by cultural diversity through age and gender differentiation (Wickramasinghe et al., 1996; Rocheleau and Edmunds, 1997; Styger et al., 1999). Although females are noted for their access to NTFPs more than males (Bradley and McNamara, 1993; Hansen, 1998; Stratford and Davidson, 2002; Lado, 2004; Dovie et al., 2005), this attribute of the females did not translate into the expected higher level of knowledge observed in this study especially with the older age group. The diversity in knowledge is often attributable to the role of age and gender groups in society that translates mostly into division of labour at the household level and even to the community level. Groups seeking to live and work in the big cities for instance may be least knowledgeable about local resources (Styger et al., 1999), (e.g., the male group aged 31–50 years). It would have been plausible to conclude that the older generation will be more knowledgeable because of many years of association with the natural environment but their knowledge base could also be influenced by changes in livelihoods and the probable local extinctions of species previously known to them. Dovie et al. (2005) reports that females in rural areas often changed their livelihood options in response to household needs because males spent long working lives in the cities. In spite of this, there may be variations in ethnicity and cultural space, playing important roles across different ethnic and cultural regions. Based on these social dynamics, it made sense to pose the two hypotheses underlying the study and that the older generation and females will be far more knowledgeable in listing the useful woody plants. The results however showed that older men and not women were more knowledgeable.

The hypothesis that female perceptions of woody species diversity and numbers could be higher than for males also did not hold as males scored higher numbers and diversity of the woody species. However, females aged below 51 years were more knowledgeable, compared to their male counterparts. Yet the overall female knowledge weightings fell short of the males due to the very high score by the older men. This result represents a big change as one would have expected the older generations of the females to be more knowledgeable.

Generation has therefore played a role in the success of the older males and not their female counterparts. It has also been suggested that because older males spend most of their time in the fields clearing vegetation to farm, they also have more numerous and lengthy encounters with more woody plant species than females (Kristensen and Balslev, 2003). Emerging questions will be (i) do the older generation of females focus on the role and efficiency of species they use, and not particularly the names of the species? (ii) do older women associate more with woody species in the immediate household surroundings (Styger et al., 1999) than areas remote from households? (iii) could low education and culture of a probable majority of older women in remote poverty-stricken rural communities have contributed in undermining their exploration of nature and hence the names of woody plant species in their microenvironments? (iv) why were middle-aged and younger female groups far more knowledgeable in naming the species? Results of the study however suggest that the older females were specialists in woody plant species useful for fuelwood and local beverages, while the older males can be considered as generalists in their resource knowledge base. Secondly, it was possible that because females do most of the household work, their focus is often on the homestead environs (most especially the older women). Although they go out frequently during the week to do some activity such as collection of wood and the harvesting of wild fruits, they may not necessarily pay attention to the species that they do not access. Hence they tend to specialise in the resources around the homesteads, dominated often by herbs (not considered in this study) rather than woody plants. It is possible that the education of females had played a significant role when assessing the last two questions. In the social profile of one of the study sites, it was documented that the middle aged women had good levels of education compared to the older ones (see Dovie et al., 2005).

5.2. Woody plant diversity and use trajectories

Of the combined total of 267 species that were recorded in this study, some were found to have occurred in more than one vegetation type. More of the listed species occurred in the Mixed lowveld bushveld, but having the least number of families, while the least species numbers listed occurred in the Eastern thorn bushveld, but with the highest number of plant families. The differences in species diversity between the nine study sites were low, suggesting similarity in knowledge about species diversity (Table 3a and 3b). However, there were significant differences in the species numbers at the individual sites. This is supported by the significant difference between the total numbers of species in KwaJobe (within a biodiversity hotspot) and seven other sites. The dominant plant families were the Fabaceae and Euphorbiaceae, as a result of the multiple uses associated with the species. The families Celastraceae, Anacardiaceae and Ebenaceae also exhibited relatively high numbers of species having multiples uses. Some species had up to eight uses, and are potentially at greater risk of over-use (due to the multiple demands) and hence this should be reflected in the conservation status of the species. The high numbers of multiple use species has similarly been shown in an Eastern Cape study (Cocks and Wiersum, 2003). The few species that were already listed in local and Regional IUCN Red Data Lists were mostly in the families not associated with multiple uses. However, *Combretum collinum* (Combretaceae) has multiple uses, as does *Trichocladus ellipticus* (Hamamelidaceae). The fifteen tree species that appear in the plant lists currently protected by law in South Africa according to criteria such as the extent of use, keystone or cultural (DWAF, 2002) had multiple uses in this study.

Thus, there is the need to implement a locally comprehensive Red Data List strategy to recognise the state of species locally, based on indigenous knowledge and paving the way for further scientific study rather than relying only on using the conventional standards. Most importantly none of those species listed as becoming less available by the local people were included in the protected tree species of South Africa and thus potentially exposing a weakness in the conservation assessments of threatened status of species at local levels such as communal area villages. The culture of indigenous communities to diversify (McNeely, 1992; Ladio and Lozada, 2004) can help explain similarities associated with extreme uses of the fewer species (DCA results). This culture of resource use could help select species to be conserved as contribution towards livelihoods and biodiversity, especially in areas outside of protected areas. There were more species used for medicine compared to the remaining use categories. A number of the species used for medicinal purposes are known to be used often for cultural purposes (Cocks and Dold, 2004). The absence or partial supply of electricity and building materials (see Dovie, 2003; Dovie et al., 2004) could have contributed to the high numbers of species selected over the years for use as fuelwood and indigenous housing poles.

5.3. Implications of the study for conservation

5.3.1. Contributions to plant studies

Local and indigenous knowledge are useful and valuable sources of information in designing and implementing biological inventories and providing basic local information on local conditions (Wong et al., 2001). This is because biological and environmental factors alone may not adequately justify the conservation assessment of the status of particular wild species where direct harvesting and land cover changes are evident. Ecologically, local knowledge can therefore provide intellectual raw material in the context of resource use. For useful woody plant species, this knowledge can fall under the following four broad categories and the elements associated with them.

a) Plant and habitat characteristics and assessment (e.g., selecting species and habitats to study, history of species productivity, regeneration and viability, demography, species diversity, ecotypes, links with environmental variables, and habitat preferences of plants).
b) Sustainability and conservation (e.g., yield and impact studies, assessing and monitoring changes in resource availability, patterns and scale of variability in productivity and sustainability, status of community structure, ecological and habitat processes, and regeneration assessment).
c) Methodological development, planning, surveys, and monitoring.
d) Management (e.g., integrated and ecosystem-based decision making, levels of management and associated criteria).

The contributions of local knowledge to the ecological parameters indicated above will require a coherent synergy between indigenous and scientific knowledge. This synergy will have to deal with the mismatch between scientific and local definitions and meanings of woody plant resources and characteristics (Salick et al., 1999; Wong et al., 2001) and the mismatches of scale of assessments and management. The evolving discipline of "sustainability science" seeks to pursue the understanding of disciplinary and scale divides (Kates et al., 2000). In this case, the use of traditional nomenclature and classification should become an important element of biodiversity in assessing the conservation status of species, benefits and sustainability. Local knowledge that allows for the retrieval of overall concepts such as in ecology and related disciplines (e.g., conservation biology, taxonomy and systematics), will expand the information base of the disciplines.

5.3.2. The "Locally Brown List" for species level threats

The fourth broad category on implications of local and indigenous knowledge for management purposes above filters to setting various threat criteria for species locally. The scaling down of Red data lists to the local level (e.g., human communities and surrounding vegetation) will either be extremely difficult or impossible to do but there is the need to bring this knowledge to the grassroots by developing an appropriate system. This system will provide information for biologists to conduct further scientific research inquiries and also to policymakers not familiar with scientific criteria for decision-making. It is a well known fact that the agricultural and the forestry sectors have chalked-up various successes in the integration of indigenous knowledge and formal scientific knowledge (Posey, 1993; Rhoades and Bebbington, 1995; Sinclair and Walker, 1999). Based on the information from this study, related to human communities on the local availability of useful woody plants, a "Locally Brown List (LBL)" is proposed to describe locally utilised species that may be threatened locally and dependent on indigenous knowledge. Brown was chosen to imply "half-refined" because there may initially be no biological data other than species names and location which may not relate to taxa level threatened lists (e.g., IUCN, 2001; Victor and Keith, 2004) because of differences in scale and content. Three broad categories of the LBL are described. A "data deficient" has been selected as a starting point for the hierarchy to represent the absence of scientific assessment and also because it is often difficult for local people to accurately define the threat status of a species in scientific terms. They often use terms that imply "rare or encountering species based on a time period, or the difficulty in encountering species". Adding these to the biologically data deficient category then provides the opportunity for scientists to hypothesize that, the species could be worth investigating for a threatened status (Figure 5). The use of a species level threatened data will be informative at the local level when dealing with species that are useful to humans yet often disturbed or removed from their habitats for purposes other than their direct uses (e.g., farming).

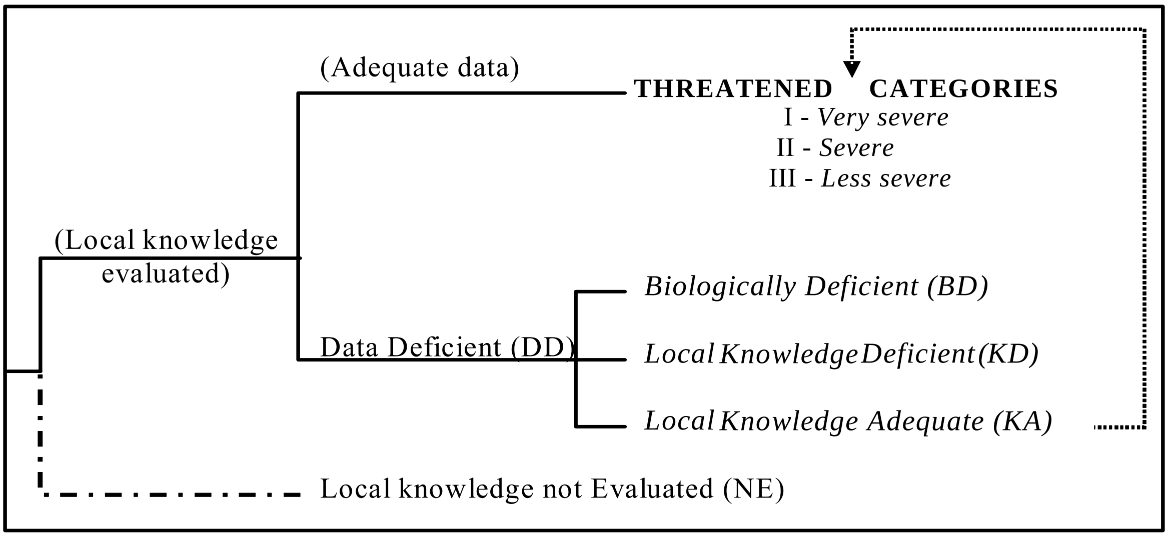

Figure 5. A "Locally Brown List" in assessing the threat status of useful woody plant species at local village levels based on the knowledge of local people.

1) Biologically Deficient (BD): This fulfils the requirements of limited or no biological information, and can therefore be written as “DD BD”.
2) Local Knowledge Deficient (KD): This subcategory identifies with the description that the available local knowledge cannot be confirmed to be robust and that the knowledge assessment carried out by the local people is incomplete, and can be cited as “DD KD”.
3) Local Knowledge Adequate: This subcategory implies that there is sufficient local evidence to determine whether or not the species is threatened, and expressed as “DD KA”. If there is enough justification to put the species with the sufficient local knowledge under any of the threatened categories, then the citation becomes “DD KA + threatened category citation, i.e., I, II, III”. The equivalent of ‘I’ in Red List terms will be ‘critically endangered’, ‘II’ will represent ‘endangered’ and ‘III’ vulnerable. This local knowledge category will have three levels to represent local perception, and opinion. These are:
   a) Species no longer in existence and cannot be encountered in original habitat (citation: DD KA1).
   b) The existence of the species in a few of original habitat (citation: DD KA2).
   c) Species locally available and yet very difficult to encounter in original habitat (citation: DD KA3).

6. CONCLUSIONS

Age and gender like several other social features of society do shape knowledge on the selection and use of woody plants (as NTFPs). Although males and older people were generally more knowledgeable in the usefulness of woody plant species, high levels of variability existed within the various age and gender categories with respect to specific numbers of species known for defined uses (Kajembe, 1994; Styger et al., 1999; Matavele and Habib, 2000; Ladio and Lozada, 2004). There were species that were frequently mentioned and probably common, and others not, that will need some level of management, as well as those that were part of known threatened lists that would require specialised management needs. An example is the “orange list”, described by Victor and Keith (2004), which largely uses biological data, and the proposed local knowledge categorization, the “Locally Brown List” from this study. The implication thereof is that practical knowledge about resource use by local people is a pointer to assessing the conservation status of useful woody plant species (Guyer and Richards, 1996). Using methods that fully accommodate all gender and age groups to assess information about local resource use will provide specific information on the relationships between humans and biological diversity. In conclusion, detailed outcomes of the analyses of this study suggest that females (especially the middle-aged) and younger people represent key elements of change, having the knowledge to contribute to conservation assessment and ecological work. The proposal to integrate local knowledge into science using specific protocols only suggests the prioritisation of species towards appropriate biological assessment and additionally to capture ecologically "less important" but anthropogenically important species and not to set priorities for conservation. Diversity in knowledge is expected to create awareness of threats to natural resources, impacting on livelihoods and the future of natural resources. Such knowledge will better inform conservation and development policy noted to exclude and often barring local people from access to resources. In conclusion, there is the need to rethink the use of modern science alone to inform policy by testing the impacts of local and indigenous knowledge (Sinclair and Walker, 1999) and skill to facilitate inclusiveness at all levels of decision-making.

References

Berlin, B., 1992. Ethnobiological Classification: Principles of Categorization of Plants and Animals in Traditional Societies. Princeton University Press, Princeton.

Bradley, P.N., McNamara, K., 1993. Living with trees, policies for forestry management in Zimbabwe. World Bank Technical paper no. 210. The World Bank, Washington DC.

Campbell, B.M., Costanza, R., Van der belt, M., 2000. Land use options in dry tropical woodland ecosystems in Zimbabwe: Introduction, overview and synthesis. Ecological Economics 33, 341-351.

Chazdon, R.L., Coe, F.G., 1999. Ethnobotany of woody species in secondary-growth, old-growth, and selectively logged forests of Northeastern Costa Rica. Conservation Biology 13(6), 1312-1322.

Cocks, M., Dold, T., 2004. The informal trade of *Cassipourea flanaganii* as a cosmetic in South Africa. In: Sunderland, T.C.H., Ndoye, O. (Eds.), Forest Products, Livelihoods and Conservation: Case Studies of Non-Timber Forest Products Systems, Vol. 2, Africa. CIFOR, Bogor, pp. 73-90.

Cocks, M.L., Wiersum, K.F., 2003. The significance of plant diversity to rural households in Eastern Cape province of South Africa. Forests, Trees and Livelihoods 13, 39-58.

Coe, F., Anderson, G., 1997. Ethnobotany of the Miskitu of eastern Nicaragua. Journal of Ethnobotany 17, 171-214.

Coe, F., Anderson, G., 1999. Ethnobotany of the Sumu (Ulwa) of south-eastern Nicaragua and comparisons with the Miskitu plant lore. Economic Botany 53, 342-365.

Cunningham A.B., Davis G.W., 1997. Human Use of Plants. In: Cowling, R.M., Richardson, D.M., Pierce, S.M. (Eds.), Vegetation of Southern Africa. Cambridge University Press, Cambridge, pp. 474-506.

Cunningham, A., 1996. People, park and plant use. Recommendations for multiple-use zones and development alternatives around Bwindi Impenetrable National Park, Uganda. People and Plants Working Paper No. 4. UNESCO, Paris, pp. 58.

Cunningham, A., Mbenkum, F.T., 1993. Sustainability of harvesting *Prunus africana* bark in Cameroon. People and Plants working Paper. UNESCO, Paris, pp. 28.

Cunningham, A.B., 1987. Commercial Craftwork: Balancing out human needs and resources. South African Journal of Botany 53(4), 259-266.
Djik, J.F.W., 1999. An assessment of non-wood forest product resources for the development of sustainable commercial extraction. In: Sunderland, T.C.H., Clark, L.E., Vantomme, P. (Eds.), Non-Wood Forest Products of Central Africa: Current Research Issues and Prospects for Conservation and Development. FAO, Rome, pp. 37-49.
Dovie, D.B.K., Witkowski, E.T.F., Shackleton, C.M., 2005. Monetary valuation of livelihoods for understanding the composition and complexity of rural households. Agriculture and Human Values 22, 87-103.
Dovie, D.B.K., Witkowski, E.T.F., Shackleton, C.M., 2004. The fuelwood crisis in southern Africa – relating fuelwood use to livelihoods in a rural village. GeoJournal 60(2), 123-133.
Dovie, D.B.K., 2003. Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa? International Journal of Sustainable Development and World Ecology 10, 247-262.
Dovie, D.B.K., Shackleton, C.M., Witkowski, E.T.F., 2002. Direct-use values of woodland resources consumed and traded in a South African village. International Journal of Sustainable Development and World Ecology 9(3), 269-283.
DWAF, 2002. Revision of the National List of Protected Trees as per Section 12, National Forests Act of 1998. NBI, Pretoria.
Dzerefos, C., Shackleton, C.M., Witkowski, E.T.F., 1999. Sustainable utilisation of woodrose-producing mistletoes (Loranthaceae) in South Africa. Economic Botany 53(4), 439-447.
Elisabetsky, E., 1996. Community ethnobotany: setting foundations for an informed decision on trading rain forest resources. In: Balick, J., Elisabetsky, E., Laird, S.A. (Eds.), Medicinal Resources of the Tropical Forest: Biodiversity and its Importance to Human Health, Ecology and Resource Management Series. Columbia University Press, New York, pp. 402-420.
Figueiredo, G.M., Leitao-Filho, H.F., Begossi, A., 1993. Ethnobotany of Atlantic forest coastal communities: diversity of plant uses in Gamboa (Itacuruca Island, Brazil). Human Ecology 21, 420-430.
Guyer, J., Richards, P., 1996. The invention of biodiversity: social perspectives on the management of biological variety in Africa. Africa 66(1), 1-13.
Hansen, B., 1998. Changing patterns of natural woodland dependency and use – intergenerational perceptions, traditions and customs: a case study of Bushbuckridge district, Northern province, South Africa. Unpublished MA Thesis, University of Copenhagen, Copenhagen.
Hilton-Taylor, C., 1996. Red data list of Southern African plants. Stretlizia 4, National Botanical Institute, Pretoria.
Hunn, E., 1993. "What is traditional ecological knowledge?" and "the ethnobiological foundation for traditional ecological knowledge." In: Williams, N.M., Baines, G. (Eds.), Traditional Ecological Knowledge: Wisdom for Sustainable Development. Centre for Resource and Environmental Studies, Australian National University, Canberra, pp. 13-20.
IUCN, 2001. IUCN Red list categories and criteria: Version 3.1. IUCN, Gland.
Johnson, L.M., 2000. A place that's good – Gitsan landscape perception and ethnoecology. Human Ecology 28(2), 301-325.
Kajembe, G.C., 1994. Indigenous management systems as a basis for community forestry in Tanzania: a case study of Dodoma urban and Lushoto Districts. Tropical resources Management Papers No. 6, Wageningen Agricultural University, Wageningen.
Kates, R.W., Clark, W.C., Corell, R., Hall, M.J., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bollin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grübler, A.,

Huntley, B., Jäger, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P., Mooney, H., Moore III, B., O'Riordan T., Svedin, U., 2001. Sustainability Science. Science 292, 641-642.
Kleymeyer, C.D., 1994. Cultural traditions and community-based conservation. In: Western, D., Wright, M., Strum, S. (Eds.), Natural Connections: Perspectives in Community-Based Conservation. Island Press, Washington DC, pp. 323-346.
Kreuger, R.A., 1988. Focus groups: A practical guide for applied research. Sage, London.
Kristensen, M., Balslev, H., 2003. Perceptions, use and availability of woody plants among the Gourounsi in Burkina Faso. Biodiversity and Conservation 12(8), 1715-1739.
Ladio, A.H., Lozada, M., 2004. Patterns of use and knowledge of wild edible plants in distinct ecological environments: a case study of a Mapuche community from northwestern Patagonia. Biodiversity and Conservation 13(6), 1153-1173.
Lado, C., 2004. Sustainable environmental resource utilisation: a case study of farmers' ethnobotanical knowledge and rural change in Bungoma district, Kenya. Applied Geography 24, 281-302.
Lawes, M.J., Eeley, H.C., Shackleton, C.M., Geach, B.S. (Eds.), 2004. Indigenous Forests and Woodlands in South Africa: Policy, People and Practice. University of Natal Press, Durban.
Letsela, T., Witkowski, E.T.F., Balkwill, K., 2002. Direct use values of communal resources in Bokong and Tsehlanyane in Lesotho: whither the commons? International Journal of Sustainable Development and World Ecology 9, 351-368.
Luoga, E.J. Witkowski, E.T.F., Balkwill, K., 2000. Differential utilisation and ethnobotany of trees in Kitulanghalo Forest Reserve and surrounding communal lands. Economic Botany 54, 328-343.
Lykke, M.A., Fog, B., Madsen, J.E., 1999. Woody vegetation changes in the Sahel of Burkina Faso assessed by means of local knowledge, aerial photos, and botanical investigations. Danish Journal of Geography (Special Issue) 2, 57-68.
Magurran, A.E., 2004. Measuring biological diversity. Blackwell Publishing, Malden, Oxford, Carleton.
Manandhar, N., 1995. An inventory of some herbal drugs of Myagdi District, Nepal. Economic Botany 49(4), 371-379.
Matavele, J., Habib, M., 2000. Ethnobotany in Cabo Delgado, Mozambique: use of medicinal plants. Environment, Development and Sustainability 2, 227- 234.
McNeely, J., 1992. Nature and Culture: conservation needs them both. Nature 28(3), 37-43.
Mies, M., Shiva, V., 1993. Ecofeminism. Zed Books, London.
Posey, D.A., 1993. Indigenous knowledge in the conservation and use of world forests. In: Ramakshina, K., Woodwell, G. (Eds.), World Forests for the Future, their Use and Conservation. Yale University Press, New York.
Rhoades, R., Bebbington, A.J., 1995. Farmers who experiment: an untapped resource for agricultural research and development. In: Warren, D.M., Slikkerveer, L.J., Brokensha, D. (Eds.), The Cultural Dimension of Indigenous Knowledge Systems. Intermediate Technology Publications, London, pp. 269-307.
Rocheleau, D., Edmunds, D., 1997. Women, men and trees: gender, power and property in forest and agrarian landscapes. World Development 25(8), 1351-1371.
Romero, C., Dovie, D.B.K., Luoga, E., Schmmidt, S., Gambiza, J., Grundy, I. in press. The effects of commercial bark harvesting on Baobab Adansonia digitata in the Save Odzi valley, with considerations for management, In: Household Livelihoods, Marketing and Resource Impacts: A Case Study of Bark Products in Eastern Zimbabwe. Advances in Economic Botany.

Salick, J., 1995. Toward an integration of evolutionary ecology and economic botany: personal perspectives on plant/people interactions. Annals of the Missouri Botanical Garden 82, 68-85.
Salick, J., Bium, A., Martin, G., Apin, L., Beaman, R., 1999. Whence useful plants? A direct relationship between biodiversity and useful plants among the Dusun of Mt. Kinabalu. Biodiversity and Conservation 8, 797-818.
Scherrer, A.M., Motti, R., Weckerle, C.S., 2005. Traditional plant use in the areas of Monte Vesole and Ascea, Cilento National Park (Campania, Southern Italy). Journal of Ethnopharmacology 97, 129-143.
Scoones, I.C., Melnyk, M., Pretty, J. (Eds.), 1992. The Hidden Harvest: Wild Foods and Agricultural Systems. A literature review and annotated bibliography, 111.1. ODI, London.
Scott-Shaw, R., 1999. Rare and threatened plants of KwaZulu-Natal and neighbouring regions. KwaZulu-Natal Nature Conservation Service, Cascades.
Shackleton, C.M., Shackleton, S.E., Ntsudu, M., Ntzebeza, J., 2002. The role and value of savanna non-timber forest products to rural households in the Kat River Valley, South Africa. Journal of Tropical Forest Products 8(1), 45-65.
Sinclair, F.L., Walker, D.H., 1999. A utilitarian approach to the incorporation of local knowledge in agroforestry research and extension. In: Buck, L.E., Lassoie, P., Fernandes, E.C.M. (Eds.), Agroforestry in Sustainable Agricultural Systems. Lewis Publishers, pp. 245-275.
Stagegaard, J., Sorensen, M., Kvist, L.P., 2002. Estimations of the importance of plant resources extracted by inhabitants of the Peruvian Amazon flood plains. Perspectives in Plant Ecology, Evolution and Systematics 5(2), 103-122.
StatSoft, Inc. 2002. STATISTICA for windows. StatSoft, Inc., Tulsa.
Stratford, E., Davidson, J., 2002. Capital assets and intercultural borderlands: socio-cultural challenges for natural resource management. Environmental Management 66, 429-440.
Styger, E., Rakotoarimanana, J.E.M., Rabevohitra, R., Fernandes, E.C.M., 1999. Indigenous fruit trees of Madagascar: potential components of agroforestry systems to improve human nutrition and restore biological diversity. Agroforestry Systems 46, 289-310.
ter Braak, C.J.F., 2003. Program CANOCO version 4.5. Centre for Biometry, Wageningen.
Victor, J.E., Keith, M., 2004. The Orange list: a safety net for biodiversity in South Africa. South African Journal of Science 100, 139-141.
Wickramasinghe, A., Ruiz-Perez, M., Blochus, J.I., 1996. Non-timber forest products gathering in Ritigala forest (Sri Lanka): household strategies and community differentiation. Human Ecology 24, 493-519.
Wild, R.G., Mutebi, J., 1996. Conservation through community use of plant resources: establishing collaborative management at Bwindi Impenetrable and Mgahinga Gorilla National Parks, Uganda. People and Plants Working Paper 5. UNESCO, Paris.
Williams, L.V., Balkwill, K., Witkowski, E.T.F., 2001. A lexicon of plants traded in the Witwatersrand umuthi (medicinal) shops, South Africa. Bothalia 31, 71-98.
Wong, L.G., Thornber, K., Baker, N., 2001. Resource assessment of non-wood forest products. Experience and biometric principles. FAO, Rome.
WWF, 1994. Biodiversity in the Western Ghats – an information tool kit. World Wide Fund International for Nature, New Delhi.

CHAPTER 5

Relating knowledge from field ecology and local people for useful woody species in localised savanna environments

Abstract

The biggest challenge of the significant contribution of non-timber forest products (NTFPs) to majority of local and national economies is sustaining the products and their sources. Synergies between indigenous and scientific knowledge on locally available useful species will offer potential solutions to the challenge. In spite of the information that exists on merging ecological and social science research outcomes to optimise conservation goals, the merger has hardly been demonstrated empirically for NTFPs in savannas. Differences in the types of measurements and scales of assessment will be of concern, but can be managed (e.g., using absolute species numbers to represent sites, rather than the averages of replicates within sites). In this chapter, the absolute number of species sampled for each methodology represented the individual sites. From village workshops using focus group discussions (FGD) to ecological sampling using modified Whittaker plots (MWP), quantitative data on useful woody plant species were analysed across several sites within communal area savanna villages. Of the nine broad categories of NTFPs that were identified at the village level analysis, eight represented uses of species in the field plots. These were for medicine, wild edible fruits, fuelwood, housing and fencing poles, craft and cultural uses and local beverages. The total number of locally available useful woody species from MWP was 50.6% of that from FGD. The total co-occurring or shared species between the FGD and MWP was 101, belonging to 31 plant families and dominated by the Fabaceae (25 species). Significant differences between the FGD and MWP were recorded for the absolute number and diversity of the useful woody species in all the nine villages, suggesting differences in sampling for locally available useful woody species. The similarity between the FGD and MWP for total useful woody plant species could be described as intermediate, having a Sorenson index of 0.50. The cumulative number of shared useful woody species between the MWP and FGD correlated strongly ($r = 0.99$, $p < 0.0001$) across the nine villages. Housing and fencing poles, craft and fuelwood correlated strongly along the first PCA axis for FGD and MWP, with wild edible fruits and medicinal plants on the second PCA axis. The higher useful woody species numbers for the FGD possibly implies that local people were highly knowledgeable in what they encounter and use locally. As a result, merging the results of field and community level knowledge will increase the efficacy of ecological information gathering whilst improving the informed management of woody plant species assemblages and utilisation locally.

Keywords: Focus group discussion, local knowledge, modified Whittaker plots, NTFPs, savannas, Sorensen's index.

1. INTRODUCTION

1.1. The human ecology and resource use

The exploration of plant resources for pharmaceutical and agricultural purposes (i.e., bioprospecting) is a significant industry (Garcia-Brokhausen, 1997; Begossi et al., 2000; Wynberg and Swiderska, 2001; Ghimire et al., 2005), often operating to the detriment of the supplying country. Locally, pristine areas can be stripped of important species due to livelihood and market pressures of the local and traditional economies. The bioprospecting of plant resources are often based on knowledge from the long term nurturing of many species by indigenous communities, cultivated from co-evolutionary relationships between humans and their environment (Bell, 1995; Salick et al., 1999; Begossi et al., 2000; Cunningham, 2001; Ladio and Lozada, 2004). However, the relationships have often been viewed from a broader perspective which makes it difficult to relate to species assemblages, ecological patterns and processes. Several studies have recently shown that humans have consciously created niches that maintain precise relationships with biodiversity (Salick et al., 1999; Moore et al., 2002; Crivos et al., 2004). Without this diversity, the ability to adapt to changing needs and conditions would be lost (Sinclair and Walker, 1999; Koziell, 2001; Stankey and Shindler, 2006). For successful long-term conservation, peoples' knowledge of biodiversity is important (Ticktin, 2005; Ghimire et al., 2005; Lawrence et al., 2005), in addition to the fundamental biological characteristics (i.e., genetic strains, species) and ecological assemblages of the composition, structure and functions of biodiversity. Additionally, comprehending biodiversity's established or potential utility for human benefit and the ensuing trends in usage is vital for management. While these are well documented for a number of tropical rainforests, there are undoubtedly several gaps in our knowledge of savannas.

1.2. Ecological and social approaches for understanding NTFPs

Several techniques for evaluating, recording and inventorying biological and spatial dynamics of vegetation change are well documented (e.g., Whittaker, 1977; Greig-Smith, 1983; Stohlgren et al., 1995; Barnett and Stohlgren, 2003). The daunting tasks facing the techniques lie in the estimation and measurements of products obtained from such vegetation which is mostly utilised for non-timber forest products (NTFPs). The traditional studies of NTFPs are mostly ecological and carried out through inventory and mapping techniques (e.g., Phillips, 1983). The techniques range from the use of simple ground survey and aerial photography through to satellite imagery (e.g., Lykke et al., 1999). Foresters and ecologists use those methods for describing the distribution of species population in relation to size-class, structure and, or growth stages. The approaches are appropriate for understanding populations prone to harvesting and life cycle characteristics. The approaches further delve into the regeneration and quantitative measures of harvestable material, in addition to assessing the attributes of biodiversity. These have subsequently been usefully adopted and replicated in ethnobotanic research (e.g., Martin, 1995; Peters, 1996; Cunningham, 2001) although they may be woefully inadequate in the area of management. This is because the approaches often tend to omit societal judgement structures (e.g., norms, traditional rules, institutions) through which local decisions on resource use are made, often by resource poor rural communities. However, the sustainable use and development of NTFPs will largely depend on giving a high priority to society's understanding and use of biological resources and the broader social and economic roles of ecosystems (Ruiz Pérez and Byron, 1999).

The understanding of NTFP use provides complex and dynamic challenges beyond scientific or ecological theory because it is about human security, survival systems and adaptation to immediate and future options (Dovie, 2003a). This understanding will be invalidated if little or no attention is paid to the role of humans in studying NTFP resources. A methodological approach to holistic inventory and evaluation should as a matter of rule, rely on a full array of methods that elucidate the concurrent importance of socio-cultural, economic and scientific information. Therefore, demanding that approaches be implicit of the history of local people in relation to the exploitation and the local availability of species. Local knowledge, indigenous perception and local participation are beneficial for inclusion in approaches that seek to draw lessons from participatory action research, or learning approaches (Pretty, 1994; Buchy and Hoverman, 2000). However, the questions of how participatory are the approaches, at what scale and what they precisely seek to achieve have not been fully explored? Will one consider the use of questionnaires as participatory, if so within what context and if not, why? What are the guidelines for defining participation and participatory rather than 'meanings', and how different do people and groups define and perceive 'participation'? (Dovie, 2003b). These questions and several others remain realities that undermine the participation of local people in community-based forest resource utilisation and conservation projects. The decision by most research and development workers to involve local people whose livelihoods are dependent on NTFPs in projects, often remain unresolved during the planning process until there is a conflict during the project's lifecycle (Dovie, 2003b). The lingering perception of poverty, associated with NTFP – dependent resource-poor rural households has largely influenced investigations into these resources, such that local people have become the culprits of degradation. Hence there is the need to provide better meaning for NTFP assessment using non-ecologically based techniques, but having ecological relevance.

1.3. Interfacing ecological and community knowledge

If ecology can provide the basic knowledge required for enhancing local scientific and technical expertise for initiating sound conservation, then why not ethnography? To answer this question, the local availability and use of woody plant species were studied in highly diverse South African communal area savannas (Figure 1). The extraction of NTFPs, by rural communities was selected for this study. NTFPs have been well studied yet many difficulties transcend their management (Ticktin, 2005; Lawrence et al., 2005) and have prompted new approaches for understanding the synergies between ecological and local human attributes such as skill and knowledge underlying NTFP use, which will alleviate management bottlenecks. The inclusion of community knowledge in ecological studies is frequently ignored and only resulting in the least attention given to NTFPs in ecology motivated management schemes (Sandewall et al., 2001; Dovie, 2003b). Unless the interface between ecological and community knowledge are well understood and integrated, the processes and criteria for setting management criteria for NTFPs and hence biodiversity, will be compromised (Ruiz Pérez and Byron, 1999; Dovie, 2003b). The two-way understanding of useful woody species diversity is an important tool for ecologists trying to comprehend community structure and organization, rarity and commonness of species (Rosenzweig, 1995; Magurran, 2004) where human use is evident (Peters, 1996; Chazdon and Coe, 1999; Begossi et al., 2000; Ghimire et al., 2005). As part of this knowledge, a practical approach for relating community knowledge data on the absolute number and diversity of useful woody plant species locally available are examined. The objectives were, to (a) relate the understanding of the number and diversity of woody plant species based on ecological and community knowledge, (b) examine the implications of the relationships in (a) above for NTFP management, and (c) highlight emerging methodological issues and potential advances.

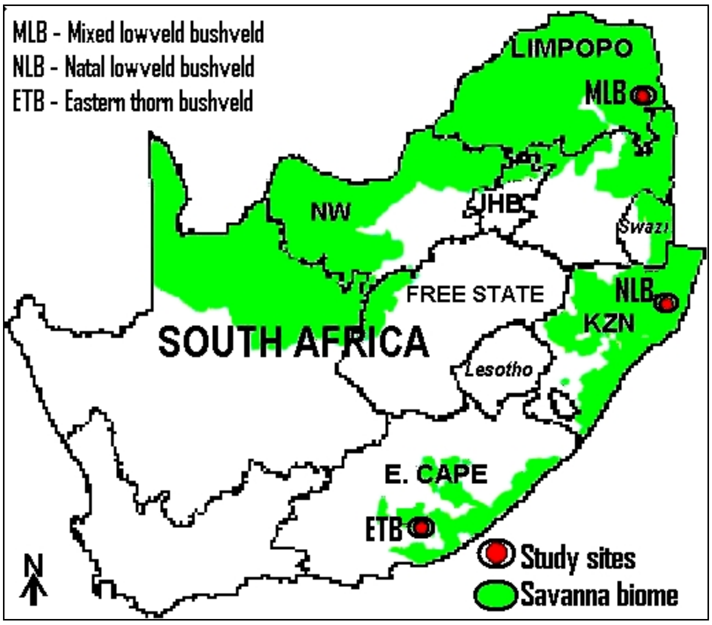

Figure 1. Broad location of the three vegetation types encountered in this study.

2. METHODS

2.1. Data collection

Participatory focus group discussions, 'FGD' were undertaken at all nine sites. The FGD entailed six groups based on age and gender for obtaining names of woody plant species and their uses. The focus groups at each site were made of individuals below 31 years old, 31–50 years, and 51 years and above, for both males and females (Figure 2a). The groupings were intended to capture differences in generation, gender knowledge and experiences of resource use. This permitted a balanced gender auditing as women are not allowed to speak out in the presence of men in certain traditional communities as part of their cultures. The focus groups were also run such that there was earlier consensus on time periods because women for instance need to take care of household chores whilst the men visited their fields. In some cases, young people had their own activities that were appropriately built into the process.

The modified Whittaker vegetation plots, denoted by 'MWP' (Stohlgren et al., 1995; Barnett and Stohlgren, 2003), were used for field sampling of woody plant species. The plots were laid along three ordinal disturbance gradients (transects) from village settlements (Shackleton et al., 1994). The location of the plots relative to the village were defined as near (close to village), far (close to edge of woodland away from village) and intermediate (between the two extremes). The placement was based on the assumption that harvesting intensity decreases with distance from human settlement (Shackleton et al., 1994; Sekhwela, 2003). The impacts of heavy development (e.g., infrastructure, farms) that constitute sources of major disturbance to vegetation, and known as edge effects were minimised by placing plots at significant distances from such sources. Sampling results from nine sites with nine plots each (n = 81) were used from original 10 sites. This was because there were no focus groups results from one of the sites. Sub-sampling was carried out within a layout of an outer contiguous overlapping 0.1ha plots (Barnett and Stohlgren, 2003). Village key informants (e.g., Figure 2b) assisted in the initial identification and uses of species where applicable. Voucher specimens were collected for post field confirmation. A useful species was defined as one with direct uses to the local people including cultural purposes, and non-useful species were those with no such direct uses. Eight use categories were identified for the field sampling, which excluded wood for indigenous furniture that was observed for the FGD.

Figure 2. (a) Left: Focus group discussions in Finale A in the Mixed lowveld bushveld vegetation in the Limpopo province, with females aged 51 years and above, (b) Right: Local people participating in the placement of sampling plots, and identifying some species during transect walks at Fairbairn in the Eastern thorn bushveld, Eastern Cape province (Photo: DBK Dovie).

2.2. Data analysis

2.2.1. Community and field knowledge

A checklist of useful woody plant species was compiled for each site, based on local knowledge from six focus groups of age and gender. First, the species were pooled, and counted once (i.e., no species was counted twice) for each village to constitute the absolute number of species representing the respective site. Similarly in the field, all the species were pooled and counted at one appearance from all the MWPs to represent the absolute numbers for each village. Second, the number of times that each species appeared as listed by each of the six groups represented the number of the individual useful woody species for the FGD, the species richness equivalent of the MWP at each site. The ninth use category (i.e., indigenous furniture) recorded for the FGD but not MWP was excluded, leaving eight use categories for all analyses. The absolute number of species for each of the villages therefore formed the basis of the analysis for both the FGD and MWP. It implied that the replicates of gender and age groups at the FGD level and the plots and transects at the MWP level did not apply. The reason was to pool data that were analysable at the same scale (i.e., village level only) and minimising the effects of scale. The analyses of the broad vegetation types was based on the mean values of the absolute number of species and ensuing diversity from the villages studied within that vegetation type, and hence expressed in means and standard errors (SE). Similarly, values representing all the study sites combined were expressed as means and standard errors (SE).

The diversity of the useful species at each site was calculated using the Shannon Wiener Diversity Index (*H'*). This is defined as $H' = -\sum p_i \ln p_i$ where, $p_i = n_i / N$ is the relative abundance of useful species, n_i = individual useful woody species number, and N = total number of individuals (Magurran, 2004). The absolute useful species numbers and diversity for both MWP and FGD was graphically presented in bar graphs. Two broad definitions for useful species were used. First is the 'all useful species', representing all species that were identified to have uses for both the FGD and MWP. Second is the 'shared useful species', representing species that were identified from all the useful species to have concurrently appeared on both the FGD and MWP lists across the combined sites species. The shared species are therefore the subsets of the total number of the useful species. Useful woody species with limited distributions within Whittaker plots were referred to as "rare". The Sorensen's index (S_s) was used to measure the resemblance of the useful woody species that were recorded for both the FGD and MWP across the combined sites and at the village levels for the shared (joint) occurrences of the species based on the total shared species for all the sites. Hence, $S_s = 2a/(2a+b+c)$, where a = number of species present in sample 1 and 2, b = number of species present in sample 2 but absent from sample 1, c = number of species in sample 1 but absent from sample 2.

2.2.2. Statistics

Descriptive and univariate statistics were mostly used. A T - test was used to examine the mean number and diversity of useful species between the FGD and MWP across the combined sites for “all useful” and “shared” species. Scatterplots were used for establishing the correlations between the FGD and MWP all and shared absolute number and diversity of useful woody species, as well as their cumulative relationships. The scatterplots generated correlation coefficient values for comparisons between the numbers and diversity of the useful species. Principal component analysis (PCA) was used to examine the variation among useful species, their use categories and the broad level correlations for both the FGD and MWP using the programme CANOCO (Höft et al., 1999; ter Braak, 2003). STATISTICA Version 6 program (StatSoft, 2002) was used for the statistics.

2.2.3. Methodological limitation and resolution

The major methodological drawback that may be associated with integrating the knowledge of useful woody species sampled in the field using ecological techniques, and knowledge from the local people will be the difference in scale. It is important that the knowledge from the local people be based solely on the area or the microenvironment that will be sampled ecologically. The obvious emerging issue will be how to develop replicates that can be matched to generate meaningful comparisons and outcomes between two or more different sources of information. The limitation of minimising the differences in scale lies within the sampling scale of the vegetation. Whilst the community knowledge was based on the local vegetation in its entirety, the field knowledge drew its inferences from a representative sample of transects and plots that could not cover every species within the large expanse of the vegetation that resource extraction takes place. In this study, the absolute numbers of the species for each site were used rather than averages based on replicates (i.e., age and gender groups from FGD, transect and plots from MWP). As an attempt to integrate quantitative knowledge from two different perspectives, a lot more needs to be done in order to account for differences in the scale of measure. A regression fit from a correlation analysis resulting from the absolute number and diversity of species for the FGD and MWP has also been used to describe species in this study.

3. RESULTS

3.1. Absolute number and diversity of useful woody plant species

3.1.1. All useful woody plant species

Overall and at the broader useful woody plant species level, 267 useful woody species were recorded during the FGD compared to 135 sampled from the MWP. Whilst nine use categories were identified for the FGD species, eight were documented for the MWP. The nine for FGD were medicinal, wild edible fruits/seeds, fuelwood, housing and fencing poles, craft, and indigenous furniture, cultural and traditional beverages. The MWP use categories were without the indigenous furniture.

More absolute number of all useful species was recorded for the FGD than MWP at all nine sites (Figure 3a). The "all useful" woody species diversity followed the same trend as the absolute number of useful woody species at the nine individual sites (Figure 3b). The absolute number of all species differed significantly between the FGD and MWP (t = 6.49, df = 16, p <0.001), with the FGD having 63 ± 5.7 number of species per village (site) than the MWP (24.7 ± 1.4) (Figure 4a). Diversity also differed significantly (t = 9.5, df = 16, p <0.0001), between the FGD and MWP and FGD having higher diversity (H' = 3.9 ± 0.1) than the MWP (H' = 2.4 ± 0.1) across the combined sites (Figure 4b). At each of the sites, the absolute number and diversity of all useful woody species was highest for the FGD compared to the MWP. The mean absolute number of all useful woody species for both the FGD and MWP was highest for the Natal lowveld bushveld at 77.0 ± 23.0 and 27.5 ± 1.5, respectively (Table 1). The absolute diversity followed the same trend for the FGD. There was no correlation between the FGD and MWP absolute number and diversity of the useful woody species.

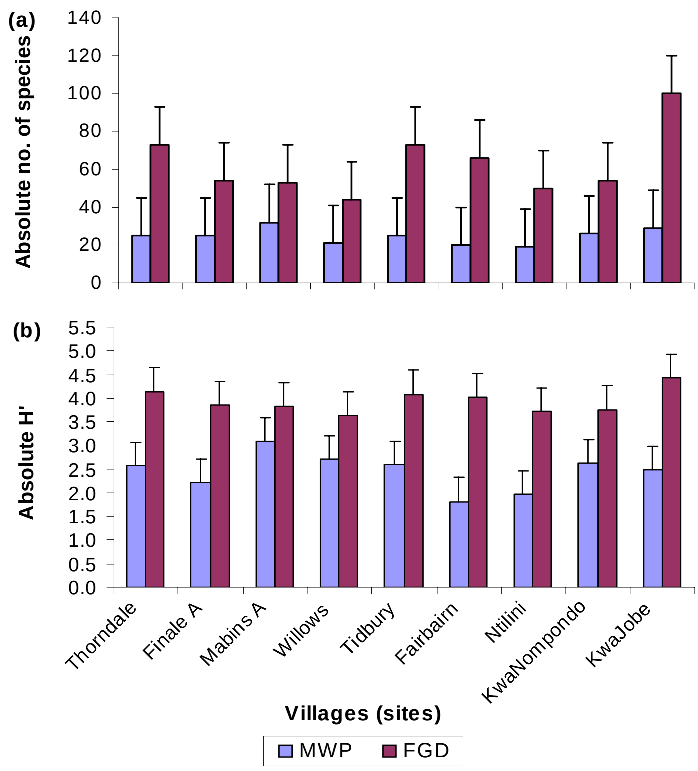

Figure 3. The absolute (a) numbers and (b) diversity, of all useful woody species for the FGD and MWP at all nine sites.

Table 1. The mean (±SE) absolute number and diversity of all useful woody species for the FGD and MWP within broad vegetation types.

Broad vegetation type	**Absolute no. of species**		**Absolute diversity**	
	MWP	**FGD**	**MWP**	**FGD**
Mixed lowveld bushveld	25.8 (2.3)	56.0 (6.1)	2.6 (0.2)	3.9 (0.1)
Eastern thorn bushveld	21.3 (1.9)	63.0 (6.8)	2.1 (0.2)	3.9 (0.1)
Natal lowveld bushveld	27.5 (1.5)	77.0 (23.0)	2.6 (0.1)	4.1 (0.3)

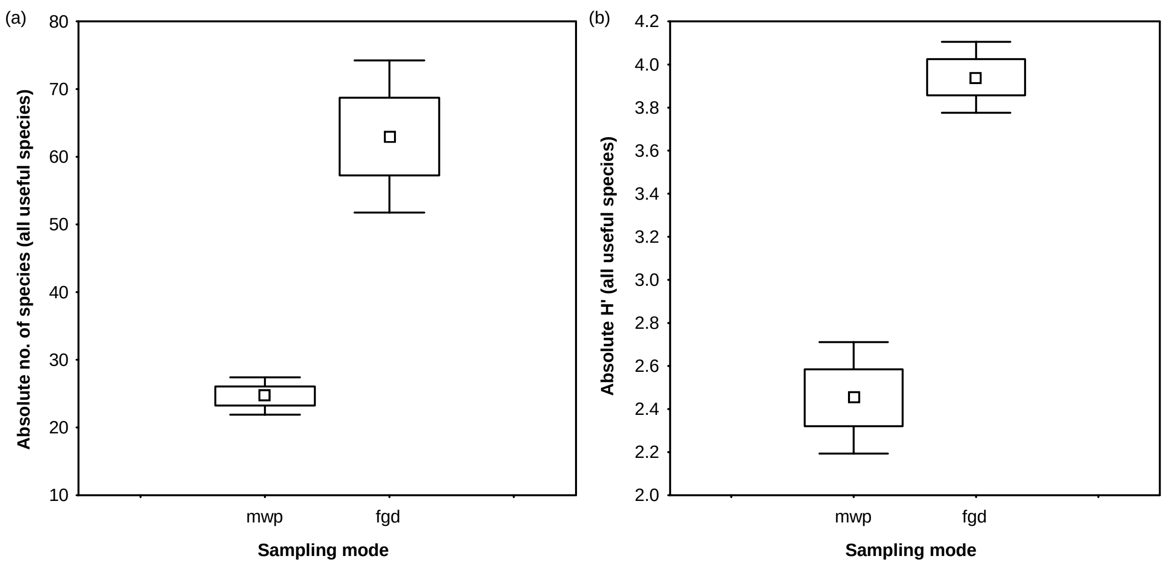

Figure 4. Box and Whisker plot for differences in absolute (a) number and (b) diversity, for the FGD and MWP sampling across combined sites for all the useful woody species.

3.1.2. The shared useful woody species

The 101 FGD and MWP shared useful woody species constituted 37.8% of all useful species of the FGD, and 74.8% of all the MWP useful species. The shared species belonged to 31 plant families. Of these 31 families, over half were represented by only six plant families namely, Fabaceae (25 species), Celastraceae (9), Ebenaceae (7), Rubiaceae (6), Combretaceae (6) and Anacardiaceae (6) (Appendix I). The MWP sampling showed that 66% of the shared useful woody species were restricted to particular locations, the majority occurring in the Mixed lowveld bushveld vegetation in the Limpopo province. Most of these restricted species were also found to have multiple uses. In reference to the restricted location of the useful species, *Strychnos madagascariensis* for example can be found in Finale A, Mabins A and Willows in the Mixed lowveld bushveld in the 'far' locations only, but at KwaNompondo in Natal lowveld bushveld within the 'intermediate' locations only. The remaining 34% of the species may be described as widespread and common across all locations of the sites within the respective broader vegetation types.

Apart from Mabins A in the Mixed lowveld bushveld vegetation where the absolute number of the shared useful woody species was higher for the MWP than the FGD, and much higher values for the remaining sites for the FGD (Figure 5a). Absolute species diversity was highest for the FGD at all nine sites (Figure 5b). There was a significant difference (t = 5.8, df = 16, $p < 0.00001$), between the FGD and MWP absolute number of useful species (Figure 6a), with the FGD having highest mean absolute number of species (30.0 ± 3.6) per village than MWP (22.2 ± 1.1). The absolute diversity between the FGD and MWP also differed significantly (t = 2.7, df = 16, $p < 0.05$) with the FGD having mean diversity (3.2 ± 0.1) higher than MWP (2.3 ± 0.1) (Figure 6b). The Mixed lowveld bushveld had the highest mean absolute number of species for the MWP (21.8 ± 1.3) whilst the Natal lowveld bushveld recorded the highest for the FGD (39.5 ± 12.5) (Table 2). The Eastern thorn bushveld recorded the least values for the absolute number of the woody species for the FGD and MWP. The diversity of the shared useful woody species followed the same trend as the absolute number of the shared useful woody species (Table 2). Cumulatively, the absolute number of shared useful woody species between the FGD and MWP were strongly correlated ($r = 0.99$, $p < 0.0001$; Figure 7).

Table 2. The mean (±SE) absolute number and diversity of shared useful woody species for the FGD and MWP within broad vegetation types.

Broad vegetation type	**Absolute no. of species**		**Absolute diversity**	
	MWP	**FGD**	**MWP**	**FGD**
Mixed lowveld bushveld	21.8 (1.3)	27.8 (5.8)	2.5 (0.2)	3.1 (0.2)
Eastern thorn bushveld	17.3 (1.9)	26.7 (0.9)	2.0 (0.2)	3.1 (0.0)
Natal lowveld bushveld	21.5 (2.5)	39.5 (12.5)	2.3 (0.1)	3.5 (0.3)

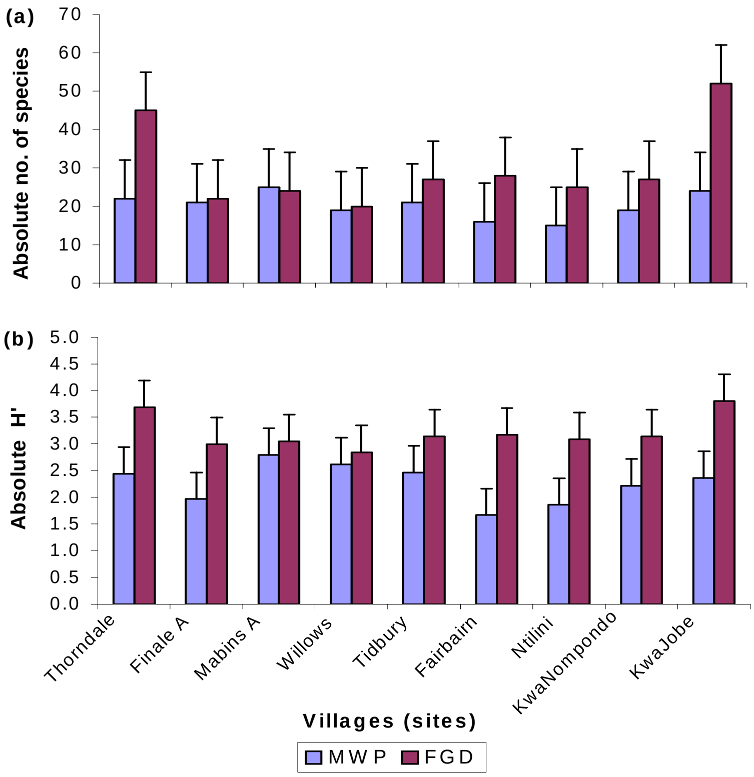

Figure 5. The absolute (a) numbers and (b) diversity, of shared useful woody species for the FGD and MWP at all nine sites.

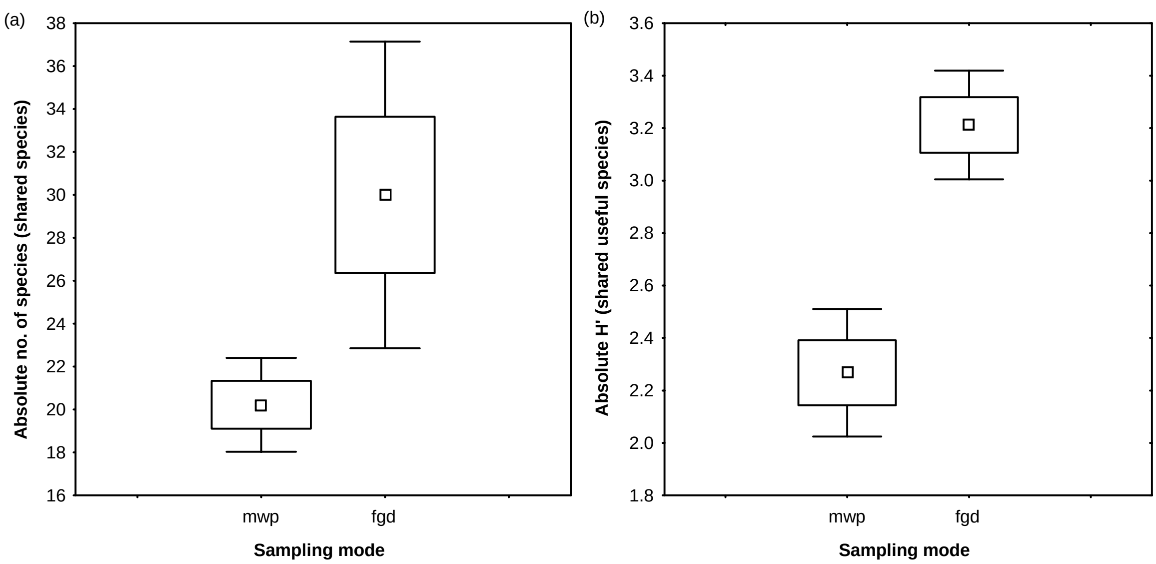

Figure 6. Box and Whisker plot for differences in absolute (a) number and (b) diversity, for the FGD and MWP sampling across combined sites for shared useful woody species.

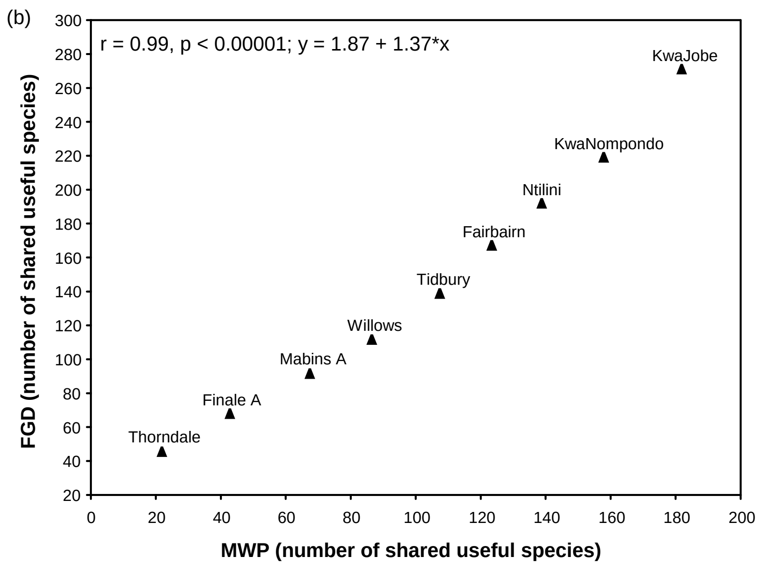

Figure 7. The scatter plot between the cumulative FGD and MWP absolute number of species across the combined sites.

3.2. Similarities between FGD and MWP useful woody species

The occurrences of the useful woody species recorded for the FGD and MWP across the combined sites showed intermediate resemblance in the diversity of the species (Sorensen index, S_s = 0.50). At the individual site levels, the shared useful woody species' resemblance within the overall shared useful species was highest in Ntilini (S_s = 0.60), followed by Tidbury (S_s = 0.58), Thorndale (S_s =0.57), KwaJobe (S_s = 0.53), Fairbairn (S_s = 0.50), KwaNompondo (S_s = 0.43), Willows (S_s = 0.41), Finale A (S_s = 0.37) and Mabins A (S_s = 0.33), in a decreasing order. The sites in the Eastern thorn bushveld therefore showed the highest resemblances in the diversity of the species for both the FGD and MWP, compared to the Natal lowveld bushveld and Mixed lowveld bushveld sites. The absolute shared useful species at the individual sites between the FGD and MWP was highest for KwaJobe at 20 species followed by Thorndale (19) and Tidbury (14) with the least in Final A, Mabins A and Willows all having eight species each and found in the Mixed lowveld bushveld.

The PCA biplot for the FGD showed that the first axis explained most of the variation among the variables, at 35.2% and the combined first two axes explaining more than half the total variance, with fuelwood, housing poles, craft and fencing poles correlating strongly with the first axis amongst eight use categories (Figure 8a). On the second axis however, the strong correlations involved wild edible fruits, fencing poles, medicinal and traditional beverage uses (Figure 8a). Similarly for the MWP, 36.6% of the variations among the variables were explained by the first axis, and the combined first and second axes explaining more than half of the total variation (Figure 8b). The first axis of the MWP plot (Figure 8b) correlated strongly with four use categories (i.e., housing poles, craft, fuelwood and fencing poles in a decreasing order), whilst the second axis correlated with wild edible fruits, fencing poles, medicinal and beverage uses, also in a decreasing order (Figure 8b). Only fencing poles correlated with the first and second PCA axes for both the FGD and MWP. Housing poles, craft, fuelwood and fencing poles strongly correlated with the first axis for both the FGD and MWP, whilst wild edible fruits and medicinal plants were the two strongly correlated use categories on the second axis for both the FGD and MWP. While the distribution of the useful woody species along both axes for the FGD showed a clumped attribute in two major groups, the useful species in the MWP were comparatively even and scattered. In both cases, high numbers of useful woody species were associated with wild edible fruits, also having the highest rate of change, followed by fuelwood and housing poles (for FGD) and, housing and fencing poles (for MWP).

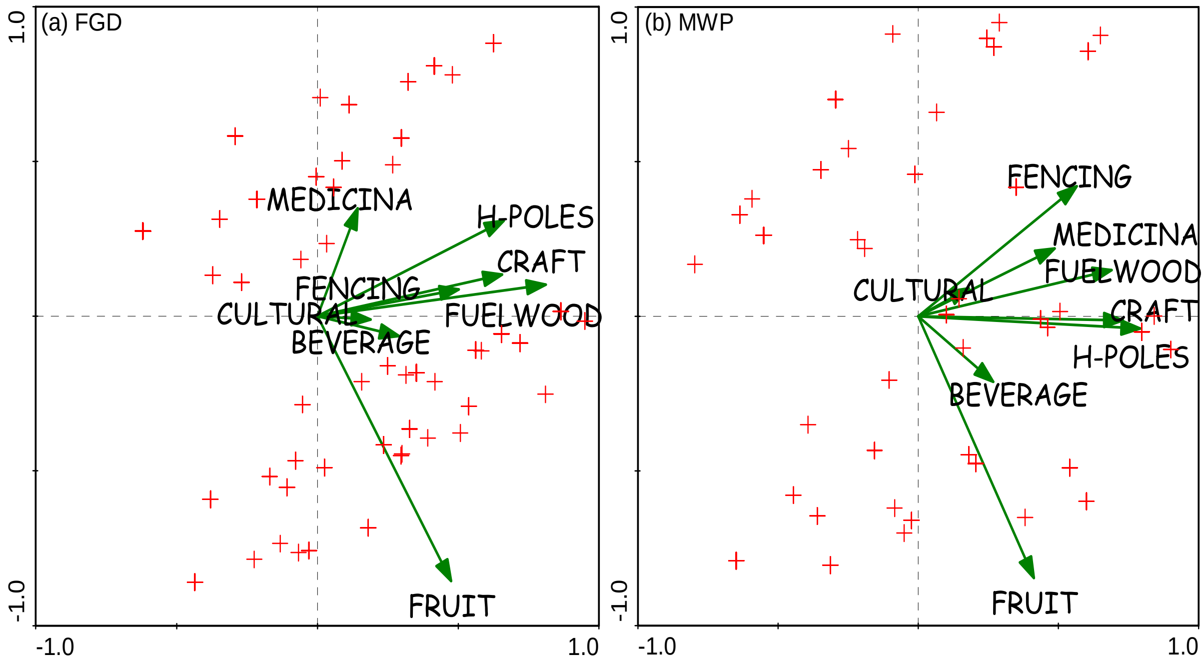

Figure 8. A PCA biplot comparing useful woody plant species (++) and use categories along the ordination axes for (a) FGD and (b) MWP, sampling.

4. DISCUSSION

4.1. Useful woody species numbers and diversity

Ecological methods are useful tools for assessing and understanding the state and assemblages of species and suggesting indicators for appropriate management (e.g., Schmida and Wilson, 1985; Stohlgren et al., 1995; Kunin and Lawton, 1996; Barnett and Stohlgren, 2003). They have provided important information about the population and conservation dynamics of a number of species (Chazdon and Coe, 1999; Cunningham, 2001; Ghimire et al., 2005). In the case of useful woody plant species, such information have more often than not, been based on physical evidence of use (e.g., clear felling of trees, cutting of branches, extensive harvesting of bark). Under the circumstance of physical evidence only, it becomes extremely difficult to detect or map out the frequently utilized woody species that may be facing threats of rarity, risk of extinction or opportunities of commonness. The utilization of woody plant species within the diverse savannas of South Africa through NTFPs come in different use categories, plant parts harvested, techniques and timing of harvesting, which may not necessarily show any physical signs of usage and harvests. The experiences of local harvesters and users will therefore become very pertinent sources of information, and mostly including history, and perceptions (Dovie, 2003b). Historical and experiential interventions of this nature will be needed for a more useful ecological assessment and monitoring where species utilization by humans are a concern.

This study shows that about half (i.e., 135) of the 267 species listed to be useful during the community workshops (i.e., focus groups discussions, FGD) were also sampled in the field. The MWP was highly representative of the areas sampled yet failed to cover as many of the numbers of the woody plant species with uses compared to the FGD checklist. Of the overall 135 species from the MWP, 101 were shared with the focus group results and 34 new ones were recorded in the field, implying that over 74% of species that were covered by the FGD occurred in the field plots. This confirms previous studies that generally describe local people as highly knowledgeable in their environment and the resources therein (Agrawal, 1995; Begossi et al., 2000; Dovie, 2003b). In spite of the high proportion of known species with uses, the diversity of the useful woody species between both the FGD and MWP were on average similar, based on an intermediate Sorensen index of 0.50 across the combined sites. This is not surprising because there were possibly more species that were used by the local people and yet were not easily detected during the ecological sampling and thus raising logical concerns about the choice of techniques for a broad level sampling of plant community assemblages where anthropogenic influences may be pronounced. The trend in the similarities between the FGD and MWP shared useful woody species numbers for the Eastern thorn bushveld vegetation type was the result of the well represented species at the individual sites. The high significant difference between the FGD and MWP absolute species number and diversity at all the sites explained the high disparity between the two techniques. A thorough analysis of the disparity will suggest checklists of useful woody species to complement ecological data towards monitoring and management of woody plant communities and vegetation. The same trend of the variation in the number of the shared useful woody species and diversity at the sites implied consistency of local knowledge at all the sites. This reflects homogeneity in knowledge of the local people with what species they know to be locally available to them for use as NTFP. In a single case in the Mixed lowveld bushveld vegetation where the MWP sampled shared species numbers exceeded the FGD at Mabins A, it was possible that the local people have not been able to optimise benefits accruing from the majority of the species locally available. This can produce a potential drawback for the sustainability of such underutilised species because it will be difficult to use local knowledge to assess and evaluate the existence of certain species within that environment that may be at risk of extinction.

Estimating or measuring the quantitative relationships that exist between the FGD and MWP for useful species numbers and diversity may contribute practical information on local species availability and harvesting as foreknowledge for studying NTFP species in the field. Such information will possibly guide future research techniques and designs towards more pragmatic approaches that relate specifically to society, resource use and biodiversity. Cumulatively, the correlation between both sources of knowledge were stronger and indicating the high possibility that in plant communities where higher number of species can be documented from local knowledge we will expect to find similarly high numbers in the field and *vice versa*, but not necessarily similarity within the species themselves. The PCA biplot (Figure 8) provides additional quantitative support by showing that the NTFP use categories that strongly correlated with the first axis, which is the most important were the same for both the FGD and MWP (i.e., housing poles, craft materials, fuelwood and fencing poles). On the second PCA axis, fencing poles and craft materials were among the top four correlates for both the FGD and MWP (Figure 8). These further suggest that the skill and knowledge of local people about their environment (Dovie, 2003a,b; Ghimire et al., 2005) cannot be underrated in the name of 'modern science' (Figure 9). A modern science should rather attempt to mechanize and standardize local knowledge through traditional nomenclature and folk biology using technological interfaces and appropriate frameworks to manage the issues of scale and homogeneity of outcomes from the two different perspectives (Daniel, 1997; Dovie, 2003; Stankey and Schindler, 2006). However, the correlation involving useful species diversity between the two sampling tools was not significant and hence unimportant for suggesting any trends. The 66% of the FGD and MWP co-occurring useful species restricted to particular locations of the vegetation presents a challenge for the population and habitat dynamics of those useful woody species. Thus what will be the extent of those locations and proportion of species that need to be managed towards the sustenance of the species? It also followed that several of such useful species had multiple NTFP uses and some occurring at more than two sites within different vegetation types. It also raises questions over the distribution of those useful species over the whole savanna vegetation. These therefore will provide a source of useful local information for designing appropriate field sampling, monitoring and evaluation tools to ascertain the distribution patterns of the useful woody species. The tools will take into consideration variables such as nutrients, ground water regimes, grazing of non-woody species (herbaceous species) and herbivory as well as the dispersal and propagation trends of the species in the context of human use. The 34% of the useful species described as common may have wider distributional and growth patterns and habitats. Additionally they are possibly favoured by harvesting as a form of disturbance and or do not have highly limiting growth factors such as nutrients and dispersal agents, suggesting the need for further studies to understand this pattern.

Figure 9. A traditional healer explains the cultivation of some medicinal plants and the preservation of diversity in response to extreme rareness in the wild, towards his practice (Photo: DBK Dovie).

4.2. NTFP management and methodological outcomes

The synergies between the information from both the community and field knowledge suggest a shared relevance for understanding the composition of useful woody species from which the NTFPs were harvested. The two-pronged approach based on ethnographic and ecological principles will jointly lead to the optimum coverage of gaps in the knowledge of the local availability of useful locally available woody species involving location and distribution (Salick et al., 1999; Ghimire et al., 2005). The low numbers of the useful woody species that the field sampling was able to cover reveals the possibility of the lag that can be experienced when using stand alone scientific approaches to optimise the understanding of localised dynamics of species experiencing heavy human use. Although field sampling can lead to the identification of large numbers of species having a number of uses based on reference materials such as field guides, they may not relevantly reflect what local people specifically use. In spite of the difficulties noted for the use of community knowledge and the scale of applicability, outcomes are often comparable to scientific results (Sinclair and Walker, 1999; Lawrence et al., 2005), making it a crucial potential intervention in localized resource use and conservation (Begossi et al., 2000; Ladio and Lozada, 2004; Lawrence et al., 2005).

Community knowledge will further lead to the identification of species with potential threats from multiple uses or with narrow distributional ranges within the local environment based on information from key local informants (Figure 10). This is because the usefulness of a species may differ from one environment to the other based on the needs of society, culture of resource use, attitude and the immediate environmental and economic conditions. Additionally, the official recognition of the value of species locally based on community knowledge about rare and little known species facing threats of depletion from NTFPs could guide the direction of conservation locally that previously targets only nationally or internationally recognised charismatic species (Stankey and Shindler, 2006). The biggest challenge facing NTFP resources is possibly the inadequacy of appropriate field sampling tools because of time and cost of use, and/or the imposing of ecological field techniques over community knowledge. This has led to the lack of all inclusive relevant information that encompasses local perception about plant communities of NTFP sources and leading to ineffective NTFP management strategies (Stræde et al., 2002; Ticktin, 2005). An informed decision making process of the management of locally available but used species needs to consider specialised knowledge of resource use and the anticipated impacts of changes in diversity and distribution that are known to the local people.

Figure 10. Transect walks with local informants to identify uses of species outside the GPS positions before laying the modified Whittaker Plots in Mabins A (Photo: DBK Dovie).

5. CONCLUSIONS

The study reveals the difference in the knowledge base of local people in the assessment of locally available woody plant species that are useful as NTFPs. More woody species in use by the local people were identified through community knowledge than by field ecological sampling. Several useful woody species with multiple uses that may be facing unknown future challenges of availability and sustainability were not detected by the field ecological sampling, possibly because they have been over-harvested and not easy to randomly locate using plots. As a result, ecological sampling needs to be used in tandem with local people's knowledge where human use of species prevails. Both the FGD and MWP results suggest that housing poles, craft materials, fuelwood and fencing poles are important uses among the other use categories (PCA results) and hence the woody species associated with those uses may be facing high usage. The small overlap in the number of useful woody species identified between the community knowledge and field sampling suggests that both sources of information would complement one another by providing a more complete understanding of the present status of species than either one on its own. Local people are highly knowledgeable of their local environments and they can provide the local intellect that may be used by 'modern science' to locally develop management practices to promote NTFP use, whilst sustaining the resource base. Based on the differences in the distribution patterns of the useful woody species, it is hypothesised that (a) where a lot of common useful woody species occur in a location, there will be fewer growth limiting factors than where useful species that were restricted do occur, (b) the location-restricted useful woody species may exhibit high sensitivity to plant resource availabilities (water, nutrients, light) and harvesting disturbance, and (c) multiple-use species will be located within narrow distributional ranges and growth resource-limited microenvironments. These three hypotheses will pose new challenges for further studying the structure and composition of useful woody plant species based on ethnobotanically informed ecological techniques, leading towards improvements in the management of woody species diversity in and around these human settlements within savannas.

Appendix I. The shared useful woody species between the FGD and MWP.

Species name	Plant family	Medicine	Fruit	Fuelwood	Craft	Housing Poles	Fencing	Cultural	Beverage
Aloe africana	Aloaceae	√	√	√	0	0	0	0	0
Aloe thraskii	Aloaceae	√	0	0	0	0	0	√	0
Lannea discolor	Anacardiaceae	√	√	0	0	0	0	0	0
Lannea schweinfurthii	Anacardiaceae	√	√	√	0	√	0	0	0
Rhus fastigiata	Anacardiaceae	√	√	√	0	0	√	0	0
Rhus gueinzii	Anacardiaceae	√	√	√	√	0	√	0	0
Rhus lucida	Anacardiaceae	0	√	√	0	0	√	0	0
Sclerocarya birrea	Anacardiaceae	√	√	√	√	√	√	√	√
Monanthotaxis caffra	Annonaceae	√	0	0	0	0	0	0	0
Uvaria caffra	Annonaceae	0	√	0	0	0	0	0	0
Carissa bispinosa	Apocynaceae	0	√	0	0	0	√	0	0
Carissa tetramera	Apocynaceae	0	√	√	0	0	√	0	0
Cussonia paniculata	Araliaceae	√	√	√	√	0	0	0	0
Hyphaene coriacea	Arecaceae	√	√	0	√	0	0	0	√
Balanites maughamii	Balanitaceae	√	0	√	√	√	√	0	0
Ehretia rigida	Boraginaceae	√	√	√	√	√	√	0	0
Buddleja saligna	Buddlejaceae	0	0	√	0	√	0	0	0
Boscia albitrunca	Capparaceae	√	0	√	0	0	0	0	0
Capparis tomentosa	Capparaceae	√	0	0	0	0	0	0	0
Cassine aethiopica	Celastraceae	√	√	√	0	√	0	0	0
Cassine peragua	Celastraceae	√	√	√	0	0	√	0	0
Cassine transvaalensis	Celastraceae	√	√	√	0	√	0	0	0
Gymnosporia buxifolia	Celastraceae	√	√	√	0	0	√	0	0
Gymnosporia senegalensis	Celastraceae	√	√	√	√	0	0	0	0
Maytenus acuminata	Celastraceae	√	0	0	0	0	0	0	0
Maytenus heterophylla	Celastraceae	√	0	√	√	0	√	0	0
Maytenus procumbens	Celastraceae	√	0	0	0	0	0	0	0
Maytenus undata	Celastraceae	0	√	√	√	0	0	0	0
Combretum apiculatum	Combretaceae	√	√	√	√	√	√	0	0

Species name	Plant family	Medicine	Fruit	Fuelwood	Craft	Housing Poles	Fencing	Cultural	Beverage
Combretum collinum	Combretaceae	√	0	√	√	√	0	0	0
Combretum hereroense	Combretaceae	√	√	√	√	√	0	0	√
Combretum imberbe	Combretaceae	√	√	√	√	√	√	0	0
Combretum zeyheri	Combretaceae	0	0	√	0	0	√	0	0
Terminalia sericea	Combretaceae	√	0	√	√	√	√	0	0
Diospyros lycioides	Ebenaceae	0	0	√	0	0	0	0	0
Diospyros mespiliformis	Ebenaceae	√	√	√	√	√	0	0	0
Dombeya rotundifolia	Ebenaceae	√	√	√	√	√	0	0	√
Euclea crispa	Ebenaceae	√	√	√	√	√	0	0	0
Euclea divinorum	Ebenaceae	√	√	√	√	0	√	0	0
Euclea natalensis	Ebenaceae	√	√	√	0	√	0	0	0
Euclea undulata	Ebenaceae	√	0	0	0	0	0	0	0
Antidesma venosum	Euphorbiaceae	√	√	√	√	√	√	0	0
Cleistanthus schlechteri	Euphorbiaceae	0	0	√	√	0	0	0	0
Euphorbia tetragona	Euphorbiaceae	√	0	√	0	0	√	0	0
Spirostachys africana	Euphorbiaceae	√	√	√	√	√	√	0	0
Acacia ataxacantha	Fabaceae	√	√	√	√	√	√	0	0
Acacia borleae	Fabaceae	√	0	√	√	√	√	√	0
Acacia burkei	Fabaceae	√	√	√	0	0	√	0	0
Acacia caffra	Fabaceae	√	√	√	√	√	√	0	0
Acacia exuvialis	Fabaceae	√	0	√	√	0	√	0	0
Acacia gerrardii	Fabaceae	√	√	√	0	0	√	0	√
Acacia karroo	Fabaceae	√	√	√	√	√	√	0	0
Acacia kraussiana	Fabaceae	√	0	√	0	0	0	0	0
Acacia nigrescens	Fabaceae	√	0	√	0	√	√	0	0
Acacia nilotica	Fabaceae	√	√	√	√	√	√	0	0
Acacia robusta	Fabaceae	√	0	√	0	√	√	0	0
Acacia senegal	Fabaceae	0	0	√	0	0	0	0	0
Albizia adianthifolia	Fabaceae	√	√	√	0	0	0	0	0
Albizia harveyi	Fabaceae	√	0	√	√	√	√	0	0

Species name	Plant family	Medicine	Fruit	Fuelwood	Craft	Housing Poles	Fencing	Cultural	Beverage
Cassia abbreviata	Fabaceae	√	0	√	0	0	0	0	0
Dalbergia melanoxylon	Fabaceae	√	0	√	√	0	0	0	0
Dialium schlechteri	Fabaceae	√	√	√	0	0	0	0	0
Dichrostachys cinerea	Fabaceae	√	0	√	√	√	√	0	0
Mundulea sericea	Fabaceae	√	0	0	0	0	0	0	0
Ormocarpum trichocarpum	Fabaceae	√	0	√	√	√	0	0	0
Peltophorum africanum	Fabaceae	√	√	√	√	√	√	√	√
Philenoptera violacea	Fabaceae	√	0	√	√	√	0	0	√
Pterocarpus rotundifolius	Fabaceae	√	√	√	√	√	√	0	0
Schotia afra	Fabaceae	√	√	√	0	0	√	√	0
Schotia brachypetala	Fabaceae	√	√	√	√	√	√	0	0
Dovyalis longispina	Flacourtiaceae	0	√	0	0	0	0	0	0
Dovyalis rotundifolia	Flacourtiaceae	0	√	0	0	0	0	0	0
Scolopia zeyheri	Flacourtiaceae	0	√	√	0	0	0	0	0
Ficus glumosa	Moraceae	√	√	√	0	√	0	0	0
Ficus sur	Moraceae	√	√	√	√	√	0	0	0
Psidium guajava	Myrtaceae	√	√	√	0	√	0	0	0
Syzygium cordatum	Myrtaceae	√	√	√	√	√	√	0	0
Ximenia caffra	Olacaceae	√	√	√	0	√	√	0	0
Olea europaea	Oleaceae	√	√	√	√	√	√	√	0
Portulacaria afra	Portulacaceae	√	√	0	0	0	0	0	0
Ptaeroxylon obliquum	Ptaeroxylaceae	√	0	√	0	√	√	0	0
Berchemia discolor	Rhamnaceae	√	√	√	√	0	√	0	0
Berchemia zeyheri	Rhamnaceae	√	√	√	√	√	0	0	√
Scutia myrtina	Rhamnaceae	√	√	√	0	0	0	0	0
Ziziphus mucronata	Rhamnaceae	√	√	√	0	√	√	√	0
Canthium inerme	Rubiaceae	√	√	√	√	√	0	0	0
Canthium mundianum	Rubiaceae	0	√	0	√	0	0	0	0
Coddia rudis	Rubiaceae	√	0	√	√	0	√	0	0
Gardenia volkensii	Rubiaceae	√	0	√	√	√	0	0	0

Species name	Plant family	Medicine	Fruit	Fuelwood	Craft	Housing Poles	Fencing	Cultural	Beverage
Plectroniella armata	Rubiaceae	√	√	√	0	0	√	0	0
Vangueria infausta	Rubiaceae	√	√	√	√	√	0	0	√
Zanthoxylum capense	Rutaceae	√	0	√	√	√	0	0	0
Azima tetracantha	Salvadoraceae	√	0	√	√	0	√	√	0
Pappea capensis	Sapindaceae	√	0	√	√	0	0	0	0
Manilkara mochisia	Sapotaceae	√	√	√	0	√	0	0	0
Sideroxylon inerme	Sapotaceae	0	√	√	√	√	0	0	0
Sterculia rogersii	Sterculiaceae	√	√	√	√	0	0	0	0
Strychnos madagascariensis	Strychnaceae	√	√	√	√	√	0	0	0
Strychnos spinosa	Strychnaceae	√	√	√	0	√	√	0	0
Grewia bicolor	Tiliaceae	√	√	0	0	√	0	0	0
Grewia occidentalis	Tiliaceae	√	√	√	√	√	0	0	0

References

Agrawal, A., 1995. Dismantling the divide between indigenous and scientific knowledge. Development and Change 26, 413-439.

Barnett, D.T., Stohlgren, T.J., 2003. A nested-intensity design for surveying plant density. Biodiversity and Conservation 12(2), 255-278.

Begossi, A., Hanazaki, N., Peroni, N., 2000. Knowledge and use of biodiversity in Brazilian Hotspots. Environment, Development and Sustainability 2, 177-193.

Bell, J., 1995. The hidden harvest. Seedling 12(3), 23-31.

Buchy, M., Hoverman, S., 2000. Understanding public participation in forest planning: a review. Forest Policy and Economics 1, 15-25.

Chazdon, R.L., Coe, F.G., 1999. Ethnobotany of woody species in secondary-growth, old-growth, and selectively logged forests of Northeastern Costa Rica. Conservation Biology 13(6), 1312-1322.

Crivos, M., Martínez, M.R., Pochettino, M.L., 2004. Nature and domestic life in the Valle del Cuñapirú (Misiones, Argentina): Reflections on Mbyá-Guaraní ethnoecology. Agriculture and Human Values 21, 7-21.

Cunningham, A.B., 2001. Applied Ethnobotany: People, Wild Plant Use and Conservation. Earthscan Publications Ltd, London.

Daniel, M., 1997. The Changing Landscape of Plant Sciences: Taxonomy and Ecology. Vedams Books, New Delhi.

Dovie, D.B.K., 2003a. Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa? International Journal of Sustainable Development and World Ecology 10, 247-262.

Dovie, D.B.K., 2003b. Whose involvement? – Can Hierarchical Valuation Scheme intercede for participatory methods for evaluating secondary forest resources use? Forest Policy and Economics 5(3), 265-283.

Garcia-Brokhausen, S., 1997. Genetic Resources – Biodiversity is the tropical forest's "greatest treasure". GATE, technology and development 2, 18-22.

Ghimire, S.K., McKey, D., Aumeeruddy-Thomas, Y., 2005. Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC. and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. Biological Conservation 124, 463-475.

Greig-Smith, P., 1983. Quantitative Plant Ecology. Blackwell Scientific Publications, Oxford.

Höft, M., Barik, S.K., Lykke, M., 1999. Quantitative Ethnobotany: Applications of Multivariate and Statistical Analyses in Ethnobotany. People and Plants working paper. UNESCO, Place de Fontenoy.

Koziell, I., 2001. Diversity not adversity: sustaining livelihoods with biodiversity. IIED, London.

Kunin, W.E., Lawton, J.H., 1996. Does biodiversity matter? Evaluating the case for conserving species. In: Gaston, J.K. (Ed.), Biodiversity: A Biology of Numbers and Difference. Blackwell Science Ltd, London, pp. 283-308.

Ladio, A.H., Lozada, M., 2004. Patterns of use and knowledge of wild edible plants in distinct ecological environments: a case study of a Mapuche community from northwestern Patagonia. Biodiversity and Conservation 13(6), 1153-1173.

Lawrence, A., Phillips, O.L., Ismodes, A.R., Lopez, M., Rose, S., Wood, D., Farfan, A.J. 2005. Local values for harvested forest plants in Madre de Dios, Peru: towards a more contextualised interpretation of quantitative ethnobotanical data. Biodiversity and Conservation 14, 45-79.

Lykke, M.A., Fog, B., Madsen, J.E., 1999. Woody vegetation changes in the Sahel of Burkina Faso assessed by means of local knowledge, aerial photos, and botanical investigations. Danish Journal of Geography (Special Issue) 2, 57-68.

Magurran, A.E., 2004. Measuring Biological Diversity. Blackwell Publishing, Oxford.

Martin, G.J., 1995. Ethnobotany: A methods manual. A People and Plants Conservation Manual No. 1. Chapman and Hall, London.

Moore, J.L., Manne, L., Brooks, T., Burgess, N.D., Davies, R., Rahbek, C., Williams, P., Balmford, A., 2002. The distribution of cultural and biological diversity in Africa. Proceedings of the Royal Society of London 265, 1645-1653.

Peters, C.M., 1996. Beyond nomenclature and use: a review of ecological methods for ethnobotanists. In: Alexiades, M.N. (Ed.), Selected Guidelines for Ethnobotanical Research. The New York Botanical Garden, New York, pp. 241-276.

Phillips, M.S., 1983. Measuring tree and forests. Forestry Division, University of Daresalaam, Daresalaam.

Pretty, J.N., 1994. Alternative systems of inquiry for sustainable agriculture. IDS Bulletin 25 (2), 37-48.

Rosenzweig, M.L., 1995. Species Diversity in Space and Time. Cambridge University Press, New York.

Ruiz Pérez, M.R., Byron, N., 1999. A method to analyse divergent case studies of non-timber forest products and their development potential. Forest Science 45(1), 1-14.

Salick, J., Bium, A., Martin, G., Apin, L., Beaman, R., 1999. Whence useful plants? A direct relationship between biodiversity and useful plants among the Dusun of Mt. Kinabalu. Biodiversity and Conservation 8, 797-818.

Sandewall, M., Ohlsson, B., Sawathvong, S., 2001. Assessment of historical land-use changes for purposes of strategic planning – a case study in Laos. Ambio 30(1), 55-61.

Schmida, A., Wilson, M.V., 1985. Biological determinants of species diversity. Journal of Biogeography 12, 1-20.

Sekhwela, M.B.M., 2003. Woody vegetation resource changes around selected settlement along aridity gradient in the Kalahari, Botswana. Journal of Arid Environments 54, 469-482.

Shackleton C.M., Griffin N.J., Banks J.M., Mavrandonis J.M., Shackleton S.E., 1994. Community structure and species composition along a disturbance gradient in a communally managed South African savanna. Vegetatio 115, 157-167.

Sinclair, F.L., Walker, D.H., 1999. A utilitarian approach to the incorporation of local knowledge in agroforestry research and extension. In: Buck L.E., Lassoie, J.P., Fernandes, E.C.M. (Eds.), Agroforestry in Sustainable Agricultural Systems. CRC Press LLC, USA, pp. 245-275.

Stankey, G.H., Shindler, B., 2006. Formation of social acceptability judgments and their implications for management of rare and little known-species. Conservation Biology 20(1), 28-37.

StatSoft Inc., 2002. STATISTICA for windows. StatSoft, Inc., Tulsa.

Stohlgren, T.J., Falkner, M.B., Schell, L.D., 1995. A modified-Whittaker nested vegetation sampling method. Vegetatio 117, 113-121.

Stræde, S., Nebel, G., Rijal, A., 2002. Structure and floristic composition of community forests and their compatibility with villagers' traditional needs for forest products. Biodiversity and Conservation 11, 487-508.

ter Braak, C.J.F., 2003. Program CANOCO version 4.5. Centre for Biometry, Wageningen.

Ticktin, T., 2005. Applying a metapopulation framework to the management and conservation of a non-timber forest species. Forest Ecology and Management 206, 249-261.

Whittaker, R.H., 1977. Evolution of species diversity on land communities. Evolutionary Biology 10, 1-67.

Wynberg, R., Swiderska, K., 2001. South Africa's Experience in Developing a Policy on Biodiversity and Access to Genetic Resources. International Institute for Environment and Development (IIED), London.

CHAPTER 6

Synthesis and conclusions: Relationship between woody biodiversity and use of non-timber forest products in the savanna biome of South Africa

1. INTRODUCTION

This study shows that there are broad spectrums of woody plant species belonging to several families and genera, on which people, mostly resource poor rural communities, depend for their daily lives. A wide variety of products are harvested from woody plants and includes fibre, medicines, subsistence timber, fuelwood, wild fruits and seeds and resins, which have become known as non-timber forest products (NTFPs). As a result, the harvesting and utilisation of NTFPs may provide important sources of income, savings and security for both poor and wealthy households in rural and urban dwellings (Adhikari et al., 2004; Shackleton et al., 2005; Belcher et al., 2005; Stoian, 2005). The use of woody species by local people may also provide a major tool for promoting the sustainable utilisation of natural resources based on a trade-off with other land uses such as commercial timber production (Belcher and Kusters, 2004). The study revealed that the proximity of settlements to woody plant species do influence levels of utilisation and hence the ecology of the species. The knowledge about the effects of woody plant species location will provide specific and supplementary information to understand the relationships that exist between the local availability of woody plant species in response to environmental, biological and edaphic factors (Fjeldså and Lovett, 1997; Sekhwela, 2003) which in turn will lean towards the development of sound resource management practices. The effects of broad socio-political, economic and biophysical factors such as poverty, food insecurity, and unemployment, as well as climate change effects, could trigger severe anthropogenic disturbance in the form of the over-exploitation of NTFPs, which may in turn modify vegetation structure, diversity and function. Such modifications could in turn influence the resilience or the vulnerability of both the vegetation and the species therein as well as the livelihoods of the local people, within complex linkages of land cover and land use changes. The proximate factors underlying such changes are known to be largely deforestation and the loss of woody biomass (resulting from the harvesting of plants as a form of disturbance in this study), agriculture and infrastructure development (Reid et al., 2000; Geist and Lambin, 2001).

2. SYNERGIES BETWEEN THE STUDY OBJECTIVES

The various facets of the study can be displayed in an integrative, conceptual model (Figure 1), having two interacting exposure units; the settlements and the vegetation. The single unit of analysis of the two exposure units was based on the woody plant species within the vegetation (Chapter 1). The mostly resource-poor communities who depend directly on woody species are often vulnerable to food insecurity, poverty and extreme events (e.g., drought, floods) and the lack of social and economic infrastructure. Under such events, households tended to adopt various livelihood strategies in an attempt to either cope with or adapt to their environmental conditions (Chapter 1). Such strategies will possibly result in the over-exploitation of the natural resource base, in this case the woody plant species (Chapter 2). Local people will often draw on their intellectual capabilities and experiences and knowledge acquired over generations on how best to put the biophysical environment to uses suitable for them (Chapter 3). The levels and content of the local knowledge differ between different sectors and individuals in the community, especially in relation to age and gender (Chapter 4). This knowledge of the local people can help complement and corroborate information from ecological and scientific studies in implementing sound management strategies for the sustainable use of savanna woodland resources (Chapter 5). The most favourable uses of woody species in the coping and adaptation processes are often adopted, and the sources are noted but not properly documented (e.g., names of the species, habitats) through traditional nomenclature or folk biology (Chapter 4). These products have various values attached to them in terms of monetary, cultural and economic use (Chapter 1). The knowledge of species use was documented through the use of focus groups at the community level, using various gender and age groupings towards sound age and gender auditing (Chapter 4).

The dependence on the woody plant species (Figure 1) may also trigger responses from the woody species due to the harvesting pressures and in the process creating disturbance gradients associated with the harvesting of the species (Chapter 2). The proximity of human settlements to woodland vegetation may result in the “near” locations being harvested more than the “far” and “intermediate” locations, although all locations do contain useful woody species. This spatially variable harvesting intensity constituted a source of disturbance for the woody plant species and in conjunction with other environmental (e.g., climate) and biological factors (e.g., fruit setting), may result in changes in plant species and vegetation attributes such as species richness, evenness and diversity, as well as size, distribution, density and height structure (Chapters 2 and 3). It was generally found that the far locations of the vegetation were more species rich and diverse compared to the intermediate and near locations. This is interpreted as the result of the loss of species in the near locations rather than species being added whilst one moves towards farther locations although the latter cannot be completely excluded (Chapter 3). The density and richness as well as diversity of trees generally increased from the near to the far locations whilst seedling density exhibited erratic trends (Chapter 2). The differences in knowledge, on the effects of sampling and changes in diversity at different scales and use of woody species for NTFPs can be better understood and managed when considered from a interdisciplinary perspective, implicitly including the knowledge of local people as in social anthropology (Chapter 5) as shown in Figure 1. In spite of the concerns of matching the scales of enquiry by merging scientific and traditional knowledge, a correlation between the two for the woody plant richness was observed in this study for the combined sites although significant differences existed between the two at each individual study site (Chapter 5).

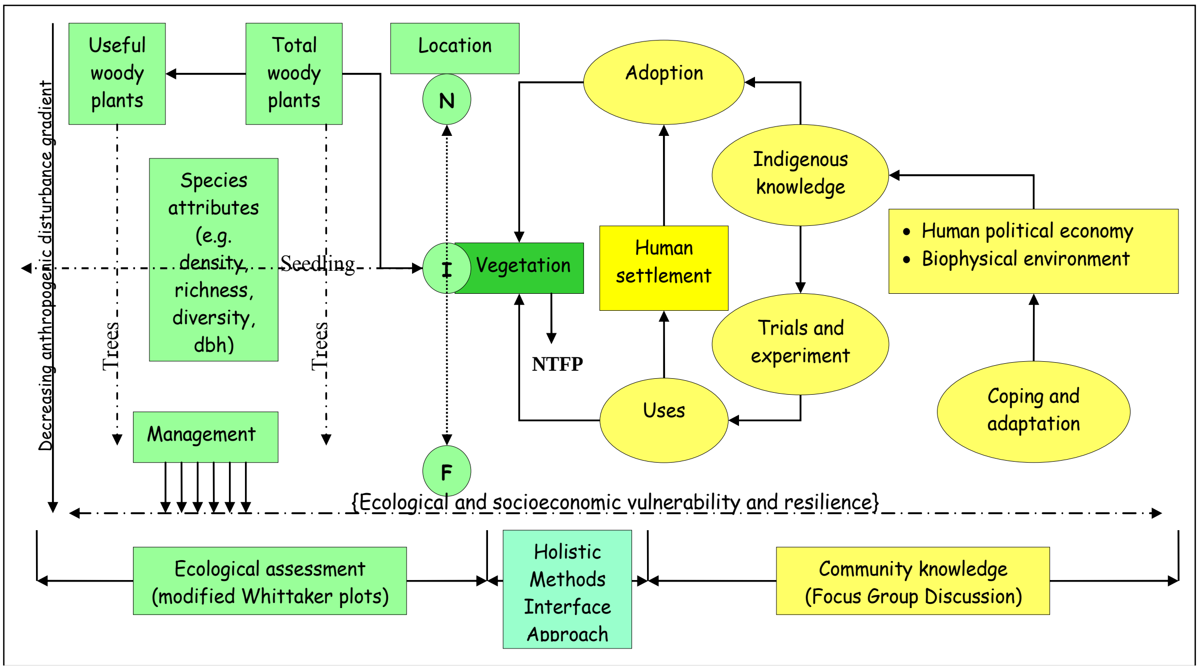

Figure 1. The synthesis of the findings of the study showing trends in woody plant species availability and use. Proximity to settlements is identified as N – near, I – intermediate, and F – far, at all the study sites.

3. WOODY PLANT SPECIES DIVERSITY, DISTURBANCE, NTFP USES AND MANAGEMENT

3.1. Disturbance gradients of woody species in savannas

The understanding of disturbance in woody plant communities is important for managing diversity in highly disturbed systems resulting from the plant harvesting activities of local people. The reason is that harvesting of plants affects plant community structure, processes and functions with varied implications for biodiversity (Pickett et al., 1989; Pickett and Parker, 1994). In this study, it has been shown that the harvesting of woody species involving wood and as evidenced by the presence of harvested stumps, decreased from near to far locations relative to human settlements. Similarly, distant locations were far specieos compared to the intermediate and near locations, a trend that has similarly been observed for savannas (Shackleton et al., 1994). The observed trends were as a result of the easier access of households to plants (and species) that are closer in times of emergencies of need and subsistence use.

Ecological disturbance theory and frameworks must consider the role of humans based on the harvesting of woody plant species (Farina, 2000; Martorell and Peters, 2005). Disturbance studies need to understand the object being disturbed (e.g., whole plant, or plant parts), the nature of the disturbance, the ensuing changes and whether or not it is a direct or indirect disturbance so as to be able to use knowledge outcomes to guide vegetation management decisions (Pickett et al., 1989). The scale of disturbance is also important to understand and often dependent on the scale at which species are assessed or measured. The linkages between humans and the environment occur at different spatial and temporal scales (Reid et al., 2000). Such scales may be modelled by human drivers (e.g., livelihood activities and strategies) that tend to influence decision-making (Blaikie et al., 1994; Dahlberg, 2000; Geist and Lambin, 2001). In this study, the large sized 0.1ha plots based on the modified Whittaker plot design were more species rich and diverse than the subplots, a result similarly observed by Shackleton (2000). Varied trends have been observed for the similarity and evenness measures of the species based on sampling scale.

This study has shown that disturbances closer to settlements are more severe, leading to the reduction in species diversity compared to the farther locations. Deliberate gathering of NTFPs has been found to be associated with areas closest to villages in several studies (e.g., Delang, 2006). Disturbance therefore is mediated and influenced by socioeconomic factors such as institutional arrangements and demography, and also by environmental and edaphic conditions such as climate and soil (Dahlberg, 2000; Martorell and Peters, 2005). In spite of the high dependence on NTFPs, the extent of damage to total biodiversity is not fully known. Several individual species have however been found to exhibit changes in response to NTFP extraction, which can contribute to knowledge on total biodiversity (e.g., Anderson and Putz, 2002; Botha et al., 2004; Ticktin, 2004; Martorell and Peters, 2005; Ghimire et al., 2005; Shackleton et al., 2005). It was observed that young individual woody plants or seedlings are facing much higher mortality compared to large adult trees possibly due to the removal of young maturing trees, livestock and human trampling and lesser adaptation to unfavourable growth conditions such as droughts and floods before they reach the reproductive stages. This finding of the status of seedlings has been similarly reported for specific species in savannas (e.g., Neke, 2005). Disturbance theory alone is therefore inadequate to provide sufficient information for managing diversity in direct human impacted systems involving the extraction of woodland resources (Mortimore and Turner, 2005) For an effective management system of species diversity based on disturbance information, there is the need to consider disturbance within the frameworks of human livelihoods, ecological health and indigenous knowledge, as well as traditional nomenclature of the local resources and systems (e.g., savannas). Disturbance should therefore be treated as a web of anthropogenic and biogeophysical processes having specific indicators that can be measured, estimated and managed. The isolation of different levels of disturbance will require that different types of management strategies are applied (Pickett et al., 1989).

The monitoring of vegetation is important because the communal areas of the sub-region especially in South Africa are characterised by intense harvesting of resources from woodlands, constituting one of the major forces behind the reduction in diversity (Shackleton, 2000; Dovie et al., 2002; Shackleton et al., 2005). As has been observed in this study, there were more useful woody species compared to those species without uses to the local people and over half of such species had multiple uses, having the potential to put additional pressure on the species that can ultimately result in changes to diversity. Cutting or felling of trees that outweigh the rate of regeneration and maintenance of the base population of woody species reduces productivity and the standing stock and reduction in woody species diversity as the most possible outcome. As a result, the monitoring of land transformation that does not account for species level changes where human uses of species for NTFPs are evident will not be adequate to inform policy. There is therefore the need to combine landscape level studies with population level ones and particularly for the species on which local people depend. Landscape level studies should therefore encompass various hierarchies that are deeply rooted in local level and species population issues. Management challenges have partially been aggravated by pressures from the conflicting interests of farmers, pastoralists and powerful commercial businesses and rapid human population growth (Wint and Bourn, 1994). Harvesting disturbance in savannas could be likened to deforestation in forest ecosystems and will require more sophisticated concepts of management at the local level to deal with (Mortimore and Turner, 2005).

3.2. The ecological dynamics of extracting non-timber forest products

The extractive disturbance of non-timber forest products (NTFPs) exerts selective and measurable pressure on woody plant species. The results of this pressure are changes in habitats and threats to woody species that may lead to the decline of species over time; uncommon species becoming rare or common ones dominating the plant community (Mortimore and Turner, 2005; Hockley et al., 2005). The findings of this study show that large sized trees coincided with multiple uses and such trees can be more vulnerable to over-harvesting than smaller sized trees. This will have to do with the ability of local people to experiment and optimise uses of large sized woody species instead of having to harvest from several small sized species before deriving the optimum expected benefits. The outcome of such harvesting will be the reduction in the minimal structure (organised entity) of the plant communities and reduced diversity (Pickett et al., 1989). It will be expected that changes in species will be heterogeneous across various locations relative to human settlements as observed in this study. The study therefore provides an entry point for studying NTFP species for their composition and structure along various resource use gradients relative to human settlements within savannas and the implications for total diversity rather than for individual species. The development of typologies of land cover types in relation to woody plant species within specific vegetation types and locations will guide management decisions (e.g., baobab as a 'parkland' species – Dhillion and Gustad, 2004). This is because the characteristics of the system or the microenvironment in which the species grow need to be investigated and built into any management criteria.

Because the dependence on NTFPs is an outcome of the link between humans and their environment, it is almost impossible to separate the two if healthy ecosystems are to be sustained (Berkes et al., 2003; Parlee et al., 2005). In times of limited economic options and the spread of risk, households often diversify their livelihood portfolios to include the direct and pertinent uses of local woody species. As the use of NTFPs shifts from subsistence to commercial, the management of NTFPs may assume interventions that are even ecologically more destructive than before (Marshall et al., 2003; Belcher and Kusters, 2004; Belcher et al., 2005). The changing role of a particular NTFP according to the circumstances of users has also been found to be a potential management challenge (Nebel, 2001; Traernicht and Ticktin, 2005). Such circumstances are reflected in the results of this study that the diversity of the useful woody species strongly correlated with total woody species diversity locally. Where households and human communities have common local knowledge about a specific resource, or because it is abundant, several management bottlenecks such as consistent monitoring will be reduced (Nebel, 2001). The pragmatic way to understand such changes will be to embark on long-term local monitoring using local resource harvesters and users to provide data for informed management decisions. The monitoring will have to take into consideration the population dynamics of the species being harvested and compared to that of non-harvested species with the aim of maintaining diversity. However, other schools of thought suggest that monitoring may have little use for NTFP management and may even divert scarce resources that could have been used for conserving priority species (e.g., Sheil, 2001). The basic uncertainty relating to the argument of Sheil (2001) about monitoring NTFP species will be the contextual definition of high priority species. Are they the commercially valuable, charismatic or functional species? What about the species that the majority of the local people depend on for their daily use and for survival? Monitoring, if not carried out for all harvested species can still be done for selected species to ascertain their status in the NTFP production cycle (Homma, 1996). Monitoring will therefore provide valuable information about the threat status of species being harvested (Hockley et al., 2005; Topp-Jørgensen et al., 2005). If target species is to be used for NTFP production in intermediate intensity management systems (e.g., mixed naturally growing species and enriched planting), regeneration will be facilitated by natural processes. Multiple uses will then be feasible and in the process leading to a relatively high biodiversity such as in swidden fields compared to when there are intense management interventions (Belcher et al., 2005). In either of the management systems, there is the need to measure or estimate impacts on the ecology of the species and biodiversity. Managing species for the production of NTFPs should go beyond population studies and take into consideration the management of specific uses or plant parts being used. This is because fruit harvesting for instance has negative impacts on dispersal and establishment, while leaf harvesting may result in the mutilation of plants and in the long term reducing the productivity of the species, including fruit setting (Dhillion and Gustad, 2004). It is also important to recognise the role of factors such as agricultural intensification, mechanisation and various policies that impact on local people's ability to manage biodiversity locally (Geist and Lambin, 2001; Anderson and Putz, 2002; Dhillion and Gustad, 2004).

For a long term management strategy for local populations of NTFP species, there is the need to compare harvesting with local availability of stocks and monitor the quantities removed, whilst emphasising the need to maintain NTFP species diversity. Because harvesting pressure tends to affect the productivity of plant populations, it has been suggested that domestication of plants for faster growth and improved NTFP quality will minimise negative impacts on the wild populations whilst evolving less genetically diverse populations (Dhillion and Gustad, 2004). A management plan for utilising locally available woody species must involve research that will measure stocks and flows of the resource base towards the setting of sustainable harvesting levels (Anderson and Putz, 2002). The modified use patterns of NTFPs are in effect able to determine to a large extent the success or failure or compromise of any NTFP and woody species management (Senaratne et al., 2003). Timing and seasonal variation for harvesting NTFPs are important variables for determining appropriate management (Mahapatra et al., 2005). Factors that can be included in the assessment of management strategies for sustainable harvesting are suggested (Table 1).

Table 1. Selected factors for assessing the sustainability of harvesting and management strategies for woody species diversity (used as NTFPs). Adapted and modified from Pinedo-Vasquez et al. (1992), Dovie et al. (2002) and Anderson and Putz (2002).

Tenure and participation	**Political economy**	**Sustainability**
Indigenous / local knowledge	Opportunity costs (value of labour and products)	Maintaining ecological variables (e.g., diversity, ecosystem services)
Resident current markets	Cross product compatibility	Compatibility with other land-uses
Local participation	Proximity to markets	Potential for monitoring
Local control of resources	Easy access to transport	Harvesting design and rotation times
Potential for certification	Capacity building	Appropriate technology
Local resource development	Steady and positive cash flows	
Ownership of intellectual property	Government support	

In addition to all the criteria that are often set for managing NTFPs, knowledge about proper identification (i.e., complete species identity, yield potential, geographic occurrence) must be made prerequisites (Peters, 1996; Nebel, 2001). In terms of indigenous knowledge, there is no doubt that confusion still exists on the identification of a number of NTFP species that are used for subsistence purposes because local people and harvesters will prefer using their traditional nomenclature to identify and describe populations (e.g., size-class distribution, density, frequency, yield, etc.). Although the involvement of local people in data collection may sometimes compromise data accuracy (although if they are well trained, this is generally not the case), it is necessary to include them. For example the same local name could refer to two or more different species but the use of key informants and focus groups such as in this study minimises data errors. Managers and scientists may also have prejudices and stereotypes about resource use that also compromise data accuracy and hence the need for a certain allowable error level and limits that can be managed by interfacing the knowledge from local people and modern science (Delang, 2006).

3.3. Managing NTFPs and accompanying species

Plantations, enhancement and enrichment planting of NTFP species have been documented as important management options for plant biodiversity, although the long term effects of these options could be detrimental (Ticktin et al., 2003; Ticktin, 2004; Mahapatra et al., 2005). The emphasis on plantations of NTFP species whether in monoculture or in mixed stands have resulted in the loss of certain endemic species. These species are either deliberately removed to promote the growth of the NTFP species, or are out-competed for growth resources and subsequently eliminated (Traernicht and Ticktin, 2005). This study identified woody species that were possibly locally threatened as indicated by the local people, especially the older generation who have not encountered those species in many years (this is shown strongly by the differences in useful species numbers identified in the plots versus by the local people). Examples were: *Catha edulis* (rare, lower risk, least concern; near threatened; Medicinal), *Ocotea bullata* (vulnerable, lower risk, conservation dependent; Vulnerable; Medicinal), *Raphia australis* (vulnerable, lower risk; medicinal), *Smodingium argutum* (rare, lower risk; near threatened; medicinal) and *Trichocladus ellipticus* (insufficiently known; near threatened; medicinal, furniture, fruit, fuelwood, craft). The reason for this rareness may be due to the overexploitation of the species interacting with unknown levels of environmental and growth conditions. Botha et al. (2004) noted that *Catha edulis* for example is undergoing tremendous harvesting and change in areas adjacent to settlements and roadsides in communities close to the Kruger National Park in South Africa. There were locally human favoured species that formed part of the protected species list of South Africa, such as *Adansonia digitata*, *Boscia albitrunca*, *Breonadia salicina*, *Catha edulis*, *Cleistanthus schlechteri*, *Combretum imberbe, Mimusops caffra*, *Ocotea bullata*, *Philenoptera violacea*, *Pittosporum viridiflorum*, *Podocarpus latifolius*, *Pterocarpus angolensis*, *Rhizophora mucronata*, *Sclerocarya birrea* and *Sideroxylon inerme*. The presence and use of these threatened species near rural communities point to the need for the relevant authorities to popularise and make people aware of threatened species and the reasons for them being considered threatened and hence their resultant listed status.

Creative criteria therefore need to be developed for describing the status of those locally rare species. A “Locally Brown list” is being proposed in this study and to be implemented locally and at species levels based solely on local knowledge and information, rather than attempting to scale down the use of Regional Red Data Lists that are now being adopted nationally in some countries (e.g., Keller et al., 2005). The role of enrichment planting and plantations in species conservation has not come under severe scrutiny because they are related to many NTFPs that are often not considered as severe threats to biodiversity. Several studies suggest that because NTFPs are highly accessible by poor rural people for livelihoods, extraction will be benign relative to commercial timber harvesting in terms of damage to total biodiversity (Saxena, 2003; Belcher et al., 2005) and are therefore favourable for conservation and cash income incentives. However, a large amount of knowledge will still be required to determine if NTFPs will be able to achieve the dual goal of conservation and sustainable income (i.e., cash and kind). One important source of information will be to understand the impacts of NTFP extraction and diversity of other (unused) species within the growing microenvironment of the NTFP species to be able to assess the precise impacts of extraction at the plant community level. All species populations are therefore a part of a dynamic system that is regulated by site-specific competition for resources (e.g., light water, nutrients) that need to be accounted for in addition to direct harvesting by humans (Dhillion and Gustad, 2004).

Additionally, the certification of known commercialised NTFPs at the local level will prompt local people to embark on best practices for the least known NTFP species by undertaking adequate local protective activities (e.g., conservancies). This is because certification will require that the NTFP is already marketed locally, having added value and diversified products, whilst there is a track record of any emerging ecological impacts and that, its production is associated with sustainable practices (Anderson and Putz, 2002). The extraction of many NTFPs has been found to follow economic cycles, going through phases of expansion, stabilisation, decline and ultimately being cultivated (Homma, 1996). If this holds true, then management interventions need to identify these various phases in the cycle and appropriate measures implemented. Threat Reduction Assessment (TRA), a monitoring tool that minimises illegal extractions, has been suggested for understanding the threat status of biodiversity as a result of resource extraction and disturbance (Salafsky and Margoluis, 1999). The TRA approach is however incomplete and needs to build into its protocol the impacts on species affected by resource use in the context of participatory forest management (Topp-Jørgensen et al., 2005). The use of enrichment and enhancement planting that are usually practised following monitoring appear to come rather too late usually at the decline stage, instead of the stabilisation phase of the NTFP production cycle. Management practices need to ensure that stocks and flows of NTFP resources remain at an acceptable level that can be described as sustainable but not at the expense of local biodiversity. In some circumstances where individuals are constrained by the production capacity of particular species, populations of such species may be prone to depletion and in such cases, enrichment planting and orchards have been suggested (Nebel, 2001; Botha et al., 2004). This must however be accompanied by low impact harvesting techniques that will foster regeneration and stand enhancement. It has been suggested that using pollarding for mature trees amongst mixed woodland vegetation has been successful in stimulating regeneration rather than clear felling of trees and thinning in parklands, which tend to disrupt biodiversity (Mortimore and Turner, 2005).

3.4. The anthropogenic dynamics of NTFP extraction and tenure

Local people's ownership of the knowledge of biodiversity is a source of potential wealth of information that needs to be captured in all resource use studies and management. This study showed that local people had uses for 267 woody species belonging to 69 plant families, in sharp contrast to what was sampled directly from the field using ecological techniques. The difference in scale (both spatial and time frames) is however recognised and acknowledged especially when it was impossible to sample each and every species across the whole vegetation as a result of cost and time. In addition, a key aspect of this study was to determine the relationship between total and useful woody plant species richness and diversity and accompanied trends in disturbance. Moreover, many of the species that people knew, may have become locally rare and even locally extinct over time. However, the identification or definition of what is a useful species is socially constructed and is not uniform within and between communities. For example, 40% woody species were identified at the focus group discussions as useful for wild fruits at the KwaJobe site in the Natal lowveld bushveld vegetation, but not at Fairbairn (36%) in the Eastern thorn bushveld. Similarly, *Schotia brachypetala* was identified as a key medicinal species in KwaJobe but not in Fairbairn where the seeds are edible. *Sclerocarya birrea* had seven uses in Finale A, but only four in Mabins A. Consequently, it is important to ensure that different constituencies and potential knowledge groups are consulted in determining the usefulness of particular species at defined sites and in future management. In this study a focus group analysis based on gender and age of the respondents provided insights and knowledge of which user groups are knowledgeable of which types of resources and for what uses. Local and indigenous knowledge are therefore vital to ecological studies in unfolding unique species, uses and processes when considering our progress towards providing appropriate management decisions.

The explicit formal recognition of tenure systems associated with traditional ownership of land, guided by traditional laws and rules will empower local people to own and protect biodiversity (Nhantumbo et al., 2001; Dovie, 2003). Such an initiative will require shifts in policy emphasis on commercial natural resource production activities and especially forestry plantation for timber. The tenure of local people further needs to encompass people's intellectual property, cultural value and indigenous knowledge about the species that are used for NTFP purposes and documented to support biological management (Salick et al., 1999; Nebel, 2001; Senaratne et al., 2003; Parlee et al., 2005). Organising and regulating access to, and the use of the broad spectra of diversity of species for NTFPs are crucial for sustainability. Hence, there is the need to build into management, adequate information about household behaviour including accessibility of the woody plant species, as well as skills and technical knowledge of harvesters (Dovie, 2003; Mahapatra et al., 2005; Delang, 2006). Additionally, policy consensus that seeks to place the degradation of natural resources at the top of the conservation agenda needs to carefully examine and include uncertainties about scientific issues and indicators of change and sustainability, in relation to management (Mortimore and Turner, 2005). Devolving the management authority of woodlands to local people will bring to them a sense of ownership and the duty of policing the utilisation of biodiversity. Incentive based management processes will draw in greater commitment from the local people but needs to be sustained until there is greater appreciation by both users and harvesters (Topp-Jørgensen et al., 2005). Of what use will it be if local people are involved in research projects on NTFPs if they are excluded from management in their own environment? The older generation of males in this study for example were noted to have more knowledge than their female counterparts and the younger generations and can therefore contribute their raw intellectual property on the status and management of the locally available species, a result similarly observed in tropical rainforests but for a few selected species and uses (Styger et al., 1999; Ladio and Lozada, 2004). The skills development of people involved in NTFP harvesting must be made a management concern, so as to reduce the "mutilation" of the resource base and hence the effects on the population of the particular species as well as the habitat (Mahapatra et al., 2005).

3.5. Local level NTFP management models

Strong tenure practices, appropriate forest and organisational institutions will be required to manage NTFP resources, built on the value system of local communities (Nebel, 2001; Adhikari et al., 2004). Extractive reserves have been a development strategy in existence for over a decade within forest ecosystems for managing biological resources, defined as "conservation units that guarantee the rights of traditional populations to engage in harvesting forest products" (Anderson, 1992). Apart from extractive reserves, community forests have also been established to provide key sources of NTFPs (Ham and Theron, 1998; Adhikari et al., 2004). In more recent times traditional and communal area conservancies are taking off to provide NTFP services, especially in southern Africa (Weaver and Skyer, 2003). The term "community forestry" has different meanings and has been misinterpreted over the years. It is also referred to as participatory forestry management, a concept whereby local people form partnerships to manage a forest and to provide resources such as non-timber forest products, be it state or communally owned (Singh et al., 1997). The Department of Water Affairs and Forestry of South Africa (DWAF) defines community forestry as "forestry designed and applied to meet local social, household and environmental needs and to favour local economic development. It is implemented by communities or with the participation of communities. It includes farm forestry, agro-forestry, community or village planting, woodlots and woodland management by rural people, as well as tree-planting in urban and peri-urban areas" (DWAF, 1996). The extractive reserves and the community forestry are efforts by villages to set aside areas recognised locally as sources of their livelihoods. Unlike community forests that are usually targeted at meeting immediate and short term needs of the local people, extractive reserves are a long-term endeavour characterised by high level of biological diversity and managed by local villagers (Pinedo-Vasquez et al., 1992).

Community reserves and forests provide many diverse products to rural people, yet they lack any legal status and so become problematic when conflicts over resource extraction arise. Hence, they should rather be organised to a level that they can be given official recognition (Nebel, 2001; Nhantumbo et al., 2001) and providing opportunities for certification (Anderson and Putz, 2002). The long term viability of such reserves will be threatened in the absence of legal and state recognition. Appropriate legislation should help transfer to village communities the rights to manage local forests for their own benefit. The biggest advantage of setting up community reserves and forests is that abandoned land (marginal or agricultural) can be used and some protective activities embarked upon to facilitate the establishment of favourable habitat conditions for biodiversity in the long term. Community forestry has made significant contributions in reviving the productivity of waste and sub-optimally used lands through ecologically sound programmes to maintain biodiversity and also generate land based employment opportunities (Singh et al., 1997). Community forestry is not meant to seek the consent of a community as an entity working together but to identify the many functional interest groups (e.g., family units, age groups, women's associations) and to work with them (Ham and Theron, 1998). Where community forestry has been successful, it has been noted that forest degradation has been minimized, coupled with enhanced quality of natural forests and enrichment planting on marginal lands thought to be "wasteland" (Singh et al., 1997).

Although tenurial rights of rural communities have proven to be a strong incentive for promoting the conservation of natural resources in several case studies, it is relevant that the distinction between private and public ownership be clarified. It has been shown that areas of high biodiversity (hotspots) overlap with places where local people possess a *de jure* tenurial security and declarations of access to resources, which exclude "outsiders" from interfering with resource use (Alcorn, 1993; McNeely, 1995). Forests have been held under complex, often overlapping tenure rights, preventing outsiders from destroying forests, a system that promotes partnerships between individuals and their community (Alcorn, 1993). A reform of property rights has to be an integral part of a policy seeking to restore local autonomy over natural resources. The present situation in this respect is unsatisfactory in most African countries. In South Africa, the Department of Water Affairs and Forestry through the National Forest Acts of 1998 has suggested the active involvement of local people in managing woodland resources, but a number of lessons still have to be learnt from other suitable models and tailored to the South African situation, especially in the communal areas. The objective should be to ensure equity in access to resources and incentives for their conservation and improvement. It is necessary to establish clear rules on the access, ownership and use of resources. In some cases, this may require individual title deeds, in others the formalization and effective enforcement of traditional systems of land tenure and use will be required. Under some circumstances, it may be necessary to evolve new property regimes and build new institutions to ensure implementation. To local people, conserving biodiversity is not new, referring to the relation between biological wealth and maintenance of survival. Various land-use patterns for activities other than NTFP extraction (e.g., slash and burn agriculture) have been found to enrich biodiversity as a result of the rotated periods between fallows (Belcher et al., 2005; Delang, 2006). In some parts of Asia, there have been restrictions on fallow periods, causing shifts that optimise other benefits to support livelihoods with NTFPs as the main target. A further restriction will be the use of rules to replace usufruct patterns of NTFP uses (Senaratne et al., 2003).

3.6. Lessons and future challenges

The two pronged approach, based on ethnographic and ecological principles adopted in this study jointly led to the optimum coverage of differences in knowledge about locally available useful species, their location and distribution. The lower numbers of useful species identified in the field sampling, was partly related to scale of sampling undertaken – it would have been impossible to sample the whole vegetation, but nonetheless it does suggest the inadequacy of ecological approaches alone to fulfil the complete understanding of the changing dynamics of NTFPs and the species that are used. Management pertaining to the use of plant parts directly relate to the population, regeneration and recruitment dynamics of locally available species, which may produce seasonal, short and long term effects on total biodiversity need to be considered when planning the management of NTFPs (Ticktin, 2005). This is because not all species are used and although a high number may be in use, the remaining few may be very important in contributing to ecosystem services and some functional diversity and yet can be highly negatively impacted. Although field ecological sampling can lead to the identification of a large number of species and their demographic patterns, with a number of uses based on reference materials such as field guides, they may not reflect what local people really use in localized environments due to differences in social constructs (Dovie, 2003). Interfacing ecological information with community knowledge will lead to the identification of species with potential threats that may result from multiple uses or species with narrow distributional ranges within the local environment.

The biggest challenge facing NTFP resources is probably the inadequacy of appropriate field sampling tools because of time and cost, or the imposition of field ecological techniques on community knowledge. This has led to the lack of relevant information about the structure and floristic composition as well as the locations of NTFP sources. The next challenge is to consider the issue of the scale of sampling of woody species and how it relates to local knowledge or traditional nomenclature. Whilst it will be almost impossible to sample all woody species, local people will be able to provide requisite information about availability but because there may be a mismatch in the information from the two sampling sources, there is the need to standardise limits and protocols in order to appropriately match the outcomes of scientific and local knowledge.

Additionally, modern science should attempt to develop the raw intellect of local people and standardize the capture of local knowledge through the proper documentation of traditional nomenclature and folk biological knowledge, such as is done in India (Daniel, 1997). Moreover, the need to set up appropriate guidelines for scientists and managers to have formal dialogue with local and indigenous people through appropriate stakeholder analysis and actively involving them in planning, implementation and monitoring is long overdue. The need for more of these kinds of studies cannot be underestimated in providing physical, natural and social scientists as well as policymakers, the opportunity to have more in-depth and meaningful dialogue, with the goal of working towards an improvement in the ecological status, the political economy and conservation management of NTFPs.

4. CONCLUSIONS

There is huge amounts of information and knowledge on the extraction of savanna resources, but it is mostly restricted to monetary and economic valuation, yield and sustainability studies, demography and patterns of use and the influences of environmental factors on harvesting regimes of selected species (e.g., Marshall et al., 2003; Lawes et al., 2004; Ghimire et al., 2005; Shackleton et al., 2005; Ticktin, 2005). The lack of specific studies on the impacts of NTFP extraction on total species diversity and richness has resulted in static knowledge about the link between NTFP extraction and biodiversity at the local level although populations of many species are believed to have been lost through NTFP use (Sinha and Brault, 2005). There is a general consensus that the local monitoring of NTFP species based on stocks and flows, as well as diversity and physical changes will guide management efforts on sustaining NTFP species and accompanied products. As part of the monitoring and management systems, indigenous systems of classifying the NTFP resources and species have been strongly advocated (Sinha and Brault, 2005; Parlee et al., 2005; Delang, 2006). Such systems of classification such as the "Locally Brown List" proposed in this study in conjunction with other classifications (e.g., Orange Lists; Victor and Keith, 2004), will improve the understanding of the conservation biology of species that may be locally at risk of extinction. For NTFP species, the vulnerability of poor and local people to the effects of harvesting disturbance and management strategies need to be acknowledged in policy debates and the human elements actively drawn into holistic biodiversity management strategies. The latter will require the redefining of biodiversity to encompass elements of disturbance theory, indigenous knowledge and tenure as well as human livelihoods and local institutions.

It is important to also acknowledge the high variability that exists in NTFP uses and the accompanied species, suggesting different types and levels of management (Mahapatra et al., 2005). Whilst some of these NTFPs will benefit from value addition to save the species involved, others may not benefit, but without appropriate monitoring mechanisms in place, the species will possibly face severe threats of reduction or loss. Whilst enrichment and enhancement planting of NTFP species are top on the agenda for management, the production cycle and the classification of the NTFP species needs to be a major focus to minimise the risk of displacing other components of diversity (Mahapatra et al., 2005; Delang, 2006). Although over-utilisation has been found to be a major concern, the underutilisation of certain species can also be as big a problem under certain circumstances in the context of local livelihoods and nature conservation management (Stræde et al., 2002). In order to manage these emerging challenges from the utilization of species for NTFPs, forest property regimes and other land tenure systems can be developed and managed to provide NTFPs whilst maintaining biodiversity (Dovie et al., 2002). This study has provided information based on both scientific and local people's knowledge on the community composition of woody plant species together with those extracted for NTFP uses by local people towards informed policy framework and better science for understanding local biodiversity.

References

Adhikari, M., Nagata, S., Adhikari, M., 2004. Rural household and forest: an evaluation of household's dependency on community forest in Nepal. Journal of Forestry Research 9, 33-44.

Alcorn, J.B., 1993. Indigenous peoples and conservation. Conservation Biology 7(2), 424-426.

Anderson, A.B., 1992. Land-use strategies for successful extractive economies in Amazonia. Advances in Economic Botany 9, 79-86.

Anderson, P.J., Putz, F.E., 2001. Harvesting and conservation: are both possible for the palm, *Iriartea deltoidea*? Forest Ecology and Management 170, 271-283.

Belcher, B., Kusters, K., 2004. Non-timber forest product commercialisation: development and conservation lessons. In: Kusters, K., Belcher, B. (Eds.), Forest Products, Livelihoods and Conservation: Case Studies of Non-Timber Forest Product Systems Volume 1 – Asia.

Belcher, B., Ruíz-Pérez, M., Achdiawan, R., 2005. Global patterns and trends in the use and management of commercial NTFPs: implications for livelihoods and conservation. World Development 33, 1435-1452.

Berkes, F., Colding, J., Folke, C. (Eds.), 2003. Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press, Cambridge.

Blaikie, P., Cannon, T., Davis, I., Wisner, B., 1994. At risk: natural hazards, people's vulnerability and disasters. Routledge, London.

Botha, J., Witkowski, E.T.F., Shackleton, C.M., 2004. Harvesting impacts on commonly used medicinal tree species (*Catha edulis* and *Rapanea melanophloeos*) under different land management regimes in the Mpumalanga Lowveld, South Africa. Koedoe 47(2), 1–18.

Dahlberg, A.C., 2000. Vegetation diversity and change in relation to land use, soil and rainfall – a case study from North East District, Botswana. Journal of Arid Environments 44, 19-40.

Daniel, M., 1997. The Changing Landscape of Plant Sciences: Taxonomy and Ecology. Vedams Books, New Delhi.

Delang, C.O., 2006. Indigenous systems of forest classification: understanding land use patterns and the role of NTFPs in shifting cultivators' subsistence economies. Environmental Management 37(4) 470-486.

Dhillion, S.S., Gustad, G., 2004. Local Management practices influence the viability of the baobab (*Adansonia digitata* Linn.) in different land use types. Agriculture, Ecosystems and Environment 101, 85-103.
Dovie, D.B.K., 2003. Whose involvement? – Can Hierarchical Valuation Scheme intercede for participatory methods for evaluating secondary forest resources use? Forest Policy and Economics 5(3), 265-283.
Dovie, D.B.K., Shackleton, C.M., Witkowski, E.T.F., 2002. Accessing natural resources: implications for sustainable management and livelihoods. In: Benjaminsen, T., Cousins, B., Thompson, L. (Eds.), Contested Resources: Challenges to Governance of Natural Resources in Southern Africa. Programme for Land and Agrarian Studies, University of the Western Cape, Cape Town, pp. 336-348.
DWAF, 1996. White paper on sustainable forest development in South Africa. Department of Water Affairs and Forestry, Pretoria.
Farina, A., 2000. The cultural landscape as a model for integration of ecology and economics. Bioscience 50(4), 313-320.
Fjeldså, J., Lovett, J.C., 1997. Geographical patterns of old and young species in African forest biota: the significance of specific montane areas as evolutionary centres. Biodiversity and Conservation 6, 325-346.
Geist, H.J., Lambin, E.F., 2001. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52(2), 143-150.
Ghimire, S.K., McKey, D., Aumeeruddy-Thomas, Y., 2005. Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC. and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. Biological Conservation 124, 463-475.
Ham, C., Theron, F., 1998. Community Forestry – Project implementation through communities as a whole or through interest groups? Southern African Forestry Journal 181, 45-49.
Hockley, N.J., Jones, J.P.G., Adriahajaina, F.B., Manica, A., Ranambitsoa, E.M., Randriamboahary, J.A., 2005. When should communities and conservationists monitor exploited resources? Biodiversity and Conservation 14, 2795-2806.
Homma, A.K.O., 1996. Modernisation and technological dualism in the extractive economy of Amazonia. In: Arnold, J.E.M., Ruíz-Pérez, M., (Eds.), Current Issues in Non-Timber Forest Products Research. CIFOR-ODA, Bogor, pp. 59-83.
Keller, V., Zbinden, N., Schmid, H., Volet, B., 2005. A case study in applying the IUCN Regional Guidelines for National Red Lists and justifications for their modification. Conservation Biology 19(6) 1827-1843.
Ladio, A.H., Lozada, M., 2004. Patterns of use and knowledge of wild edible plants in distinct ecological environments: a case study of a Mapuche community from northwestern Patagonia. Biodiversity and Conservation 13(6), 1153-1173.
Lawes, M.J., Eeley, H.C., Shackleton, C.M., Geach, B.S. (Eds.), 2004. Indigenous Forests and Woodlands in South Africa: Policy, People and Practice. University of Natal Press, Durban.
Mahapatra, A.K., Albers, H.J., Robinson, E.Z.J., 2005. The impact of NTFP sales on rural households' cash income in India's dry deciduous forest. Environmental Management 35(3) 258-265.
Marshall, E., Newton, A.C., Schreckenberg, K., 2003. Commercialization of non-timber forest products: first steps in analysing the factors influencing success. International Forestry Review 5, 128-137.
Martorell, C., Peters, E.M., 2005. The measurement of chronic disturbance and its effect on the threatened cactus *Mammillaria pectinifera*. Biological Conservation 124, 199-207.

McNeely, J.A., 1995. How traditional agro-ecosystems can contribute to conserving biodiversity. In: Halladay, P., Gilmour, D.A. (Eds.), Conserving biodiversity outside protected areas: The role of traditional agro-ecosystems. IUCN, Gland, pp. 20-40.

Mortimore, M., Turner, B., 2005. Does Sahelian smallholder's management of woodland, farm trees, rangeland support the hypothesis of human-induced desertification? Journal of Arid Environments 63, 567-595.

Nebel, G., 2001. Sustainable land-use in Peruvian flood plain forests: options, planning and implementation. Forest Ecology and Management 150, 187-198.

Neke, S.K., 2005. The Regeneration Ecology of Savanna Woodlands in Relation to Human Utilisation. Unpublished PhD Thesis, University of the Witwatersrand, Johannesburg, pp. 244.

Nhantumbo, I., Dent, J.B., Kowero, G., 2001. Goal programming: application in the management of the miombo woodland in Mozambique. European Journal of Operational Research 133, 310-322.

Parlee, B., Berkes, F., Teetl'it Gwich'in Renewable Resources Council, 2005. Health of the Land, Health of the People: A Case Study on Gwich'in Berry Harvesting in Northern Canada. EcoHealth 2, 127-137.

Peters, C.M., 1996. Beyond nomenclature and use: a review of ecological methods for ethnobotanists. In: Alexiades, M.N. (Ed.), Selected Guidelines for Ethnobotanical Research. The New York Botanical Garden, New York, pp. 241-276.

Pickett, S.T.A., Kolasa, J.J., Armesto, J.J., Collins, S.L., 1989. The ecological concept of disturbance and its expression at various hierarchical levels. Oikos 54, 129-136.

Pickett, S.T.A., Parker, V.T., 1994. Avoiding the old pitfalls: opportunities in a new discipline. Restoration Ecology 2, 75-79.

Pinedo-Vasquez, M., Zarin, D., Jipp, P., 1992. Community Forest and lake reserves in the Peruvian Amazon: A local alternative for sustainable use of tropical forests. In: Nepstad, D.C., Schwartzman, S. (Eds.), Non-Timber Products from Tropical Forests. Evaluation of a Conservation and Development Strategy. Advances in Economic Botany 9, 79-86.

Reid, R.S., Kruska, R.L., Muthi, N., Taye, A., Wotton, S., Wilson, C.J., Mulatu, W., 2000. Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. Landscape Ecology 15, 339-355.

Salafsky N., Margoluis R., 1999. Threat reduction assessment: a practical and cost-effective approach to evaluating conservation and development projects. Conservation Biology 13, 830–841.

Salick, J., Bium, A., Martin, G., Apin, L., Beaman, R., 1999. Whence useful plants? A direct relationship between biodiversity and useful plants among the Dusun of Mt. Kinabalu. Biodiversity and Conservation 8, 797-818.

Saxena, N.C., 2003. Livelihood diversification and non-timber forest products in Orissa: wider lessons on the scope for policy change? ODI Working Paper No. 223. ODI, London.

Sekhwela, M.B.M., 2003. Woody vegetation resource changes around selected settlement along aridity gradient in the Kalahari, Botswana. Journal of Arid Environments 54, 469-482.

Senaratne, A., Abeygunawardena, P., Jayatilake, W., 2003. Changing role of non-timber forest products (NTFP) in rural household economy: the case of Sinharaja World Heritage in Sri Lanka. Environmental Management 32, 559-571.

Shackleton C.M., Griffin N.J., Banks J.M., Mavrandonis J.M., Shackleton S.E., 1994. Community structure and species composition along a disturbance gradient in a communally managed South African savanna. Vegetatio 115, 157-167.

Shackleton, C.M., 2000. Comparison of plant diversity in protected and communal lands in the Bushbuckridge lowveld savanna, South Africa. Biological Conservation 94, 273-285.

Shackleton, C.M., Guthrie, G., Main, R., 2005. Estimating the potential role of commercial over-harvesting in resource viability: A case study of five useful tree species in South Africa. Land Degradation and Development 16, 273-286.

Sheil, D., 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities, and distractions. Conservation Biology 15, 1179-1182.

Singh, S., Datta, A., Bakshi, A., Khare, A., Saigal, S., Kapoor, N., 1997. Participatory forest management in west Bengal, India. In: Freese, C.H. (Ed.), Harvesting wild species – implications for biodiversity conservation. Johns Hopkins University Press, London.

Sinha, A., Brault, S., 2005. Assessing sustainability of nontimber forest product extractions: how fire affects sustainability. Biodiversity and Conservation 14, 3537-3563.

Stoian, D., 2005. Making the best of two worlds: rural and peri-urban livelihood options sustained by non-timber forest products from the Bolivian Amazon. World Development 33, 1473-1490.

Stræde, S., Nebel, G., Rijal, A., 2002. Structure and floristic composition of community forests and their compatibility with villagers' traditional needs for forest products. Biodiversity and Conservation 11, 487-508.

Styger, E., Rakotoarimanana, J.E.M., Rabevohitra, R., Fernandes, E.C.M., 1999. Indigenous fruit trees of Madagascar: potential components of agroforestry systems to improve human nutrition and restore biological diversity. Agroforestry Systems 46, 289-310.

Ticktin, T., 2004. The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology 41, 11-21.

Ticktin, T., 2005. Applying a metapopulation framework to the management and conservation of a non-timber forest species. Forest Ecology and Management 206, 249-261.

Ticktin, T., Johns, T., Chapol Xoca, V., 2003. Patterns of growth in *Aechmea magdalenae* and its potential as a forest crop and conservation strategy. Agriculture, Ecosystem and Environment 94, 123-129.

Topp-Jørgensen, E., Poulsen, M.K., Lund, J.F., Massao, J.F., 2005. Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands of Tanzania. Biodiversity and Conservation 14, 2653-2677.

Trauernicht, C., Ticktin, T., 2005. The effects of non-timber forest product cultivation on the plant community structure and composition of a humid tropical forest in southern Mexico. Forest Ecology and Management 219, 269-278.

Victor, J.E., Keith, M., 2004. The Orange list: a safety net for biodiversity in South Africa. South African Journal of Science 100, 139-141.

Weaver, L.C., Skyer, P., 2003. Conservancies: integrating wildlife land-use options into the livelihood, development, and conservation strategies of Namibian communities. A Paper Presented at the Vth World Parks Congress, Durban, September 8-17, 2003, South Africa.

Wint, W., Bourn, D., 1994. Livestock and land-use surveys in sub Saharan Africa. An Oxfam Working Paper. Oxfam, UK and Ireland.

General appendix. Woody plant species that were documented for both the focus groups (i.e., community knowledge - 1) and modified Whittaker plots (i.e., field ecological knowledge - 2) and their useful statuses across all the study sites.

Species names	**Plant family**	**Data source**	**Use status**
Barleria albostellata C.B. Clarke	Acanthaceae	2	unused
Agave americana L.	Agavaceae	1	used
Aloe africana Mill.	Aloaceae	1,2	used
Aloe boylei Baker	Aloaceae	1	used
Aloe thraskii Baker	Aloaceae	1,2	used
Harpephyllum caffrum Bernh. ex Krauss	Anacardiaceae	1	used
Lannea discolor Engl.	Anacardiaceae	1,2	used
Lannea schweinfurthii Engl.	Anacardiaceae	1,2	used
Oxyanthus latifolius Sond.	Anacardiaceae	2	unused
Ozoroa sphaerocarpa R. Fern. & A. Fern.	Anacardiaceae	2	used
Protorhus longifolia Engl.	Anacardiaceae	1	used
Rhus chirindensis Baker f.	Anacardiaceae	1	used
Rhus dentata Thunb.	Anacardiaceae	1	used
Rhus fastigiata Eckl. & Zeyh.	Anacardiaceae	1,2	used
Rhus gerrardii Harv. ex Engl.	Anacardiaceae	2	unused
Rhus gueinzii Sond.	Anacardiaceae	1,2	used
Rhus incisa L.f.	Anacardiaceae	1	used
Rhus lancea L.f.	Anacardiaceae	1	used
Rhus leptodictya Diels	Anacardiaceae	2	used
Rhus lucida Ait.	Anacardiaceae	1,2	used
Rhus natalensis Bernh. ex Krauss	Anacardiaceae	2	unused
Rhus pallens Eckl. & Zeyh.	Anacardiaceae	2	used
Rhus pentheri Zahlbr.	Anacardiaceae	2	unused
Rhus pyroides A. Rich	Anacardiaceae	2	unused
Rhus undulata E. Mey. ex Sond.	Anacardiaceae	1	used
Schinus molle L.	Anacardiaceae	1	used
Sclerocarya birrea Hochst.	Anacardiaceae	1,2	used
Smodingium argutum E. Mey.	Anacardiaceae	1	used
Annona senegalensis Pers	Annonaceae	1	used
Monanthotaxis caffra (Sond.) Verdc.	Annonaceae	1,2	used
Uvaria caffra E. Mey. ex Harv. & Sond.	Annonaceae	1,2	used
Heteromorpha trifoliata Eckl. & Zeyh.	Apiaceae	1	used
Steganotaenia araliacea Hochst.	Apiaceae	2	unused
Acokanthera oblongifolia (Hochst.) Codd	Apocynaceae	1	used
Ancylobothrys capensis (Oliv.) Pichon	Apocynaceae	1	used
Carissa bispinosa Desf.	Apocynaceae	1,2	used
Carissa edulis Vahl	Apocynaceae	1	used
Carissa tetramera Stapf	Apocynaceae	1,2	used
Landolphia kirkii (Dyer)	Apocynaceae	1	used
Rauvolfia caffra Sond.	Apocynaceae	1	used
Tabernaemontana elegans Stapf	Apocynaceae	1	used
Tabernaemontana ventricosa Hochst. ex A. DC.	Apocynaceae	2	unused
Ilex mitis Radlk.	Aquifoliaceae	1	used
Cussonia arenicola Strey	Araliaceae	2	unused
Cussonia paniculata Eckl. & Zeyh.	Araliaceae	1,2	used
Cussonia spicata Thunb.	Araliaceae	1	used
Hyphaene coriacea Welw.	Arecaceae	1,2	used
Phoenix reclinata Jacq.	Arecaceae	1	used

Raphia australis Oberm. & Strey	Arecaceae	1	used
Brachylaena discolor DC.	Asteraceae	2	used
Brachylaena elliptica Less.	Asteraceae	2	used
Brachylaena glabra Druce	Asteraceae	1	used
Brachylaena huillensis O. Hoffm.	Asteraceae	1	used
Tarchonanthus camphoratus L.	Asteraceae	2	unused
Tarchonanthus trilobus DC.	Asteraceae	2	unused
Vernonia colorata Drake	Asteraceae	1	used
Vernonia mespilifolia Less.	Asteraceae	1	used
Balanites maughamii Sprague	Balanitaceae	1,2	used
Kigelia africana Benth.	Bignoniaceae	1	used
Rhigozum obovata Burch	Bignoniaceae	2	used
Rhigozum zambesiacum Baker	Bignoniaceae	1	used
Adansonia digitata L.	Bombacaceae	1	used
Cordia caffra Sond.	Boraginaceae	1	used
Ehretia amoena Klotzsch	Boraginaceae	2	used
Ehretia obtusifolia Hochst. ex DC.	Boraginaceae	1	used
Ehretia rigida Druce	Boraginaceae	1,2	used
Buddleja saligna Willd.	Buddlejaceae	1,2	used
Commiphora glandulosa Schinz	Burseraceae	2	unused
Commiphora marlothii Engl.	Burseraceae	2	unused
Commiphora mollis F. Hoffm.	Burseraceae	2	used
Commiphora neglecta Verdoorn	Burseraceae	1	used
Commiphora pyracanthoides Engl.	Burseraceae	2	used
Boscia albitrunca Gilg & Benedict	Capparaceae	1,2	used
Boscia oleoides (Burch. ex DC.) Toelken	Capparaceae	2	used
Cadaba aphylla (Thunb.) Wild	Capparaceae	1	used
Cadaba natalensis Sond.	Capparaceae	2	unused
Capparis sepiaria L.	Capparaceae	1,2	used
Capparis tomentosa Lam.	Capparaceae	1,2	used
Maerua angolensis DC.	Capparaceae	2	used
Maerua caffra Pax	Capparaceae	2	unused
Cassine aethiopica Thunb.	Celastraceae	1,2	used
Cassine peragua L.	Celastraceae	1,2	used
Cassine transvaalensis (Burtt Davy) Codd	Celastraceae	1,2	used
Catha edulis (Vahl) S. Endlicher	Celastraceae	1	used
Elaeodendron transvaalense (Burtt Davy) R.H. Archer	Celastraceae	2	unused
Gymnosporia buxifolia Szyszyl.	Celastraceae	1,2	used
Gymnosporia glaucophylla Jordaan	Celastraceae	2	used
Gymnosporia maranguensis Loes.	Celastraceae	2	unused
Gymnosporia mossambicensis Loes.	Celastraceae	2	unused
Gymnosporia polyacantha (Sond.) Szyszyl.	Celastraceae	2	used
Gymnosporia senegalensis Loes.	Celastraceae	1,2	used
Hippocratea longipetiolata Oliver	Celastraceae	2	unused
Lauridia tetragona (L.f.) R.H. Archer	Celastraceae	1	used
Maytenus acuminata (L.f.) Loes.	Celastraceae	1,2	used
Maytenus heterophylla (Eckl. & Zeyh.) N. Robson	Celastraceae	1,2	used
Maytenus penduncularis (Sond) Loes.	Celastraceae	1	used
Maytenus procumbens (L.f.) Loes.	Celastraceae	1,2	used
Maytenus senegalensis (Lam.) Exell	Celastraceae	1	used
Maytenus undata (Thunb.) Blakelock	Celastraceae	1,2	used
Mystroxylon aethiopicum (Thunb.) Loes.	Celastraceae	2	unused
Pterocelastrus tricuspidatus Walp.	Celastraceae	1	used
Salacia leptoclada Tul.	Celastraceae	1	used
Celtis africana Burm. f.	Celtidaceae	1	used

Parinari curatellifolia Planch. ex Benth.	Chrysobalanaceae	1	used
Garcinia livingstonei T. Anders.	Clusiaceae	1	used
Combretum apiculatum Sond.	Combretaceae	1,2	used
Combretum collinum Fresen.	Combretaceae	1,2	used
Combretum erythrophyllum Sond.	Combretaceae	1	used
Combretum hereroense Schinz	Combretaceae	1,2	used
Combretum imberbe Wawra	Combretaceae	1,2	used
Combretum molle Engl. & Diels	Combretaceae	2	used
Combretum zeyheri Sond.	Combretaceae	1,2	used
Pteleopsis myrtifolia Engl. & Diels	Combretaceae	2	used
Terminalia prunioides M.A.Lawson	Combretaceae	2	unused
Terminalia sericea Burch. ex DC.	Combretaceae	1,2	used
Crassula vaginata Eckl. & Zeyh.	Crassulaceae	1	used
Cyathea capensis Pteridophyta (L. fil.) Sm.	Cyatheaceae	1	used
Diospyros alata Elmer	Ebenaceae	2	unused
Diospyros austro-africana De Winter	Ebenaceae	1	used
Diospyros dichrophylla (Gand.) De Winter	Ebenaceae	2	used
Diospyros lycioides Desf.	Ebenaceae	1,2	used
Diospyros mespiliformis Hochst. ex A. DC.	Ebenaceae	1,2	used
Diospyros natalensis (Harv.) Brenan	Ebenaceae	1	used
Diospyros rotundifolia Hiern.	Ebenaceae	1	used
Diospyros simii (Kuntze) De Winter	Ebenaceae	2	unused
Diospyros villosa (L.) De Winter	Ebenaceae	2	unused
Diospyros whyteana (Hiern) P. White	Ebenaceae	1	used
Dombeya rotundifolia Planch.	Ebenaceae	1,2	used
Euclea crispa (Thunb.) Gürke	Ebenaceae	1,2	used
Euclea divinorum Hiern	Ebenaceae	1,2	used
Euclea natalensis A. DC.	Ebenaceae	1,2	used
Euclea natalensis A. DC. subsp. obovata F. White	Ebenaceae	2	unused
Euclea natalensis A. DC. subsp. rotundifolia F. White	Ebenaceae	2	unused
Euclea schimperi (A. DC.) Dandy	Ebenaceae	2	used
Euclea undulata Thunb.	Ebenaceae	1,2	used
Erythroxylum pictum E. Mey.	Erythroxylaceae	1	used
Androstachys johnsonii Prain	Euphorbiaceae	1	used
Antidesma venosum E. Mey. ex Tul.	Euphorbiaceae	1,2	used
Bridelia micrantha Baill.	Euphorbiaceae	1	used
Bridelia mollis Hutchinson	Euphorbiaceae	2	unused
Cleistanthus schlechteri Hutchinson	Euphorbiaceae	1,2	used
Clutia pulchella L.	Euphorbiaceae	1	used
Croton sylvaticus Schlecht.	Euphorbiaceae	1	used
Euphorbia cooperi N.E.Br. ex A. Berger	Euphorbiaceae	1	used
Euphorbia grandidens Goebel	Euphorbiaceae	1	used
Euphorbia ingens E. Mey.	Euphorbiaceae	1	used
Euphorbia tetragona Baker	Euphorbiaceae	1,2	used
Euphorbia triangularis Desf.	Euphorbiaceae	1	used
Flueggea virosa (Willd.) Voigt	Euphorbiaceae	1	used
Jatropha zeyheri Sond.	Euphorbiaceae	2	unused
Margaritaria discoidea (Baill.) Webster	Euphorbiaceae	1	used
Phyllanthus reticulatus Lodd.	Euphorbiaceae	2	used
Ricinus communis L.	Euphorbiaceae	1	used
Sapium ellipticum Pax	Euphorbiaceae	1	used
Sapium integerrimum (Hochst. ex Krauss) J. Léonard	Euphorbiaceae	2	used
Spirostachys africana Sond.	Euphorbiaceae	1,2	used
Suregada zanzibariensis Baill.	Euphorbiaceae	1	used
Synadenium cupulare (Boiss.) Wheeler ex A. White	Euphorbiaceae	1	used

Bauhinia galpinii L.	Fabaceae	1	used
Cassia abbreviata Oliver	Fabaceae	1,2	used
Colophospermum mopane (J. Kirk ex Benth.) J. Léonard	Fabaceae	1	used
Dialium schlechteri Harms	Fabaceae	1,2	used
Erythrophleum lasianthum Corbishley	Fabaceae	1	used
Peltophorum africanum Sond.	Fabaceae	1,2	used
Piliostigma thonningii (Schumach.) Milne-Redh.	Fabaceae	1	used
Schotia afra Thunb.	Fabaceae	1,2	used
Schotia brachypetala Sond.	Fabaceae	1,2	used
Schotia latifolia Jacq.	Fabaceae	1	used
Schrebera alata Welw.	Fabaceae	2	unused
Senna petersiana (Bolle) Lock	Fabaceae	2	unused
Acacia ataxacantha DC.	Fabaceae	1,2	used
Acacia borleae Burtt Davy	Fabaceae	1,2	used
Acacia burkei Benth.	Fabaceae	1,2	used
Acacia caffra Willd.	Fabaceae	1,2	used
Acacia cyclops A. Cunn. ex Don	Fabaceae	1	used
Acacia davyi N.E.Br. in Burrt-Davy	Fabaceae	1	used
Acacia exuvialis Verdoorn	Fabaceae	1,2	used
Acacia gerrardii Benth	Fabaceae	1,2	used
Acacia karroo Hayne	Fabaceae	1,2	used
Acacia kraussiana Meisn. ex Benth.	Fabaceae	1,2	used
Acacia luederitzii Engl.	Fabaceae	1	used
Acacia mearnsii De Wild.	Fabaceae	1	used
Acacia natalitia E. Mey	Fabaceae	2	used
Acacia nigrescens Oliver	Fabaceae	1,2	used
Acacia nilotica Karst.	Fabaceae	1,2	used
Acacia robusta Burch.	Fabaceae	1,2	used
Acacia schweinfurthii Brenan & Exell	Fabaceae	1	used
Acacia senegal Willd.	Fabaceae	1,2	used
Acacia tortilis Hayne	Fabaceae	2	used
Acacia xanthophloea Benth.	Fabaceae	1	used
Adenopodia spicata C. Presl	Fabaceae	1	used
Albizia adianthifolia W.F. Wight	Fabaceae	1,2	used
Albizia harveyi Fourn.	Fabaceae	1,2	used
Dichrostachys cinerea R. Vig.	Fabaceae	1,2	used
Elephantorrhiza burkei Benth	Fabaceae	1	used
Newtonia hildebrandtii (Vatke) Torre	Fabaceae	1	used
Bolusanthus speciosus Harms	Fabaceae	1	used
Calpurnia aurea Benth.	Fabaceae	1	used
Crotalaria capensis Jacq.	Fabaceae	1	used
Dalbergia armata E. Mey.	Fabaceae	1	used
Dalbergia melanoxylon Guill. & Perr.	Fabaceae	1,2	used
Dalbergia obovata E. Mey.	Fabaceae	2	unused
Erythrina caffra Thunb.	Fabaceae	1	used
Erythrina latissima E. Mey.	Fabaceae	1	used
Erythrina lysistemon Hutch.	Fabaceae	1	used
Indigofera sp.	Fabaceae	2	unused
Mundulea sericea (Willd.) A. Chev.	Fabaceae	1,2	used
Ormocarpum trichocarpum (Taub.) Harms	Fabaceae	1,2	used
Philenoptera sutherlandii (Harv.) Schrire	Fabaceae	1	used
Philenoptera violacea (Klotzsch) Schrire	Fabaceae	1,2	used
Pterocarpus angolensis DC.	Fabaceae	1	used
Pterocarpus rotundifolius Druce	Fabaceae	1,2	used
Tephrosia cordata Hutchinson & Burtt Davy	Fabaceae	2	unused

Tephrosia pondoensis (Codd) Schrire	Fabaceae	2	used
Dovyalis caffra Sim	Flacourtiaceae	1	used
Dovyalis longispina Warb.	Flacourtiaceae	1,2	used
Dovyalis rotundifolia Harv.	Flacourtiaceae	1,2	used
Dovyalis zeyheri Warb.	Flacourtiaceae	1	used
Flacourtia indica Merr.	Flacourtiaceae	1	used
Flueggea verrucosa (Thunb.) G.L. Webster	Flacourtiaceae	2	unused
Scolopia mundii (Eckl. & Zeyh.) Warb.	Flacourtiaceae	1	used
Scolopia zeyheri Warb.	Flacourtiaceae	1,2	used
Trimeria grandifolia Warb.	Flacourtiaceae	1	used
Trimeria trinervis Harv.	Flacourtiaceae	2	used
Anthocleista grandiflora Gilg	Gentianaceae	1	used
Trichocladus ellipticus Eckl. & Zeyh.	Hamamelidaceae	1	used
Apodytes dimidiata E. Mey. ex Bernh.	Icacinaceae	2	unused
Kirkia wilmsii Engl.	Kirkiaceae	2	unused
Clerodendrum glabrum E.Mey.	Lamiaceae	1	used
Premna mooiensis W. Piep.	Lamiaceae	1	used
Vitex rehmannii Gürke	Lamiaceae	1	used
Cryptocarya woodii Engl.	Lauraceae	1	used
Ocotea bullata E. Mey. ex Meisn.	Lauraceae	1	used
Galpinia transvaalica N.E.Br.	Lythraceae	1	used
Hibiscus zeyheri Hochr.	Malvaceae	2	unused
Ekebergia capensis Sparrm.	Meliaceae	1	used
Melia azedarach L.	Meliaceae	1	used
Trichilia emetica Vahl	Meliaceae	1	used
Turraea floribunda Hochst.	Meliaceae	1	used
Ficus abutilifolia Miq.	Moraceae	1	used
Ficus burkei Miq.	Moraceae	1	used
Ficus burtt-davyi Hutchinson	Moraceae	1	used
Ficus glumosa Delile	Moraceae	1,2	used
Ficus natalensis Krauss ex Engl.	Moraceae	1	used
Ficus obtusifolia H.B. & K.	Moraceae	1	used
Ficus sansibarica Warb.	Moraceae	1	used
Ficus stuhlmannii Warb.	Moraceae	2	used
Ficus sur Forssk.	Moraceae	1,2	used
Ficus sycomorus L.	Moraceae	1	used
Maclura africana (Bur.) Corner	Moraceae	2	unused
Ensete ventricosum (Welw.) Cheesman	Musaceae	1	used
Rapanea melanophloeos Mez	Myrsinaceae	1	used
Psidium guajava L.	Myrtaceae	1,2	used
Syzygium cordatum Hochst. ex C. Krauss	Myrtaceae	1,2	used
Syzygium gerrardii Burtt-Davy	Myrtaceae	1	used
Syzygium guineense Guill. & Perr.	Myrtaceae	1	used
Pisonia aculeata L.	Nyctaginaceae	1	used
Ochna holstii Engl.	Ochnaceae	1	used
Ochna natalitia Walp.	Ochnaceae	2	used
Ochna pulchra Hook.	Ochnaceae	1	used
Ochna serrulata (Hochst.) Walp.	Ochnaceae	1	used
Ximenia americana L.	Olacaceae	1	used
Ximenia caffra Sond.	Olacaceae	1,2	used
Chionanthus foveolatus (Meyer) Stearn	Oleaceae	1	used
Olea europaea Thunb.	Oleaceae	1,2	used
Olinia radiata Hofmeyr & Phillips	Oliniaceae	1	used
Adenia gummifera Harms	Passifloraceae	1	used
Phytolacca americana L.	Phytolaccaceae	1	used

Phytolacca dioica L.	Phytolaccaceae	1	used
Pinus patula Schiede & Deppe ex Schlecht.	Pinaceae	1	used
Pittosporum viridiflorum Sims	Pittosporaceae	1	used
Podocarpus latifolius R.Br.	Podocarpaceae	1	used
Portulaca africana L.	Portulacaceae	2	unused
Portulacaria afra Jacq.	Portulacaceae	1,2	used
Faurea rochetiana Chiov. ex Pic. Serm.	Proteaceae	1	used
Faurea saligna Harv.	Proteaceae	1	used
Protea coronata Andrews	Proteaceae	1	used
Ptaeroxylon obliquum Radlk.	Ptaeroxylaceae	1,2	used
Berchemia discolor Hemsl.	Rhamnaceae	1,2	used
Berchemia zeyheri (Sond.) Grubov	Rhamnaceae	1,2	used
Scutia myrtina Merr.	Rhamnaceae	1,2	used
Ziziphus mucronata Willd.	Rhamnaceae	1,2	used
Cassipourea gerrardii Alston	Rhizophoraceae	1	used
Rhizophora mucronata Lam.	Rhizophoraceae	1	used
Cliffortia strobilifera Murr.	Rosaceae	1	used
Leucosidea sericea Eckl. & Zeyh.	Rosaceae	1	used
Alberta magna E. Mey.	Rubiaceae	1	used
Breonadia salicina (Vahl) Hepper & J.R.I. Wood	Rubiaceae	1	used
Canthium inerme Kuntze	Rubiaceae	1	used
Canthium kuntzeanum Bridson	Rubiaceae	2	unused
Canthium mundianum Cham. & Schltdl.	Rubiaceae	1,2	used
Canthium setiflorum Hiern	Rubiaceae	2	unused
Canthium spinosum Kuntze	Rubiaceae	2	used
Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae	2	unused
Coddia rudis (E. Mey. ex Harv.) Verdc.	Rubiaceae	1,2	used
Coffea racemosa Ruiz & Pav.	Rubiaceae	1	used
Gardenia cornuta Hemsl.	Rubiaceae	2	unused
Gardenia volkensii K. Schum.	Rubiaceae	1,2	used
Pachystigma macrocalyx Robyns	Rubiaceae	2	unused
Pavetta gracilifolia Bremek.	Rubiaceae	2	unused
Pavetta lanceolata Eckl.	Rubiaceae	2	unused
Plectroniella armata (K.Schum.) Robyns	Rubiaceae	1,2	used
Psydrax locuples (K. Schum.)	Rubiaceae	2	used
Psydrax obovata (Klotzsch ex Eckl. & Zeyh.)	Rubiaceae	2	used
Tarenna supra-axillaris (Hemsl.) Bremek.	Rubiaceae	2	unused
Tricalysia capensis Sim	Rubiaceae	2	unused
Tricalysia lanceolata Burtt-Davy	Rubiaceae	2	unused
Vangueria infausta Burch.	Rubiaceae	1,2	used
Vangueria parvifolia Sond.	Rubiaceae	1	used
Calodendrum capense Thunb.	Rutaceae	1	used
Clausena anisata Hook. f., De Wild. & Staner	Rutaceae	1	used
Teclea natalensis (Sond.) Engl.	Rutaceae	1	used
Vepris lanceolata G. Don	Rutaceae	1	used
Vepris reflexa Verdoorn	Rutaceae	1	used
Zanthoxylum capense Harv.	Rutaceae	1,2	used
Zanthoxylum davyi (Verdoorn) Waterman	Rutaceae	1	used
Salix babylonica L.	Salicaceae	1	used
Salix capensis Thunb.	Salicaceae	1	used
Azima tetracantha Lam.	Salvadoraceae	1,2	used
Allophylus natalensis (Sond.) De Winter	Sapindaceae	1	used
Hippobromus pauciflora Eckl. & Zeyh.	Sapindaceae	2	unused
Pappea capensis Eckl. & Zeyh.	Sapindaceae	1,2	used
Englerophytum magalismontanum (Sonder) T.D. Pennington	Sapotaceae	1	used

Manilkara concolor (Harv.) Gerstner	Sapotaceae	1	used
Manilkara mochisia (Baker) Gerstner	Sapotaceae	1,2	used
Manilkara nicholsonii A.E. Van Wyk	Sapotaceae	2	unused
Mimusops caffra E. Mey. ex A. DC.	Sapotaceae	1	used
Mimusops obovata Engl.	Sapotaceae	1	used
Sideroxylon inerme L.	Sapotaceae	1,2	used
Halleria lucida L.	Scrophulariaceae	1	used
Lycium acutifolium E. Mey.	Solanaceae	1	used
Lycium cinerea Thunb.	Solanaceae	2	unused
Solanum aculeastrum Dun.	Solanaceae	1	used
Solanum capense L.	Solanaceae	1	used
Solanum incanum Ruiz & Pav.	Solanaceae	2	used
Solanum nigrum Acerb. ex Dun.	Solanaceae	1	used
Solanum tomentosa L.	Solanaceae	2	unused
Sterculia rogersii N.E.Br.	Sterculiaceae	1,2	used
Strelitzia nicolai Regel & K. Koch	Strelitziaceae	1	used
Strychnos gerrardii N.E.Br.	Strychnaceae	2	used
Strychnos henningsii Gilg	Strychnaceae	1	used
Strychnos madagascariensis Poir.	Strychnaceae	1,2	used
Strychnos spinosa Lam.	Strychnaceae	1,2	used
Grewia bicolor Roth	Tiliaceae	1,2	used
Grewia caffra Meisn.	Tiliaceae	1	used
Grewia flava DC.	Tiliaceae	2	unused
Grewia hexamita Burret	Tiliaceae	2	used
Grewia microthyrsa K. Schum. ex Burret	Tiliaceae	2	unused
Grewia monticola Sond.	Tiliaceae	2	used
Grewia occidentalis L.	Tiliaceae	1,2	used
Grewia retinervis Burret	Tiliaceae	2	unused
Grewia robusta Burch.	Tiliaceae	2	used
Obetia tenax (N.E.Br.) Friis	Urticaceae	1	used
Lippia javanica Spreng.	Verbenaceae	2	used
Rhoicissus digitata Gilg & Brandt	Vitaceae	1	used
Rhoicissus tomentosa (Lam) Wild & R.B.Drumm.	Vitaceae	1	used
Rhoicissus tridentata (L.f.) Wild & R.B.Drumm.	Vitaceae	1	used