# The use, abundance and conservation of woody species in the Batemi Valley, northwestern Tanzania

by
Wynet Smith
Department of Geography
McGill University
Montreal, QC
July 1993

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfilment for the degree of Masters of Science

The use and conservation of woody species in northwestern Tanzania

## Abstract

The Batemi are an agropastoral group who inhabit a semi-arid area in Northwestern Tanzania. The group lives a traditional subsistence lifestyle and are therefore dependent on the resources that surround them. This study: 1) investigates their use of woody vegetation; 2) studies the abundance and distribution of woody vegetation in the area; and 3) experiments with assigning use values to species and with employing these uses to identify conservation priorities. The Batemi utilize over 100 woody [illegible] 7 families and 58 genera, from the environment surrounding the [illegible] construction, fuel, implements, services, food and medicine. Ra[illegible] systematic inventories in the valley showed that the most abundant species [illegible] *[illegible]ton dictygamous* and *Acacia tortilis.* Land cover in the area can be classed into three main vegetation types using a polythetic divisive program, TWINSPAN and these types are linked to three habitat types: hillside, plain and riverine. A landcover map for the area was produced from Landsat TM digital data. Based on density of woody vegetation, four categories were chosen for the final map product: thicket, woodland, wooded grassland, and grassland. To establish conservation priorities, use values are assigned based on importance of a use, number of species that can fulfil tnat use, and the rate of consumption. These values, when compared to abundance, provide a framework for considering conservation priorities. Based on various methods, *Acacia mellifera* and *Haplocoelum folioosum* are identified as two species that may require special attention.

**Resume**

Les Batemi sont un groupe agropastoral habitant une région semi-aride du nord-ouest de la Tanzanie. Le groupe vit de subsistences traditionnelles donc est dépendant des ressources naturelles environnantes. Cette étude 1) enquête sur l'usage qu'ils font de la végétation boisée 2) examine l'abondance et la distribution de la végétation boisée de la région 3) expérimente en classifiant les espèces par une échelle de valeur-utilisation et utilisant cette échelle pour identifier les priorités de conservation. Les Batemi utilisent au-dessus de 100 espèces forestières, dans 37 familles et 58 genera, trouvées dans la région environnante de leur village, pour des fins de constructions, combustion, outils, services, nourriture et médicine. Un échantillion choisie au hasard et un inventaire systématique dans la vallée démontrent que l'espèce la plus abondante est le *Croton dictygamous* et l'*Acacia tortilis*. La couverture terrestre dans la région peut être classé en trois types de végétations principales selon le programme divisible polythetique le TWINSPAN et ces types sont reliés aux trois types d'habitat : fallaise, plaine et riverain. Une carte de la couverture terrestre de la région fut produite par Landsat TM digital data. Basé sur la densité des boisés, quatre catégories ont été choisies pour la production de la carte finale : bosquet, pays boisé, savanne boisée et savanne. Afin d'établir les priorités de conservation, les espèces furent classées selon une échelle de valeur-utilisation, basée sur l'importance de son utilisation, le nombre d'espèce qui répondent à cette utilisation et le taux de consommation. Ces valeurs, une fois comparées à son abondance, procurent la base de travail dans la considération des priorités de conservation. Basé sur des méthodes variées, l'*Acacia mellifera* et *Haplocealum folioosum* sont deux espèces qui pourraient demander une attention spéciale.

**Acknowledgements**

There are a number of people that I must thank for their support and encouragement or hospitality. I will go by continent.

There are a number of people at McGill I would like to acknowledge. Special thanks to my supervisor, Thomas Meredith for his encouragement, guidance, support, and occasionally misplaced faith in me. Professors Theo Hills and Tim Johns, the other members of my committee, were also invaluable sources of information and encouragement and provided useful feedback on the thesis.

Lillian Lee of the GIS lab was incredibly helpful and patient. Professor Gail Chmura kindly allowed me to use her Mac computer to run a few programs. Professors Sherry Olson and Tim Moore provided helpful critical comments on the last draft.

I would like to acknowledge all the graduate and undergraduate students whom provided fun and excitement along the way. A special thanks to Scot, Elisa, Jennifer, and Paul for stimulating seminar conversations. Thanks to Bruce and Jill for CANOCO and TWINSPAN lessons and advice. A very special thanks to Karen Richardson for the use of her livingroom library, many dinners and more recently, a place to stay.

My family is also thanked for putting up with me all these years. I know you sometimes worry about what I'm doing, so now you can see I have actually done something in the last year and a half.

The African contingent is long. Tim Johns, Tom Kimanini, and E. Boniface Mohoro are thanked for making my first two weeks in Batemi an entertaining and learning experience. Those dinner conversations will be remembered for a long time with warmth and laughter. Tom also provided wonderful translation during my interviews with the Batemi.

In Nairobi, Pamela Keen and her entire family were a home and family away from home, providing more than just a place to stay. Simon Mathenge of the University of Nairobi Herbarium quickly and efficiently identified the specimens I brought to him.

Ken Campbell and Sally Huis of the Serengeti Wildlife Research Centre in the Serengeti National Park were incredibly hospitable and helpful to me when I showed up on their doorstep. Thanks for all your assistance and a wonderful week of conversations and dinners.

My field assistant, Frederick Sedia, was wonderful company as well as an informative guide and a keen assistant. His appreciation of my humour made lighter hours of hot days in the sun. Thanks to Juliana, Ayssac and all my other little friends in DigoDigo for their help and for keeping me company.

Manfred Oberessel, Maggie and their son Robert at the Wasso Hospital are thanked for their hospitality. They gave me a place to stay, medicine when I had malaria, and a drive to Arusha. A thanks also to M.S. Parkipuny for some interesting conversations, the chance to see the project in Olosokwan and a wild drive through the Serengeti.

The Institute for Traditional Medicine (ITM) kindly acted as my official institutional sponsor in Tanzania and the Tanzania Commission for Science and Technology provided the permission to conduct this research.

Special thanks to all those in the Batemi villages who so kindly shared their knowledge and the occasional honey beer. I hope that what I have collected can be of some use for your communities. Asante sana

Financial support was provided by a Natural Science and Engineering Research Council (NSERC) scholarship and a Federal Environmental Assessment Research Office (FEARO) student research contract.

## Table of Contents

## List of Tables

## List of Figures

# Chapter 1. Resource Use and Conservation

> Humanity stands at a defining moment in history. We are confronted with a perpetuation of disparities within and between nations, a worsening of poverty, hunger, ill-health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our-well being.
>
> United Nations, Agenda 21, Preamble, p.2.5

## 1.1 Introduction

Biodiversity conservation and protection of human well-being are increasingly seen as being inseparable (WRI *et al.* 1992). As demands on resources grow, there is increased danger of environmental degradation and cultural disintegration. Natural vegetation is important as it contributes to environmental stability and genetic, economic and cultural diversity. While conservation and integrated development strategies are needed to halt biological impoverishment of the planet (Kapoor-Vijay 1992b), management of natural resources has often been conducted without local input and without considering local use patterns, values and knowledge. Conservation of ecosystems, however, requires attention to the cultural as well as biophysical landscape of an area. Preservation without consideration of local inhabitants has not worked, as witnessed by innumerable conflicts around parks. Awareness of local needs, values and knowledge is essential for identifying problem areas and for implementing successful conservation strategies. Input from all levels of society can facilitate the finding of sustainable solutions and alternative conservation strategies. An integrated approach to the "exploitation and conservation of resources is in the long-term interest of people" (Johns and Kokwaro 1991).

## 1.2 Problem and Case Study

Increasingly, conservation and development initiatives are being focused on a local scale, as evidenced in approaches such as integrated conservation and development strategies (Brown and Wyckoff-Baird 1992). In Sale and Loliondo Divisions in Ngorongoro District, Tanzania, there is a strong desire for the development and implementation of a regional, sustainable utilization plan, with strong local participation. The area, inhabited mainly by Maasai pastoralists and Batemi agropastoralists, is semi-arid, subject to temporal and spatial variability in rainfall, and unable for the most part to support high-density populations.

As with many groups in remote, marginal areas, the Batemi and their pastoralist neighbours, the Maasai, still follow an essentially traditional way of life. Both groups rely heavily on the natural ecosystem. Changes can have severe repercussions on the well-being of communities, not only through impacts on food and medicine, but also by changing everyday cultural practices. To ensure that community needs and values are addressed within the context of changing environmental and socioeconomic conditions, a local non-governmental organization (NGO), Korongoro Integrated Peoples Oriented to Conservation (KIPOC, meaning "we shall recover" in the Maasai language), has been formed with the endorsement of the Ngorongoro District Council. The Ngorongoro District Council, KIPOC and local communities are in the process of formulating a land use plan in relation to the pastoral system. The Serengeti Regional Conservation Strategy (SRCS) has carried out aerial surveys and will be preparing maps of land use in the Loliondo area to aid in this project. Land claim negotiations underway in the region are an added source of tension and underscore the importance of resource and conservation planning.

Directly connected to these plans for a local conservation strategy is a specific focus on food and the health of local people. A health and nutrition project planned by the Ngorongoro District Council, KIPOC and MacDonald Campus of McGill University, in collaboration with the Institute of Traditional Medicine (ITM) and the Tanzania Food and Nutrition Centre, will investigate the nutritional status of the Maasai and Batemi people in Sale and Loliondo Divisions. The project will include an analysis of the use of wild plant resources and their nutritional and medicinal value.

The research undertaken for this thesis focuses on the use, distribution and conservation of woody vegetation that is integral to the human community. A preliminary ethnobotanical survey conducted in the Batemi area showed many local woody species as useful (Johns 1992). A systematic study of the general status of woody vegetation in the area and the distribution and abundance of useful woody species can provide valuable information on the biological state of these resources, areas of actual or potential vulnerability, requirements for plant conservation and implications for local communities. Recording use of vegetation (used versus unused components of the environment), mapping distribution (related to availability and territorial questions) and assigning values (to recognize importance of conservation) are all important steps towards achieving "sustainable development" planning.

## 1.3 Objectives

The overall purpose of this research is to assist in the collection of baseline data for use in local conservation and management planning for the Batemi area and to explore methods for identifying conservation priorities. Specific objectives are to:

1) investigate local use of vegetation

2) study the abundance and distribution of woody vegetation in the area

3) experiment with assigning use-values to species and with using these values to identify conservation priorities.

### 1.4 Structure of the Thesis

Chapter 2 presents basic physical and cultural factors. Population densities and resources of value to the Batemi are discussed. The variability of green vegetation is investigated using National Oceanic and Atmospheric Administration (NOAA) advanced very high resolution radiometer (AVHRR) satellite data. Land use and land cover changes are analyzed and illustrated using the Geographical Resource Analysis Support System (GRASS) Geographical Information System (GIS).

Chapter 3 presents ethnobotanical data on non-medicinal and non-food uses of woody species which were collected during June-July 1992 and August 1992. These data are supplemented by medicinal and food data collected by Johns (n.d.a, n.d.b).

Chapter 4 contains the biogeographical data collected using a random sampling method, with additional data from comprehensive inventories along irrigation channels. A land cover map for the area was produced on GRASS using Landsat Thematic Mapper (TM) digital data.

Chapter 5 explores data of pertinence to establishing conservation priorities. Use-values are assigned to species used by the Batemi. This information is then used in conjunction with the data on abundance to investigate the vulnerability of species. These data, based on categories of use, are employed to identify key socioeconomic species and the conservation priorities amongst them.

## 1.5 Literature Review

There is worldwide pressure on the biophysical environment due to increasing human population and technological demands. Global responses to the conservation crisis are evident. Recent world events include the June 1992 United Nations Conference on Environment and Development (UNCED, or the Earth Summit), a follow up to the World Commission on Environment and Development, and 1993 is the United Nations (UN) Year of the World's Indigenous Peoples. Literature outlining the crisis and recent approaches are discussed below, with a focus on rural, semi-arid areas and indigenous peoples.

### 1.5.1 The Conservation Crisis

> The degradation of land is invariably accompanied by the degradation of human well-being and social prospects (Biswas 1979, 260).

Ever-increasing demands on the biophysical environment are a source of concern as ecosystem integrity and viability are threatened either through over-use or misuse. As the biophysical environment is degraded, there are usually negative impacts for the humans who rely on those resources. Impacts are often experienced more immediately in traditional or subsistence environments, where people are directly dependent on the resources surrounding them. As economic and technological circumstances change and populations grow, well adapted traditional practices may breakdown or excessive pressure may be put on fragile resources.

A number of studies in Africa have documented the degradation of natural systems due to misuse or overuse (Dorm-Adzobu 1982; Newby and Grettenberger 1986). "Logging for export, clearing for agriculture and cutting for fuelwood all consume trees for human benefit" (Timberlake 1986, 103; cf. Rowe *et al.* 1992).

Fuelwood use is one of the most ecologically destructive uses of woody plants (Bowander 1986, 1987), but other indigenous uses can also damage plant communities. Cutting of trees for construction material can have severe repercussions. Several species of trees in the Usambara region of Tanzania have been severely depleted because of demands for building (Fleuret 1980). Clearing for agriculture also makes inroads into remaining forest areas. Even gathering can have serious effects, especially as demands grow. Vasquez and Gentry (1989) found that there were dangers of destruction of trees during harvesting in the Iquitos area of Peru.

Grazing and browsing by domestic animals are other factors that may have serious repercussions for local environments, especially in fragile, semi-arid and arid regions (Palmberg 1991). Lamprey(1984) documents the impact of Maasai pastoralism (livestock and settlement distributions) on vegetation patterns and distribution in the Maasai Mara area in Kenya. In general, the structure and composition of woody vegetation in savanna or woodland environments tends to change with increases in grazing and browsing. Usually the woody species composition increases with grazing as the decrease in the grass layer leaves more moisture available for woody species (Skarpe 1990a, 1990b). The browsing of species can result in higher woody species mortality (Reuss and Halter 1991).

### 1.5.2 Biodiversity: Conservation and Use

The increasing degradation of the biophysical environment and evidence of higher rates of species extinction (WRI *et al.* 1992) have underlined the need to conserve biological diversity by insuring that use is sustainable. Biodiversity is defined as "all species of plants, animals and micro-organisms and the ecosystems and processes of which they are a part" (Kapoor-Vijay 1992a). In a review of the biodiversity literature, three main points in the biodiversity debate are central: conservation, use and equity.

The World Conservation Union's (IUCN) World Conservation Strategy (1980) was one of the first international policy statements to call for sustainable use of ecological resources. This document defined conservation as:

> The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations. This conservation is positive, embracing preservation, maintenance, sustainable utilization, restoration, and enhancement of the natural environment (IUCN 1980).

The World Commission on Environment and Development (WCED) and the United Nations Conference on Environment and Development (UNCED) have further focused global attention on these issues. The conservation and sustainable use of biological diversity was central to the UNCED conference. Agenda 21 (UNCED 1992a), the major document arising from the conference deals with a number of important environment and development issues, including the conservation of biodiversity (Chapter 15). The Convention on Biological Diversity (UNCED 1992b), developed under the auspices of UNEP and the IUCN was signed by most member nations at the conference and more recently the U.S.A signified its intention to sign.

There are also a number of other major documents and initiatives focusing on biodiversity conservation. The Global Biodiversity Strategy (WRI *et al.* 1992) aims to outline a strategy for saving, studying, and using biodiversity sustainably and equitably. The sustainable and equitable use of biodiversity is defined as "husbanding biological resources so that they last indefinitely, making sure that biodiversity is used to improve the human condition, and seeing that these resources are shared equitably'(WRI *et al.* 1992, 13). On a practical level, the Commonwealth Science Council's (CSC) Biological Diversity and Genetic Resources (BDGR) programme seeks to develop practical plans geared towards conserving biodiversity and thus ensuring sustainable development (Kapoor-Vijay 1992a).

Interwoven with the sustainable use debate is the issue of equitable use. Use and development of ecological resources must be people-centred as well as conservation-based:

> Action to conserve biodiversity must be planned and implemented at a scale determined by ecological and social criteria. The focus of activity must be where people live and work, as well as in protected wildland areas (WRI *et al.* 1992, 23).

Although preserved areas, where human intervention is kept to a minimum, are still considered central to conservation aims, the focus has broadened to include social and cultural issues. Carroll (1992, 365) states:

> Conservation is not just biology and must be an interdisciplinary effort. Conservation must become an integrative effort to treat the landscape as a life-support system for economic and biological diversity.

The CSC's programme portrays a similar approach: "The conservation of biological wealth is not simply a traditional protection agenda, but a scientific, economic, social, political and development issue"(Kapoor-Vijay 1992a, 6).

Local peoples and national economies need to be able to derive social and economic benefits from the conservation of biodiversity (NRC 1992). Carroll (1992, 363) states that "patterns of use must be considered along with the characteristic of the local ecosystem in any long-term attempt at management". This type of outlook is significantly different from that of years ago, when protected areas or parks were set up without real consideration for the impact on local populations.

1.5.3 Identification of Priorities

As discussed above, local resource use, knowledge and culture systems have become a central issue in the conservation and development debate. There are a variety of reasons for this, including: the need to recognize use patterns; the importance of that local knowledge as a data source, especially in remote, or marginal areas which are not well studied by western science; and the role that this information can therefore play in designing successful conservation strategies.

i) The first component of this issue deals with the direct reliance of rural and indigenous groups on biological resources for meeting daily necessities, with the need to recognize particular uses of each community or region.

For a number of societies, gathering is still an important activity; many agropastoral or subsistence farming groups "still obtain a significant portion of ... subsistence requirements from the ecosystems that embed and surround the agricultural plots"(Altieri *et al.* 1987). Use of natural ecosystems, or modified versions of them, provides "a diversity of products through a strategy of multiple use"(Altieri *et al.* 1987). Grivetti's (1978a, 1978b) study of the Tswana of the Kalahari reveals the diversification of the food base arising from plant gathering. Fleuret's (1979, 1980) studies in the Usambara mountains of Tanzania underscores the important nutritional and economic role that wild plants can have for traditional societies (see also FAO 1983, 1988). Vegetation gathering has an economic and ecological basis; it provides essential supplies of food, raw materials et cetera and also has strong cultural tradition (Altieri *et al.* 1987). Traditional medicines from indigenous vegetation provides the primary health care needs for 80 percent of people in developing countries (Farnsworth 1988).

Woody vegetation can play a particularly important role in the economic, social and cultural life of indigenous people. Woody vegetation provides a variety of useful products, such as construction materials, food, medicine, fuel, fodder, and also serves as a barrier against environmental degradation (see Altieri *et al.* 1987; Douthwaite 1987; Newby and Grettenberger 1986; Palmberg 1992; Reid *et al.* 1990). Many woody species in East Africa have also been identified as playing an important economic role within local cultures (Pichi-Sermolli 1955). In fact, for many subsistence farmers, "trees are often the only source of some of the necessities of life. As the trees disappear, these essential products become scarcer..." (Timberlake 1986, 112). Studies such as Boom's (1989), which shows that the Chacobo of Brazil utilize 82% of species and 95% of individual trees, illustrate the breadth of indigenous use of "natural" vegetation.

Amongst the range of resources in a given area, there may be some that are particularly valuable or central to the economic, cultural or social life. The identification of these Valued Ecosystem Components (VECs) (Beanlands and Duinker 1983) or key socioeconomic species (Kapoor-Vijay 1992b) can be helpful in identifying priority issues. This type of approach is being adopted recently, as evident in the Commonwealth Science Council's programme's list of objectives. There are two concerning the identification of key species: 1) survey and authentication of species of socioeconomic value and 2) Identification of key species for conservation and development (Kapoor-Vijay 1992a, 13). "Key" species are termed either 'ecological key species'(which play a key ecological role) or 'service species', which "make contributions to people's social and economic well-being. Key service species are important with respect to certain categories of use, such as commodities, genetic resources, cultural value or environmental management (Kapoor-Vijay 1992a, 45).

Both types are considered life-support species. Fries' (1991) recommendations for a research strategy for study of East African forests focus on studying local use of species as well as conducting basic inventories. Recent ethnobotanical studies (Pinedo-Vasquez *et al.* 1990; Prance *et al.* 1987) have attempted to establish use-values for locally valued plants in order to identify conservation priorities. For example, Prance *et al.* (1987) found that certain plant families in Amazonia should have high priority for conservation and that certain types of forest should be a high priority habitat type.

ii) As well as the basic importance of addressing local needs and values, there is the value of local knowledge and conservation practices as vital data sources. The consideration and incorporation of local values and knowledge is crucial as locals usually have in-depth knowledge about their environments that outsiders will not have. They have intimate knowledge of cycles, of environmental changes, and frequently of ecological processes. Johannes and Hatcher(1986) point out that traditional practices and values are often a rich repository of conservation policy in terms of well-developed systems of knowledge and practices specifically adapted for the area.

Various studies detail local or indigenous knowledge and its application to conservation and resource management. Many ethnobotanists, anthropologists and cultural geographers have examined indigenous classification systems (see Berlin *et al.* 1974; Nabhan *et al.* 1991; Nietschmann 1973; Toledo 1991), exploring the depth of local knowledge and means of organizing data. Many argue that indigenous groups are not mere resource foragers but are resource managers as well (see Alcorn 1989; Oldfield and Alcorn 1991a), although Dasmann (1991) disputes the need to differ between use and management. Many recent studies do show, however, that many groups are not merely responding to given environmental limits, but clearly manipulate and manage critical resources. Relevant examples include Alcorn's (1989) study of the management of agroecosystems in Peru and Mexico and Denevan and Padoch's (1988) work with the Bora Indians in Peru. A particularly interesting example is the Kayapo of Brazil, who practice wide-ranging resource management, including such subtle, trail-side management of vegetation that it appears as natural to outsiders (see Anderson and Posey 1989; Posey 1983, 1984).

The application of this type of local information in conservation strategies can be extremely useful and valuable (Brokensha *et al.* 1980; Klee 1980). Local knowledge systems can yield new ideas about conservation and management of valuable resources and identify new biotic resources for utilization (NRC 1992). Reid *et al.* (1990) recommend gathering of more information on local uses, in order to help improve traditional land management practices in the Tamaulipan thornscrub of Mexico.

Besides the fact that local knowledge can improve the management and conservation process through increased information, there is also the fact that consideration of local knowledge systems and values will make conservation strategies and management plans more acceptable to local communities. Johannes and Hatcher (1986, 379) state,

> Modern management regimes in which traditional management customs are recognized and incorporated (where practical) are likely to gain greater local support and thus be easier to enforce. Traditional authority and indigenous environmental regulations often carry more weight ... than do remote government edicts.

Plans are more likely to be accepted and thus to succeed if they reflect local values, needs and knowledge. Conservation efforts will ultimately fail if they do not integrate local needs and prevailing land use practices (Oldfield and Alcorn 1991b).

## 1.6 Value of the Results

This thesis attempts to relate practical fieldwork on the use and distribution of native woody species to the process of establishing conservation priorities. This work is supported by the local communities and it is hoped that it will be useful to them in i) systematically documenting valued species, ii) defining the territorial extent of their resource base, and iii) developing a conservation strategy.

As one of the main concerns of this research is to produce useful information to supplement local knowledge, the final results of the research and any recommendations will be presented to the Ngorongoro District Council, KIPOC and local communities, and the Tanzania Commission for Science and Technology for input into land use plans. All research findings will also be presented to the Institute of Traditional Medicine and the Tanzania Food and Nutrition Centre.

It is hoped that documenting the importance of local plant communities will help groups such as KIPOC ensure that, whatever the ecological stress of current development pressures, the "we will recover" ambition will be possible. It is also hoped that the thesis will make some contribution to the dialogue on conservation and development.

# Chapter 2. Study Area: Environment and Culture

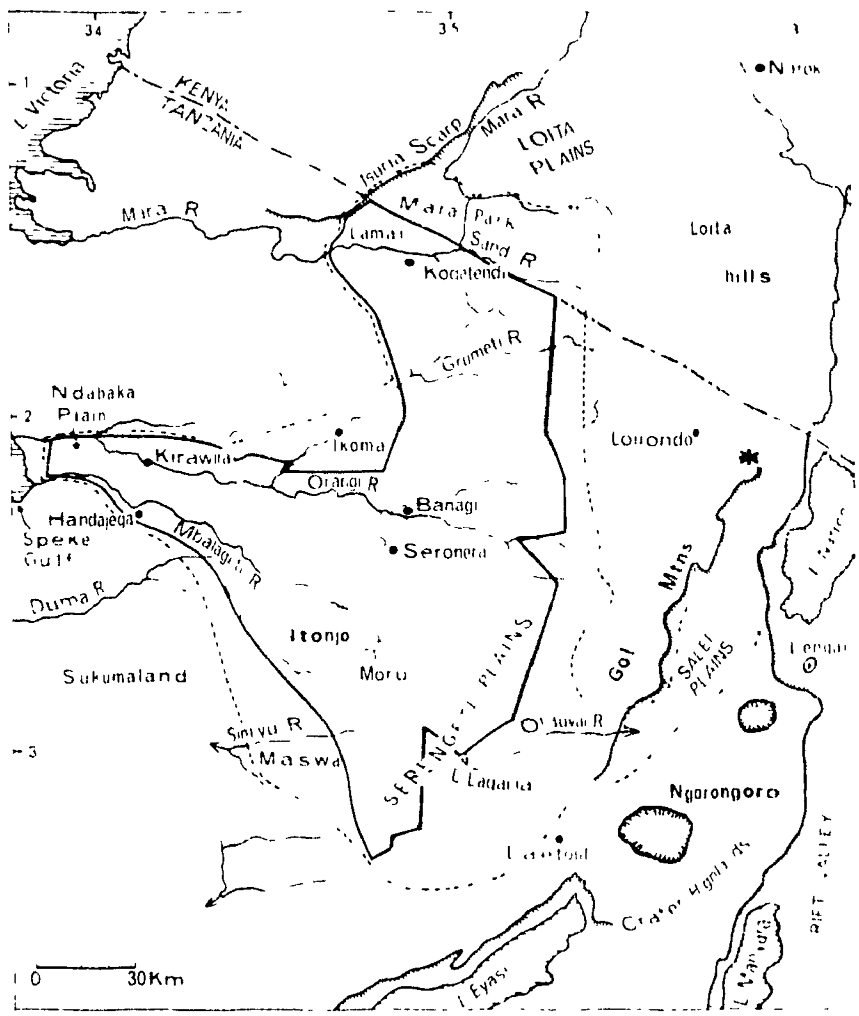
## 2.1 Introduction

The Batemi are a Bantu agropastoral group, who inhabit an area surrounded by Maasai tribal territory. Unlike their neighbours the Maasai, this group has not been widely studied. Besides an ethnographic study undertaken in the late 1950s (Gray 1963), the only literature available are obscure Tanzanian government reports which briefly discuss the Batemi (Fosberg 1957 in Gray 1963). More recently ethnobotanical work (Johns n.d.a, n.d.b) and some work on irrigation (Potanski n.d.) have been undertaken in the area.

The group has traditionally existed on an almost completely self-sufficient basis, practising two forms of subsistence: stock raising and cultivation by irrigation (Gray 1963). It is thought they have been located in the area for at least one hundred and fifty years (Gray 1963). As a subsistence agropastoral group, the Batemi rely heavily on traditional resources for their livelihood. Their well-being is therefore dependent on the state of the environment, and on their ability to retain a sustainable relationship with it. The Batemi valley faces most of the pressures that confront many rural areas in semi-arid regions, including a growing population, declining resources, changing cultural values and imposition of external management structures from a national level.

The study area is in Sale Division, Ngorongoro District, in the northwestern section of Tanzania (Figure 2.1). The Batemi villages (six, plus some sub-villages) are located to the east of the Rift Valley, to the north of the Ngorongoro Conservation

Figure 2.1 Location of Study area.



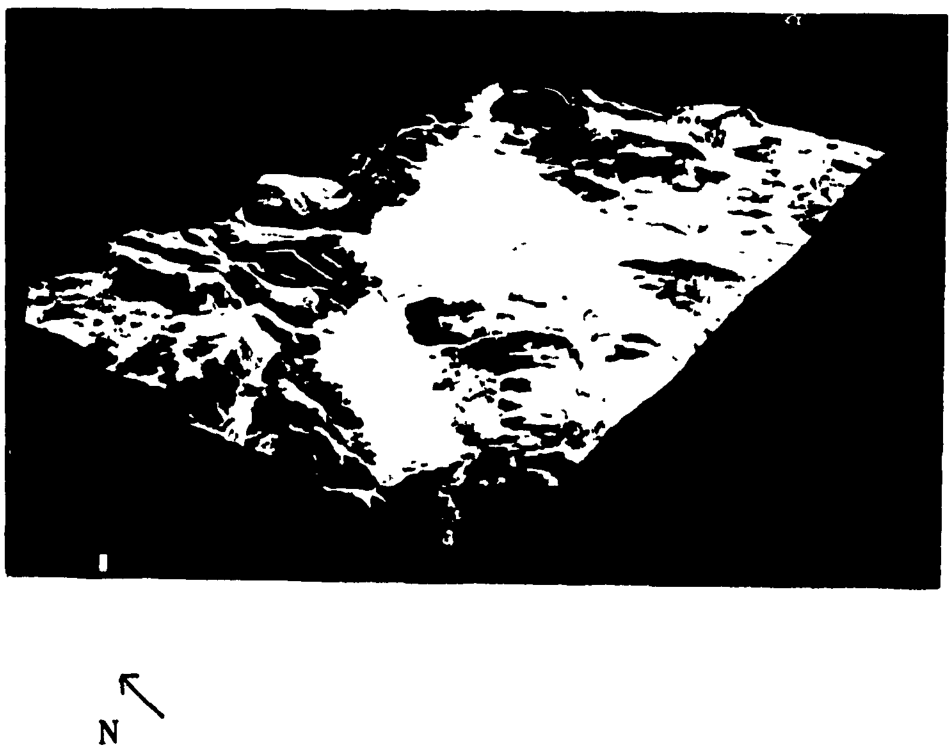

Source: Sinclair 1979. * — STUDY AREA

Area and about twenty kilometres south of the Kenyan border. Three of Sale Division's census wards (DigoDigo, Oldonyosambu and Sale) are inhabited almost exclusively by the Batemi. This study is restricted to DigoDigo ward, the central and most densely populated of the three wards. Four of the six main Batemi villages (DigoDigo, Samunge, Mugholo and Kisangiro) are located in this ward.

The main part of DigoDigo Ward is a valley, bordered by escarpments to the north and various hill ranges to the east and west (Figure 2.2). On the south side, there is a general drop in elevation towards the Sale Plain. Elevations range from about 1200 m above sea level on the valley floor to 2000 m in the hills north of the valley.

This chapter will provide an introduction to the physical and cultural environment and the relationship between the two components. It examines variability in bioproductivity over time and space. Changes in the valley in terms of

Figure 2.2 A digital elevation model of the Batemi area. The image shown is a 2-4-7 band composite from Landsat Thematic Mapper digital data. The viewing site is from the south-west corner at an angle of 30 degrees. The green represents dense vegetation (thicket or woodland). The white mainly consists of the villages, agricultural fields, and areas of wooded grassland and scattered trees. The pink areas are areas of more open woodland.



land use patterns and community settlements are also examined. The data in this chapter, except those attributed to other sources, are from the author's observations and interviews.

## 2.2 Physical Environment

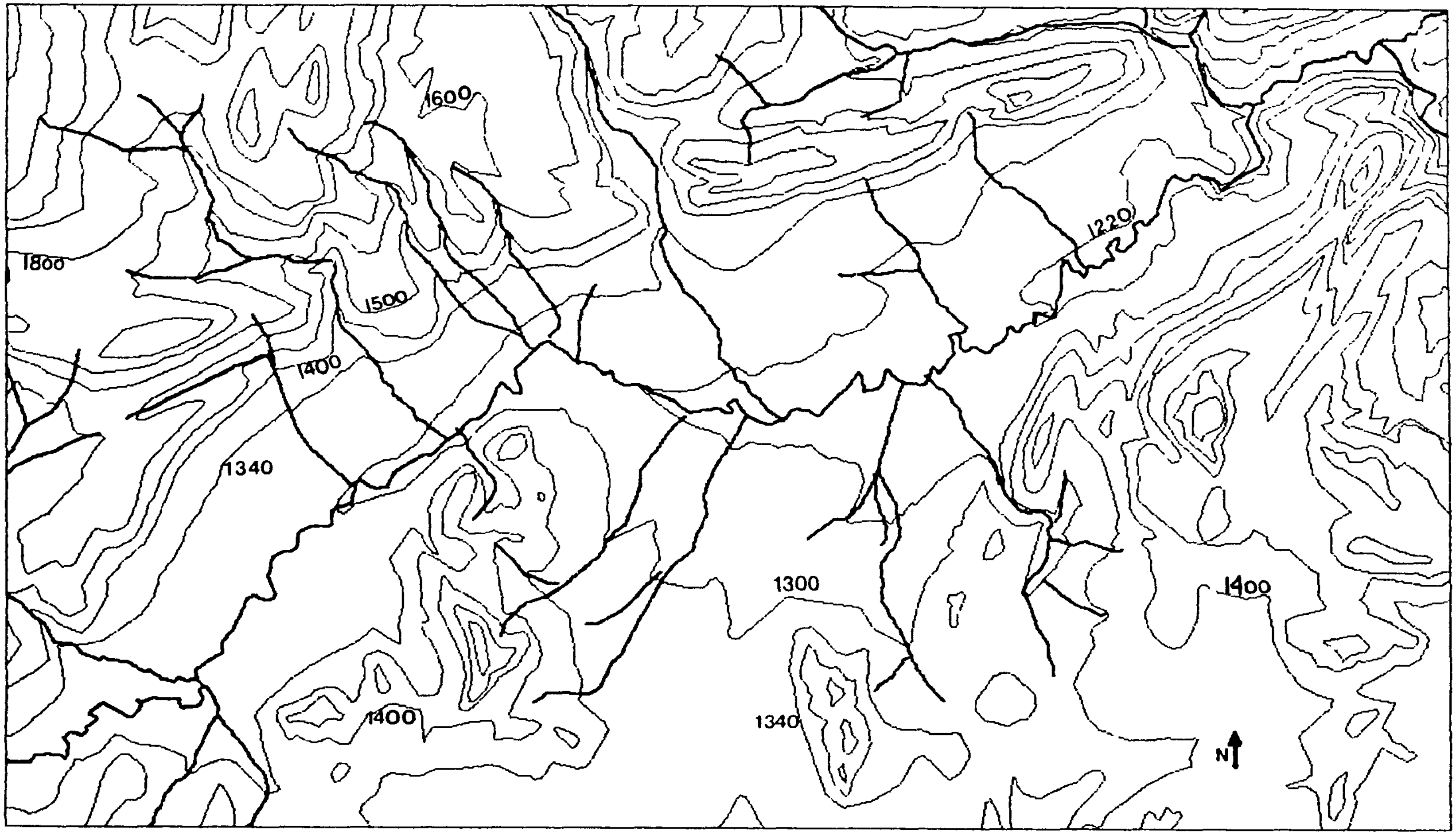
### 2.2.1 Climate

Although there is no local weatherstation at present, rainfall data were collected in the late 1940s and early 1950s and reveal a great temporal and spatial variability. Eight years of data gave an average annual rainfall of 412 mm, with only one year exceeding 660 mm and two years exceeding 440 mm (Gray 1963). The peaks of the rains are in April and January with some rain falling in September and October. The area falls within 400-600 mm isohyet of average annual rainfall (Tomsett 1969 in Porter 1976; cf. with White 1983) and is classed as semi-arid, defined by Christiansson *et al.* (1991) as an average annual rainfall of 250-500 mm and at least a 7.5 month dry period.

### 2.2.2 Hydrology

The Batemi area is part of an interior drainage basin (Atlas of Tanzania 1967). The Loliondo highlands are the dividing line between those rivers that drain towards Lake Victoria and those towards Lake Natron. Figure 2.3 depicts the rivers and streams in the area. Natural springs are scattered along the base of the escarpment on the north side of the valley.

Figure 2.3  River and stream network in the Batemi area.




Scale 1:75,000

0 5KM

Legend: ———— - Rivers and streams

———— - Elevation (m)

Wynet Smith 1993

9766000.5

UTM Region: 797000.5 813000.5

9757000.5

### 2.2.3 Vegetation

There has been no published study of the vegetation in the Batemi area on a local scale. A general idea of composition or type of vegetation is available from smaller scale maps and reports (White 1983; Lind and Morrison 1974; Pratt *et al.* 1966; Trapnell and Langdale-Brown 1969). In terms of phytochoria or biogeographic region, the Batemi area is situated in the Somalia-Maasai region of endemism (White 1983). The major vegetation cover in this region is deciduous bushland and thicket, specifically, *Acacia-Commiphora* deciduous bushland and thicket (White 1983). This vegetation has been termed *Commiphora* bushland by Trapnell and Langdale-Brown (1969) and wooded steppe with abundant *Acacia* and *Commiphora* species by Keay *et al.* (1959).

## 2.3 Cultural History

The semi-arid nature of the environment makes the area suitable for two forms of exploitation: stock-raising and cultivation by irrigation. As agropastoralists, the Batemi utilize most components of their environment, including: land and water for agriculture; land for grazing; and vegetation resources from the forests and fields for various types of materials (cf. Gray 1963). These uses are by no means mutually exclusive.

Local aridity means that springs, streams and rivers are the source of life for the Batemi. The Batemi have manipulated the various elements of the natural ecosystem to create a system of irrigation that has functioned sufficiently well to support their population (Gray 1963). For example, the village of DigoDigo waters many fields from two irrigation channels and one stream (Figure 2.4).

Figure 2.4 An irrigation channel and agricultural fields at the south-end of DigoDigo. The irrigation channel cutting across the landscape has its source in a spring and a small stream. The second row of less dense vegetation to the right is along the stream. A second irrigation channel is partially visible in the lower right-hand corner of the photograph.

The traditional practice of irrigation in East Africa is quite unusual. At the time Gray (1963) wrote his ethnography there were only four groups practising irrigated agriculture in East Africa. It is hypothesized by Gray (1963) that the Batemi system is based on an ancient irrigation culture, and that the Batemi are either the descendants of those who settled in the area with this knowledge or that they inherited the practice from their predecessors in the area. Many of the irrigation channels in the area stem from springs; the remaining ones are offshoots of river tributaries. Oldonyosambu, a village to the east of DigoDigo Ward relies solely on a river passing through the village as its source of water (cf. Gray 1963).

Streams and springs emerge from the hills, and the villages are centred mostly on the northern side of the valley, close to the main water sources. The springs flow all year round, but most of the streams are seasonal, flowing only in the rainy season. Stretching south from the villages is valley bottom and plain. Most of the northern part of the plain is used for agriculture and little "natural" vegetation remains. A mixture of crops are grown, and there are both irrigated and non-irrigated areas of cultivation. The irrigated fields are known as hura (Table 2.1), and were traditionally planted in the dry season (around September). The dry-land agricultural fields are known as magare and were traditionally planted in the rainy season, with each field only being planted every second year (Gray 1963). Intercropping of multiple layers is common. The variety of crops includes legumes, cassava, sorghum, maize and also various other more recent crops such as onion and tomatoes (Johns n.d.b). A number of fruit trees (papaya, citrus) are also grown by some people.

Table 2.1 List of Batemi words and their meaning.

| Batemi word | Meaning |
|---|---|
| Bwelo | - plain or valley floor |
| Hura | - dry-season agricultural fields (irrigated) |
| Magare | - wet-season fields |
| Shamba | - garden or small agricultural field |
| Wenamije | - clan with hereditary rights to water systems |

Further south on the plain are drier areas where the lack of streams and springs prevent irrigation. In these areas, only dry-land cultivation is conducted. The Samunge sub-village of Eyasi is an exception, as there are streams that permit irrigation. The major land use in this area, however, is grazing. The Batemi collect a large percentage of materials from the natural plant communities surrounding them. Gathering is an important part of their culture and subsistence strategy.

### 2.3.1 Organizational Structure

In the Batemi area, traditional social organization was based on clans (Gray 1963). There were clans in each village, with each clan having a certain place within a hierarchy but, at present, there are national structures imposed upon the traditional local system. Village leaders and secretaries are Government or Communist Party representatives. They are officially responsible for making decisions in their respective villages. Because the traditional Batemi groups are still very much in place, there are occasionally disputes between the different levels of authority. Each village head reports to the Division secretary, who is responsible for the five wards in Sale Division. Some laws, such as those regarding forestry resources, are national in origin and are enforced by the Division secretary and the village leaders. But traditional laws, such as the Batemi prohibition against cutting along irrigation channels (see Chapter 5), are not interfered with and are not subsumed under national law.

The springs used for irrigation are regarded as sacred (Gray 1963, 50-52). Traditionally, the irrigation system has been under communal control of a village composed of several clans, and this system has been in place at least since the 1800s

(Gray 1963). This system is still mostly in place, with the Wenamije, the group within each village who has hereditary rights, still controlling final decisions over irrigation. The village of Samunge is one exception; here the village chairman has followed Tanzanian government law that states that there should be a water committee in each Tanzanian village. Therefore, control of the irrigation system in this village is now under his control and not the traditional Wenamije clan[1]. The basic principles of the irrigation system still apply, with local communal assistance still an important component of the functioning of the system.

## 2.4 Population Growth

Population growth "affect[s] the demands on living space and other resources" (Kasperson *et al.* 1991, 47). The Batemi population in 1957 consisted of 2063 males and 2325 females for a total of 4388 people (Government of Tanzania 1957). The 1967 census indicates a population of 5,071 (Government of Tanzania 1967) for the area but this data is not directly comparable to the 1978 and 1988 data as the figures are for different census areas. For 1978, the population size of DigoDigo Ward alone was 5350 and for 1988 it was 6753 (Government of Tanzania 1978, 1988). Including Sale (1030) and Oldonyosambu (2069) wards, there was a total of 9,852 in the entire Batemi area. The population has therefore been growing steadily for the last 30 years (Table 2.2).

[1] Gray (1963) noted that Samunge had more contact with the outside world than the other villages. Whether this is a factor in the difference between the present practices in Samunge and the other three villages is not clear.

Table 2.2 Population Statistics for Area for 1957, and for DigoDigo Ward for 1978 and 1988.

| Census Year | Population Size | | |
|---|---|---|---|
| | Male | Female | Total |
| 1957 | 2063 | 2325 | 4388 |
| 1967 | | | 5071* |
| 1978 | 2523 | 2827 | 5350 |
| 1988 | 3033 | 3720 | 6753 |

Source: Government of Tanzania 1957, 1967, 1978 and 1988.

* not directly comparable to 1978 and 1988 data.

(Table 2.3), but this includes the sub-villages of Mditu, Mgero and Mgundu. Kisangiro is the least populated village with only 1119 people.

As can be seen from the statistics in Table 2.3, the population is overwhelming young, with 36.5% (2462) of the population under 9, 50.7% (3421) under 14, another 17% between 15 and 24 and a further 9.76% between 25 and 34. In other words, 78% of the population is under the age of 35. This indicates an increasing pressure on the local resources and will have implications for sustainable resource planning.

There is also a disproportionate number of females to males, 3720 to 3033 individuals respectively. The age groups under 14 are roughly gender balanced. The majority of the imbalance occurs in the young adult and adult populations, between the ages of 15 and 54 (Table 2.3). The likely explanation is that men are woring outside the area, either in cities or for others in the surrounding region informal comments by various people in the valley supported this explanation. The effects of

Table 2.3 Breakdown of population structure for separate villages and for DigoDigo Ward.

| | | AGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sex | 0-4 | 5-9 | 10-14 | 15-24 | 25-34 | 35-44 | 45-54 | 55-64 | 65+ | Total |
| Samunge | Male | 231 | 222 | 177 | 127 | 113 | 54 | 44 | 47 | 71 | 1086 |
| | Female | 256 | 258 | 184 | 260 | 158 | 102 | 85 | 51 | 72 | 1426 |
| | TOTAL | 287 | 480 | 361 | 387 | 271 | 156 | 129 | 98 | 143 | 2512 |
| DigoDigo | Male | 128 | 127 | 133 | 137 | 71 | 39 | 48 | 44 | 46 | 773 |
| | Female | 144 | 166 | 135 | 199 | 103 | 80 | 45 | 60 | 26 | 958 |
| | TOTAL | 272 | 293 | 268 | 336 | 174 | 119 | 93 | 104 | 72 | 1731 |
| Mugholo | Male | 133 | 131 | 81 | 74 | 62 | 41 | 38 | 24 | 36 | 620 |
| | Female | 149 | 148 | 87 | 131 | 73 | 58 | 43 | 34 | 48 | 771 |
| | TOTAL | 282 | 279 | 168 | 205 | 135 | 99 | 81 | 58 | 84 | 1391 |
| Kisangiro | Male | 106 | 83 | 89 | 107 | 54 | 47 | 21 | 21 | 26 | 554 |
| | Female | 87 | 93 | 73 | 124 | 65 | 45 | 33 | 31 | 14 | 565 |
| | TOTAL | 193 | 176 | 162 | 231 | 119 | 92 | 54 | 52 | 40 | 1119 |
| Total for Ward | Male | 598 | 563 | 480 | 445 | 300 | 181 | 151 | 136 | 179 | 3033 |
| | Female | 636 | 665 | 479 | 714 | 399 | 285 | 206 | 176 | 160 | 3720 |
| | TOTAL | 1234 | 1228 | 959 | 1159 | 699 | 466 | 357 | 312 | 339 | 6753 |

Source: Government of Tanzania 1988.

this gender imbalance are most likely felt by the women, who may have extra work or more decisions to make about cultivation than they formerly did. This issue would be important area to research more in the future.

## 2.5 Preliminary Investigations of Change in the Batemi Area

Along with a growing population, there have been a number of changes to the physical environment. These include ongoing variability in soil moisture availability and green vegetation, changes in village locations, and encroachments on the bush areas, particularly along the escarpment. The list of materials used to conduct these analyses, and their sources, are listed in Appendix 1.

2.5.1 Variability of Green Vegetation

The advanced very high resolution radiometer (AVHRR) carried on the current National Oceanic and Atmospheric Administration (NOAA) satellites provides data on local environmental conditions that affect crop growth and reflect current status of vegetation. AVHRR has been used extensively to monitor vegetation condition and estimate biomass (see Justice 1986 and Prince and Justice 1991 in Hutchinson 1991). Vegetation condition and amount can be estimated by combining the red and near infra-red (NIR) spectral bands in the following manner [NIR-Red]/[NIR+Red] to obtain a normalized difference vegetation index (NDVI) (Hutchinson 1991; Prince 1986). The index values vary, principally as a function of photosynthetic activity of vegetation (Tucker 1979 and Prince *et al.* 1991 in Hutchinson 1991).

NOAA, AVHRR NDVI data from the United States Agency for International Development, Famine Early Warning System (USAID/FEWS) project were used to examine the temporal variability of green vegetation in the Batemi valley for the period from 1983-1991. This data is compiled from daily information into ten-day periods (decadels), resulting in three images each month (Prince 1986). A 21 $km^2$ area (or nine pixels of seven km resolution) was extracted from the data set available at the Serengeti Wildlife Research Institute using a central coordinate of 2°10' south and 35°45' east. The data were used to compare seasonal and annual variation.

As can be seen from the NDVI values, there is a great deal of temporal fluctuation in the green vegetation in the Batemi area (Table 2.4). This fluctuation not only covers the course of a year but also occurs between the matched periods for

Table 2.4 NDVI values for the Batemi valley based on a 21 km² area.

| Period | Time | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | January | 0.29 | 0 | 0.42 | 0.32 | 0.29 | 0.49 | 0.27 | 0.34 | 0.55 | 0.29 | 0.326 |
| 2 | January | 0.27 | 0.3 | 0.3 | 0.32 | 0.38 | 0.49 | 0.27 | 0.4 | 0.57 | 0.3 | 0.36 |
| 3 | January | 0.29 | 0.31 | 0.41 | 0.2 | 0.38 | 0.53 | 0.41 | 0.46 | 0.5 | 0.25 | 0.374 |
| 4 | February | 0.32 | 0.3 | 0.43 | 0.26 | 0.34 | 0.4 | 0.46 | 0.57 | 0.46 | 0.39 | 0.393 |
| 5 | February | 0.31 | 0.19 | 0.38 | 0.23 | 0.34 | 0.5 | 0.44 | 0.58 | 0.39 | 0.42 | 0.378 |
| 6 | February | 0.38 | 0.37 | 0.36 | 0.43 | 0.24 | 0.45 | 0.31 | 0.52 | 0.3 | 0.3 | 0.366 |
| 7 | March | 0.41 | 0.29 | 0.32 | 0.44 | 0.24 | 0.36 | 0.34 | 0.46 | 0.54 | 0.3 | 0.37 |
| 8 | March | 0.35 | 0.23 | 0.34 | 0.42 | 0.3 | 0.34 | 0.2 | 0.47 | 0.56 | 0.27 | 0.348 |
| 9 | March | 0.36 | 0.22 | 0.4 | 0.47 | 0.25 | 0.42 | 0.45 | 0.41 | 0.61 | 0.27 | 0.386 |
| 10 | April | 0.38 | 0.23 | 0.32 | 0.48 | 0.22 | 0.37 | 0.48 | 0.47 | 0 | | 0.429 |
| 11 | April | 0.33 | 0.15 | 0.45 | 0.49 | 0.37 | 0.4 | 0.5 | 0.56 | 0.57 | | 0.328 |
| 12 | April | 0.44 | 0.16 | 0.46 | 0.5 | 0.37 | 0.45 | 0.45 | 0.46 | 0.58 | | 0.424 |
| 13 | May | 0.44 | 0.4 | 0.52 | 0.52 | 0.4 | 0.45 | 0.54 | 0.47 | 0.59 | | 0.43 |
| 14 | May | 0.5 | 0.41 | 0.49 | 0.54 | 0.41 | 0.48 | 0.46 | 0.48 | 0.53 | | 0.481 |
| 15 | May | 0.43 | 0.38 | 0.44 | 0.51 | 0.46 | 0.33 | 0.43 | 0.49 | 0.52 | | 0.478 |
| 16 | June | 0.43 | 0.27 | 0.34 | 0.43 | 0.46 | 0.27 | 0.38 | 0.55 | 0.49 | | 0.443 |
| 17 | June | 0.39 | 0.29 | 0.31 | 0.38 | 0.43 | 0.36 | 0.3 | 0.42 | 0.48 | | 0.402 |
| 18 | June | 0.34 | 0.2 | 0.29 | 0.29 | 0.38 | 0.29 | 0.3 | 0.4 | 0.45 | | 0.373 |
| 19 | July | 0.28 | 0.16 | 0.2 | 0.31 | 0.31 | 0.26 | 0.26 | 0.34 | 0 | | 0.317 |
| 20 | July | 0.26 | 0.27 | 0.17 | 0.26 | 0.26 | 0.27 | 0.17 | 0.31 | 0 | | 0.236 |
| 21 | July | 0.23 | 0.25 | 0.21 | 0.23 | 0.2 | 0.19 | 0.2 | 0.2 | 0.32 | | 0.219 |
| 22 | August | 0.19 | 0.24 | 0.17 | 0.21 | 0.28 | 0.16 | 0.24 | 0.26 | 0.21 | | 0.226 |
| 23 | August | 0.16 | 0.14 | 0.1 | 0.19 | 0.24 | 0.18 | 0.18 | 0.17 | 0.16 | | 0.218 |
| 24 | August | 0.15 | 0.16 | 0.14 | 0.18 | 0.23 | 0.16 | 0.26 | 0.13 | 0.13 | | 0.169 |
| 25 | Septemb. | 0.16 | 0.14 | 0.17 | 0.13 | 0.22 | 0.18 | 0.2 | 0.16 | 0.23 | | 0.171 |
| 26 | Septemb. | 0.16 | 0.13 | 0.12 | 0.16 | 0.21 | 0.17 | 0.2 | 0.18 | 0.25 | | 0.177 |
| 27 | Septemb. | 0.17 | 0.1 | 0.12 | 0.17 | 0.19 | 0.18 | 0.15 | 0.1 | 0.24 | | 0.176 |
| 28 | October | 0.21 | 0.09 | 0.07 | 0.16 | 0.19 | 0.18 | 0.07 | 0.16 | 0.2 | | 0.158 |
| 29 | October | 0.2 | 0.13 | 0.12 | 0.16 | 0.17 | 0.18 | 0.13 | 0. 3 | 0.17 | | 0.148 |
| 30 | October | 0.24 | 0.16 | 0.11 | 0.18 | 0.21 | 0.13 | 0.16 | 0.18 | 0.18 | | 0.166 |
| 31 | November | 0.33 | 0.11 | 0.12 | 0.16 | 0.15 | 0.14 | 0.23 | 0.2 | 0.18 | | 0.172 |
| 32 | November | 0.33 | 0.13 | 0.21 | 0.3 | 0.2 | 0.24 | 0.18 | 0.22 | 0.23 | | 0.18 |
| 33 | November | 0 | 0.17 | 0.34 | 0 | 0.23 | 0.31 | [illegible] | 0.1 | 0.23 | | 0.227 |
| 34 | December | 0.46 | 0.18 | 0.31 | 0.35 | 0.24 | 0.37 | 0.21 | 0.22 | 0.14 | | 0.176 |
| 35 | December | 0.45 | 0.16 | 0.47 | 0.35 | 0.42 | 0.36 | 0.23 | 0.27 | 0.26 | | 0.276 |
| 36 | December | 0.43 | 0.26 | 0.36 | 0.34 | 0.48 | 0.36 | 0.3 | 0.22 | 0.3 | | 0.33 |
| | Average | 0.3075 | 0.2133 | 0.2914 | 0.3075 | 0.2969 | 0.3167 | 0.2933 | 0.03378 | 0.3367 | 0.3311 | |

Source: NOAA, AVHRR NDVI data.

* Zeros indicate missing values.

different years. Annual variation is quite extreme; Figure 2.5 illustrates the range in values for two years (1984 and 1989) and for the average over the ten year period. There is tremendous intra-year and inter-year variation. Figure 2.6 illustrates the range in values for early May for the ten-year period. This time of year is just after the peak of the rainy season and therefore should have relatively high values for green vegetation. Most of the values are high, but there is still a range from 0.4 to 0.59. The fluctuation in rainfall leads to vulnerability of the human economy as people have planted in anticipation of the rains. As it is the end of the dry season, when evapotranspiration is high and there is little or no stored soil moisture, this time of year is especially critical for the Batemi.

### 2.5.2 Village Changes

As noted earlier, the Batemi villages were traditionally located on the rocky slopes of the escarpments that run along the northside of the valley, near the water sources. When Gray wrote his ethnography, the Batemi were still located in traditional sites as depicted in Figure 2.7, and he noted that specific sites were apparently chosen for their defensibility (1963, 29). The villages were relocated to flatter areas in the mid-1970s as a result of the Tanzanian villagization program. An alternate or additional reason given by villagers was that the Batemi no longer needed to worry about defense against the Maasai.

Using the available remote sensing materials (Appendix 1), the past and present locations of villages were investigated. Locations of villages were noted on 1958 and 1972 photographs and used in conjunction with topographic maps and field data to digitize village boundaries. Historical references (Gray 1963 and information from residents) provided additional information on changes.

Figure 2.5 NDVI values for 1984 and 1989. The values are given in 36 decadel periods (for period dates see Table 2.5). The values illustrate the inter-year as well as intra-year variability in green vegetation.

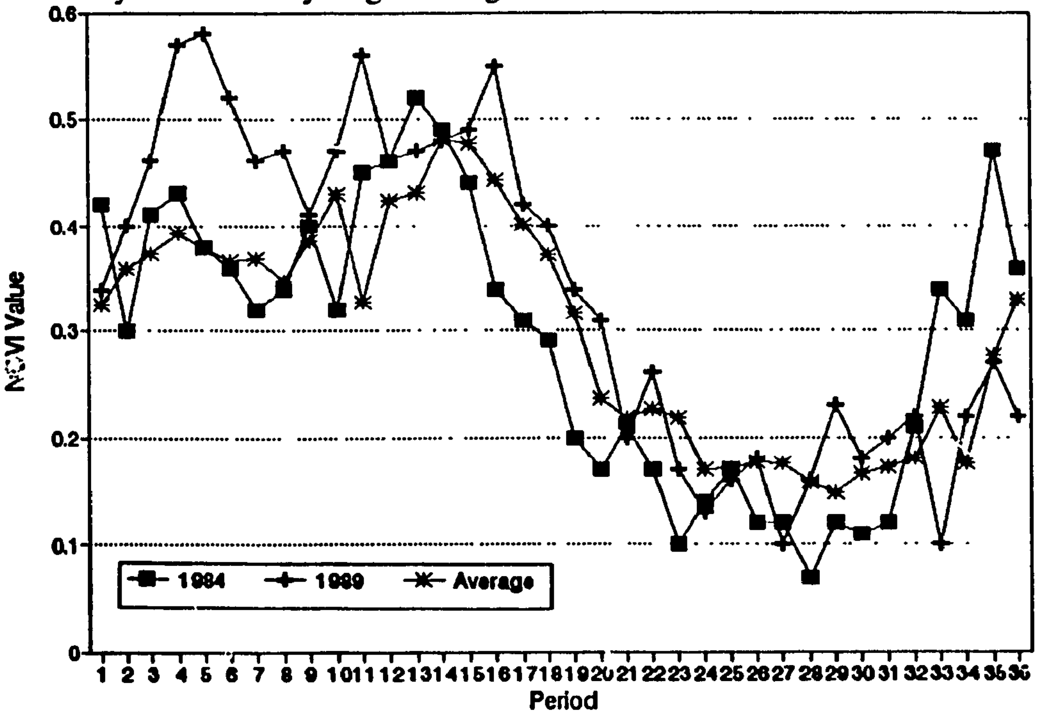



Figure 2.6 NDVI values for the first ten days in May for a nine year period (1982 to 1991). There is a great deal of variability in this time of year even though it is only a month after the beginning of the wet season.

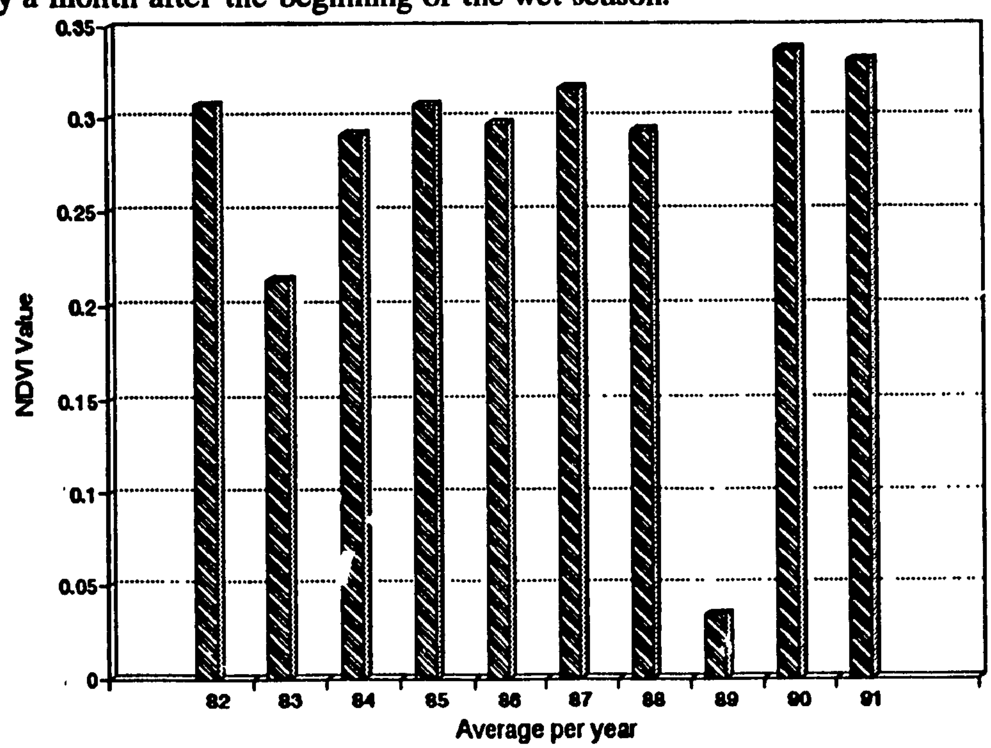
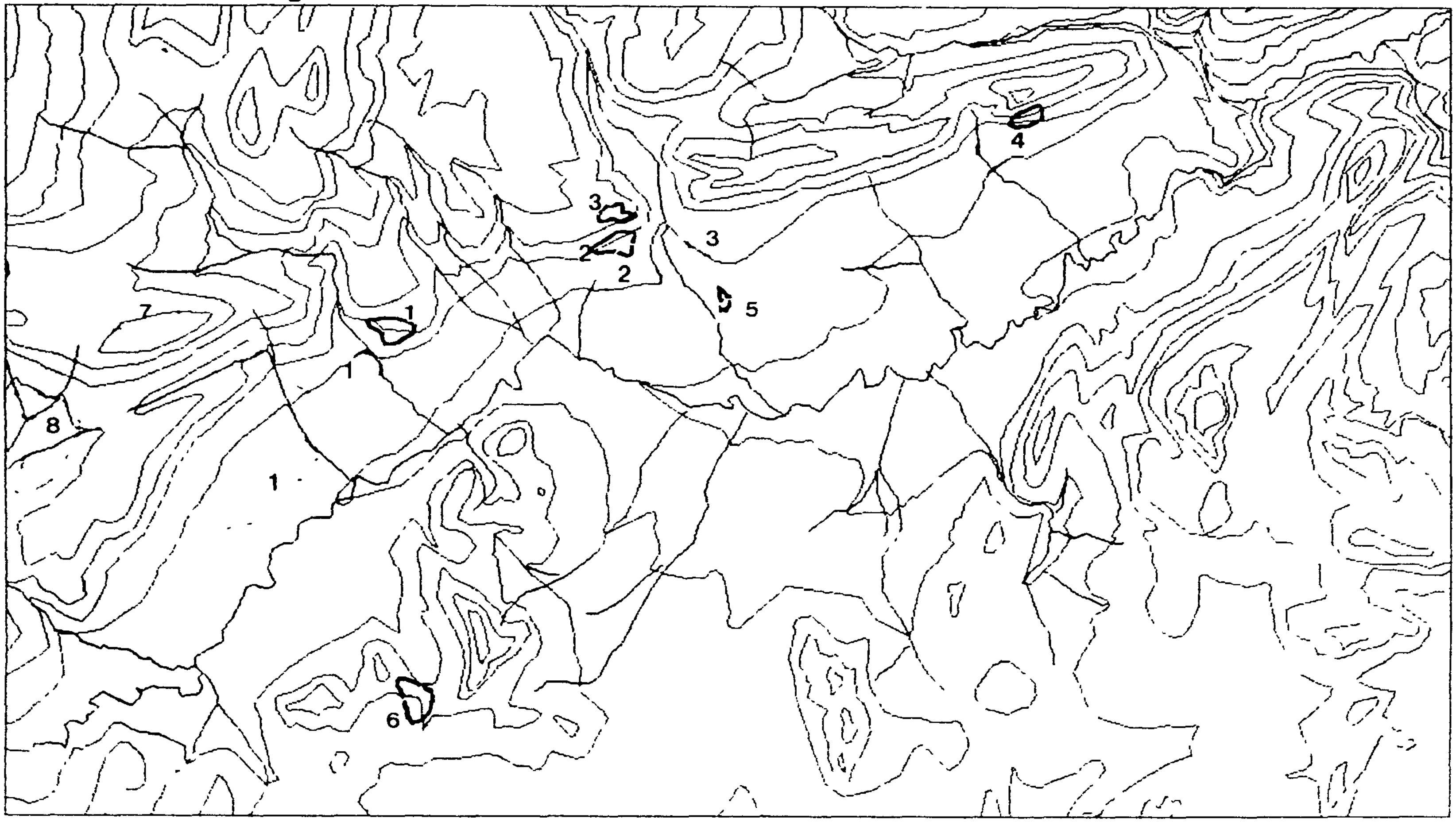


Figure 2.7 Location of traditional DigoDigo village. Houses were traditionally clustered on lower slopes of the hills at the north-side of the valley. Most of the village now extends south onto the valley floor.

The locations of the villages pre-1975 and post-1975 are shown in Figure 2.8. The new settlements (Mgero and Mgundu) are also shown. As the population has grown, there has been an increasing settlement further south on the plain, although some people have also moved up into the hills as evident in the two new sub-villages. The people settling in the plains area will often have at least a small piece of land in an irrigated area in order to grow crops that do require irrigation. Figure 2.8 also illustrates the location of the villages in relation to the streams.

Figure 2.8 Location of the Batemi villages. The original and present locations are indicated along with the newer villages. Note the location of the villages in relation to the rivers and streams.




Scale 1:75,000

0 ——— 5 KM

Wynet Smith 1993

<u>Legend:</u>

- Location of villages prior to 1974
- Location of villages after 1974
- Elevation
- Streams

1 - Samunge
2 - DigoDigo
3- Mugholo
4 - Kisangiro
5 - Government and schools
6 - Eyasi
7 - Mgundu
8 - Mgero

2.5.3 Changes in Land Cover

Determination of the extent of change in woody vegetation cover over the last thirty years was based on the analysis of the aerial photographs from 1958 and 1972, satellite information for 1990 and 1991, and recent field observations. The 1972 air photo was scanned and transferred into the GRASS GIS system. Major areas of change were noted and manually digitized using the 1972 scanned aerial photograph as the base. Areas were classified as being deforested between 1958 and 1972 or post-1972. The area totals were calculated by GRASS. Error was estimated by obtaining areas from a manual calculation using a dot-grid technique.

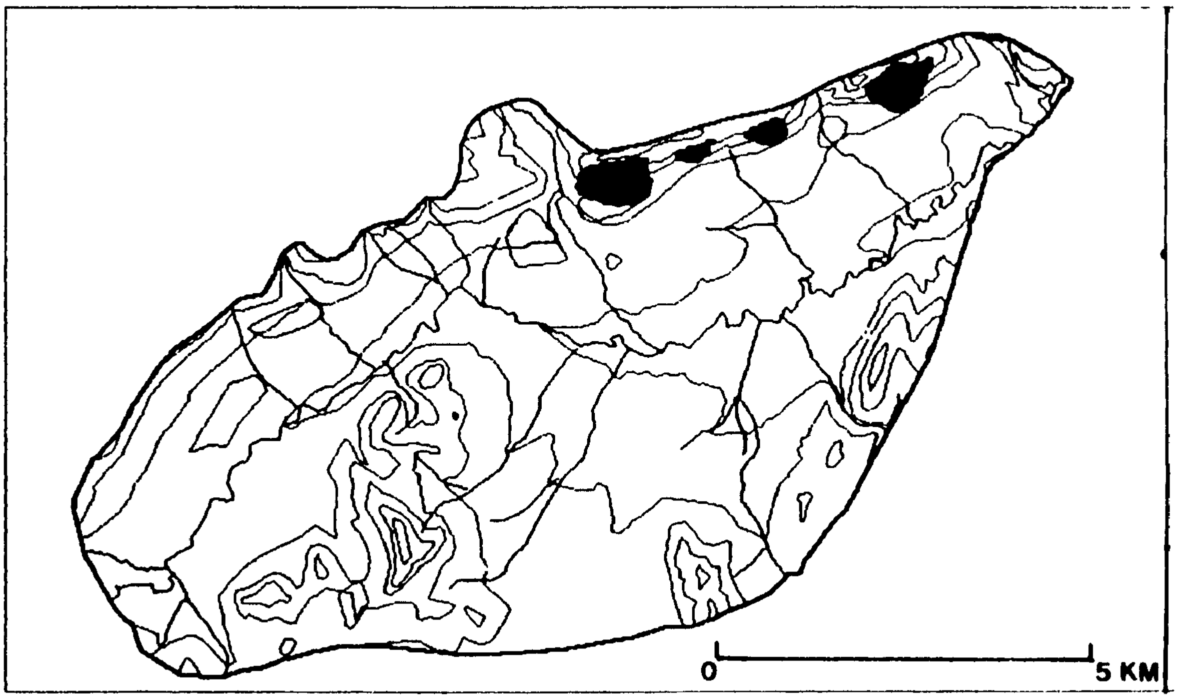
Between 1958 and 1972, 1.09 $km^2$ or 109 hectares in forest area along the escarpment were lost and another 0.27 $km^2$ or 27 hectares[2] were cleared after 1972, probably in 1974/75 with the movement of the villages and for agricultural plots. Figure 2.9 depicts the areas of major bush clearing. The areas calculated are based on easily identified deforested sections of the valley and do not identify areas of spot cutting. At present, there are a number of small areas along the northern escarpments that are being marked for clearing for agricultural plots. The overlay of the present village locations indicates that at least some of the larger deforested areas are due to the relocation of villages.

Besides these areas of major forest or bush clearing, there has also been cutting of trees on the valley floor. Local villagers described the necessity of villagers

[2] According to the dot method, 1.28 $km^2$ was cut prior to 1972 and 0.35 $km^2$ after 1972. So the computer method actually underestimates the extent of the area deforested.

moving further out into the plain as a result of population growth. Despite the slope gradient of 1-3% in this area, severe erosion is taking place due to agriculture and increased grazing pressures by goats and sheep. Figure 2.10 illustrates the type of erosion that is common on the valley floor.

Figure 2.9 Cleared forest areas in the Batemi valley. The areas illustrated only indicate areas of major bush clearance. This does not outline areas of moderate woody vegetation cover that have been subject to cutting.




Scale 1:100,000

Wynet Smith 1993

Legend:

- Areas cleared between 1958 and 1972
- Areas cleared after 1972

- Elevation
- Rivers
- Villages

Figure 2.10 Erosion on the flat land of the plains is quite common in some areas of the valley. Possible causes are overgrazing and consequent decline in vegetation cover.

## 2.6 Conclusion

Within the Batemi valley, some fairly major changes have taken place during the last 25 years: social, cultural, political, and environmental. It is important to consider all of these factors in resource management and conservation planning. The areas that change fastest are most urgent from a conservation standpoint, but they may also be richest areas (which is why they attract action). In the next chapter, the Batemi use of "natural" woody vegetation is examined.

# Chapter 3. Use of Woody Plants

## 3.1 Introduction

Woody vegetation is an important economic, social and cultural resource in many rural societies. Individual species may serve special needs and some species may be highly valued. Traditional husbandry or conservation practices may be imbedded in the culture and will be sensitive to local resource needs. As planning and resource management discussions are centralized (or become the responsibility of centralized agencies) it is important to be aware of the detail of the interaction between natural and social systems. Knowledge of key resource species and of traditional conservation practices can be valuable additions to sustainable development and conservation planning.

In Gray's (1963) ethnographic study of the Batemi, he mentions a number of types of use of wild plants, including material for houses, village gates, fences, firewood, digging sticks, food and medicinal uses. Batemi reliance and potential impact on natural vegetation continue today. This chapter presents more detailed findings on Batemi use of woody vegetation.

Ethnobotanists collect data on traditional or indigenous use of "wild" plants. Standard categories of data collected include: fuelwood, construction, household implements, fibres, food, medicine and rituals (for examples, see Boom 1989 and Prance *et al.* 1987). Data are usually collected and then classified into these categories or ones based on indigenous use. Ethnobotanical work has been traditionally very qualitative, with data collected in a casual, non-quantitative manner. Studies rarely outline methods used to collect and cite data (Johns *et al.* 1990). More recently, studies have been attempting to quantify the importance of medicinal plants

(Johns *et al.* 1990) and to quantify the percentage of available species that indigenous groups use (for examples see Boom 1989 and Prance *et al.* 1987). Other studies attempt to quantify use-values (Prance *et al.* 1987; Vasquez and Gentry 1989).

In most studies, data are collected either through an interview-artifact technique or, more recently, an inventory procedure (Boom 1989; Joint Forest Management 1992a and 1992b). The former method involves asking names of species used for specific purposes; the latter involves inventorying a section of forest, frequently a hectare, and then inquiring about the uses of each species. The interview-artifact method is the standard ethnobotanical approach. The second approach has been used more in recent years in studies undertaking to quantify use of species and the extent of traditional or local knowledge that may have applications in conservation (see Boom 1989; Peters *et al.* 1989; Prance *et al.* 1987). While a combination of these methods would be desirable, time constraints made that impractical in this case and only the former was used.

### 3.2 Data Collection

Data on non-medicinal use of woody vegetation -- construction, implements, fuelwood and services -- were collected during two visits to the Batemi area. The data were collected during informal interviews with groups from six different locations (the villages of DigoDigo, Mugholo, Samunge, Kisangiro, Oldonyosambu and the Samunge sub-village of Mditu) (see Table 3.1 and Figure 2.8). These informal groups were made up of people who were in the central village areas during interviews being conducted by Johns *et al.* (n.d.a, n.d.b). With one exception, the interview groups were all male, ranging in age from about 14 to 65. The problem of access to women is worthy of comment. While it is true that women are quite knowledgeable about

Table 3.1 Description of Interview groups.

| Village | Interview Group |
|---|---|
| DigoDigo | six males |
| Kisangiro | seven males, various ages |
| Samunge | five males |
| Mugholo | nine males |
| Oldonyosambu | eight males |
| Mditu | three young males |
| | others - young women or girls |

the environment and do a large percentage of the work, they tend not to be forward in dealing with outsiders. I had hoped that my being female would make access easier but because I was required to work through a translator, and the vast majority of educated youth are male, it was still difficult to interview women.

Additional information was gathered by further individual or group interviews and by the author's observations in the field during the biological survey in August. Some of the conversations in the field were with females, such as when I encountered women or girls collecting firewood.

The interviews were conducted by the author with interpretation by Tom Kimanani in June and July 1992 and Frederick Sedia in August 1992. The artifact/interview technique discussed above was used.

Data on four categories of use were collected: firewood, construction, household implements, and services. Groups were asked to name species used for specific objects within these non-medicinal use categories. Respondents were asked to name species used for the following construction materials: house poles and doors, beehives, village gates, hyaena traps, fences, furniture and rope. Queries were made concerning various implement objects such as walking sticks, bows and arrows, cooking utensils, digging sticks and handles for hoes. Service uses discussed included live uses of woody vegetation, such as fences or boundaries and shade.

Interview groups were also asked to identify the preferred or most valued species for a given use, if there was one, or if there were many species that could be used for a given purpose.

The analysis involved tabulating all reported uses within a use category and listing all species named. Multi-purpose species were identified. These are defined as those species used in two or more general use categories. For these purposes, the food and medicinal data collected by Johns *et al.* (n.d.a, n.d.b) are included. Species that are particularly valued for one specific use are termed single-use species.

Indirect uses such as animal food and ecological value (that is, keystone species of environmental significance) were not pursued. Data on food and medicinal use were not collected as these were being studied by Johns *et al.* (n.d.a, n.d.b). References to the religious significance of specific species used by the Batemi were noted but this information is less systematic and is discussed only in Chapter 5.

Additional data collected in the interviews, including peoples' comments about species that are perceived to be declining or harder to find and where rare species can be found are included in Chapter 5 under the broader category of "traditional" knowledge.

### 3.3 Results

A total of 102 woody species, representing at least 58 genera (6 species are still unidentified) and 37 families, are used by the Batemi (Table 3.2). Many of these are multiple-purpose species.

Table 3.2 List of woody species used by the Batemi. Multi-purpose species numbers indicate number of general uses. The numbers in the next four categories (construction or building materials, implements, fuelwood and services) indicate the number of times the species was cited as being used for some purpose within each given category. Under medicine and food, the numbers indicate individual citations of use (data from Johns *et al.* n.d.a, n.d.b).

| Family | Species | Vernacular | Multi | Build | Implem. | Fuel | Service | Medic. | Food |
|---|---|---|---|---|---|---|---|---|---|
| Amaranthaceae | *Sericomopsis hildebrandtii* | nalubaru, nambaru | 1 | | | | | 3 | |
| Anacardiaceae | *Lannea schimperi* | kijombeta | 1 | | | | | | 2 |
| | *Lannea sp.* | mtoregani | 1 | 2 | | | | | |
| | *Lannea schimperi* | mginkinywa | 1 | | | | | 3 | 3 |
| | *Lannea stuhlmannii* | msarya | 1 | | | | | | 2 |
| | *Ozoroa mucranata* | mgalati | 2 | 6 | | | | 7 | |
| | *Rhus natalensis* | busigiyo | 1 | | | | | | 2 |
| Annonaceae | *Uvaria schlefferi* | msilimbu | 1 | 1 | | | | | 3 |
| Apocynaceae | *Acokanthera oppositifolia* | msongo | 1 | | | | | | |
| | *Carissa edulis* | lumeme/mbaghao | 2 | | | | | 9 | 2 |
| Asclepiadaceae | *Sarcostemma viminale* | minyore/mbebe | 1 | | | | | 2 | |
| Asteraceae | *Vernonia amygdalina* | mtembereghu | 2 | 1 | | | | 3 | |
| Balanitaceae | *Balanites aegyptica* | mjuiya | 2 | | | 1 | | 5 | |
| Boraginaceae | *Cordia africana* | mringaringa | 2 | 6 | | | | | 1 |
| | *Cordia sp.* | mgombeha | 3 | 6 | | 1 | | | 1 |
| | *Cordia gharaf* | muhabusu/ngereh | 2 | 1 | | | | | 1 |
| | *Cordia quarensis* | ng'ong'o | 1 | | | | | | 1 |
| | *Cordia sp.* | mto | 2 | | 2 | 1 | | | |
| Burseraceae | *Commiphora africana* | kidirigheta | 1 | 2 | | | | | |
| | *Commiphora ellembekii* | mwaraheta | 1 | 5 | | | | | |
| | *Commiphora madaganscensis* | msisiyo | 1 | | | | | 2 | |
| | *Commiphora pelleifolia* | muluba | 2 | 5 | | | | | 3 |
| | *Commiphora schimperi* | msilale/mrunye | 1 | | | | | | 1 |
| | *Commiphora sp.* | mrumye | 1 | | | | | | |
| Caesalpiniaceae | *Tamarindus indica* | nsisi | 1 | | | | | | 6 |
| Canellaceae | *Warburgia salutaris* | msega | 1 | | | | | 14 | |
| Capparaceae | *Boscia angustifolia* | munyagu | 1 | 2 | | | 1 | | |
| | *Boscia coriacea* | jugumetu | 1 | | | | | 3 | |
| | *Capparis sp.* | mrera | 4 | 1 | | 1 | | | |
| | *Maerua sp.* | kasingiso | 1 | | | | 2 | | |

| Family | Species | Vernacular | Multi | Build | Implem. | Fuel | Service | Medic. | Food |
|---|---|---|---|---|---|---|---|---|---|
| Combretaceae | *Combretum molle* | mtewamgongo | 2 | 1 | | 1 | | | |
| | *Combretum padoides* | mkong'oni | 1 | 1 | | | | | |
| | *Combretum sp.* | msaghu | 1 | | | | | | |
| Ebenaceae | *Euclea racemosa* | masaganetu | 4 | 3 | 1 | | | 4 | 4 |
| Euphorbiaceae | *Acalypha volkensii* | munyuri | 1 | | 1 | | | | |
| | *Bridelia micrantha* | bara | 1 | 3 | | | | | |
| | *Croton dictygamous* | mgilalugi/msini | 4 | 1 | 3 | 1 | | 6 | |
| | *Croton megalocarpus* | ekitalambu | 2 | 1 | | | | 11 | |
| | *Euphorbia candelabrum* | kiroha | 1 | | | 1 | | | |
| | *Euphorbia cuneata* | kidingo ka mgongo | 1 | | | | | | 1 |
| | *Euphorbia tirucalli* | kidigho | 2 | | | 1 | 1 | | |
| | *Jatropha curcus* | mgulungulu | 2 | | 1 | | 2 | | |
| | *Ricinus communis* | mubono | 1 | | 1 | | | | |
| Guttiferea | *Garcenia livingstonei* | mbigo | 1 | | | | | | 7 |
| Liliaceae | *Aloe sp.* | kihandi | 1 | | | 1 | | | |
| | *Aloe sp.* | elambola | 2 | | | 1 | | | 1 |
| | *Aloe sp.* | elongo | 1 | | | | | | |
| Loganiceae | *Strychnos henningsii* | kibunja | 4 | 3 | 4 | 1 | | 8 | |
| Malvaceae | *Hibiscus calyphyllus* | kiraraha | 1 | | 1 | | | | |
| Meliaceae | *Trichilia emetica* | mdaghamira | 2 | | | 1 | | 2 | |
| | *Turrea robusta* | mnyama | 1 | | | | | | |
| Mimosaceae | *Acacia brevispica* | mhereki | 1 | | | 1 | | | |
| | *Acacia goetzi* | msigisigi | 3 | 2 | | 1 | | 4 | |
| | *Acacia mellifera* | mng'orora | 4 | 10 | 2 | 3 | | 12 | |
| | *Acacia nilotica* | kijemi | 4 | 6 | | 2 | | 13 | 2 |
| | *Acacia nubica* | oldebe | 1 | | | | | 9 | |
| | *Acacia robusta* | mzironi | 1 | | | | | | |
| | *Acacia xanthophloea* | mrera | 2 | | | 2 | | 3 | |
| | *Acacia tortilis* | mkamahe | 3 | 5 | | 4 | | 4 | |
| | *Acacia senegal* | mhuti | 2 | 1 | | | | 7 | |
| | *Albizia anthelmintica* | mrira/mukutani | 2 | 1 | | | | 10 | |
| | *Dichrostachays cinerea* | kiholi | 1 | 4 | | | | | |
| Moraceae | *Ficus sycomorus* | makoyo | 3 | 7 | | 1 | | | 7 |
| | *Ficus sp.* | mtoyo | 1 | | | | | | 3 |
| | *Ficus glumosa* | mubugi | 2 | | | | | 2 | 3 |
| | *Ficus populifolia* | mgagatya | 1 | | | | | | |

| Family | Species | Vernacular | Multi | Build | Implem. | Fuel | Service | Medic. | Food |
|---|---|---|---|---|---|---|---|---|---|
| Moraceae | *Ficus sp.* | msaganola | 1 | | | | | | |
| | *Ficus wakefieldii* | ndera | 1 | | | | | | 5 |
| Myrsinaceae | *Myrsine africana* | nghasi | 1 | | | | | 14 | |
| Olacaceae | *Ximenia caffra* | mloma | 2 | | | | | 4 | 8 |
| Papilionaceae | *Abrus precatorius* | mnyete | 1 | | 1 | | | | |
| | *Ormocarpum sp.* | ekurehe | 1 | | | | | | 1 |
| | *Ormocarpum kirkii* | mlemanjagu | 1 | | | | | 9 | |
| Phytolacaceae | *Phytolacca dodecandra* | mhaka | 1 | | | | | 4 | |
| Plumbaginaceae | *Plumbago zeylanica* | lughiri | 1 | | | | | | |
| Rubiaceae | *Canthium setiflorum* | mgogora | 1 | | | | | | 4 |
| | *Hymenodictyon parvifolium* | kirighogho | 1 | | | | | | |
| | *Vangueria apiculata* | mgholoma | 2 | 1 | | | | | 3 |
| Rutaceae | *Clausenia anisata* | mnyoka | 1 | | 1 | | | | |
| | *Teclea simplifolia* | mwarari | 1 | 1 | | | | | |
| | *Zanthoxylum chalybeum* | mulongo | 3 | 3 | 1 | 1 | | | |
| Salvadoraceae | *Salvadora persica* | msago | 2 | | 2 | | | 15 | |
| Sapindaceae | *Haplocoelum folioosum* | egirigirya | 2 | 5 | | 2 | | | |
| | *Pappea capensis* | kiboboyo | 3 | | | 1 | | 12 | 2 |
| Sapotaceae | *Mimusops kummel* | ghanana | 3 | 7 | | | 1 | | 1 |
| Simbarubaceae | *Harrisonia abyssinica* | toro | 1 | | | | | 25 | |
| Solanaceae | *Solanum incanum* | mdaghu | 1 | | | | | 2 | |
| | *Solanum setaceum* | mghamia mariba | 2 | | | | | 4 | 1 |
| | *Withania somnifera* | mjoni | 1 | | | | | | |
| Sterculiaceae | *Dombeya umbraculifera* | gwaretu | 2 | 2 | 2 | | | | |
| | *Sterculia quenquiobia* | mgurumetu | 1 | 3 | | | | | |
| Tiliaceae | *Grewia bicolor* | ebusheni | 2 | 4 | 8 | | | | |
| | *Grewia trichocarpa* | esere | 2 | | 2 | 1 | | | |
| | *Grewia villosa* | msabasabwa | 1 | | | | | 2 | |
| Verbenaceae | *Clerodendrum myricoides* | mgutugutu/mhura | 1 | | | | | 6 | |
| | *Clerodendrum rotundifolium* | kijuba | 1 | | 1 | | | | |
| | | esughubetu | 1 | 1 | | | | | |
| | | kijerwe | 1 | 2 | | | | | |
| | | kiteo | 1 | 2 | | | | | |
| | | lorieni | 1 | | 1 | | | | |
| | | madasha | 1 | | 1 | | | | |
| | | mdubai/oldubai | 1 | | | | | 4 | |

* The last six species have not been identified.

### 3.3.2 Fuelwood

Use of wood for fuel is probably the most intensive and ecologically-significant use of trees and shrubs in the area. Wood is the main source of fuel and lighting in the valley. Most people burn wood directly; a few people in Samunge make charcoal and this is sold in Loliondo. There are very few individuals who have kerosene lamps. Firewood is collected in a number of ways: ranging from the gathering of dead branches and trunks to felling of trees or cutting of branches.

In general, respondents indicated a tendency or willingness to utilize any available species for firewood. A number of specific species were mentioned, however, for a total of 23 species (Table 3.3). The species mentioned most

Table 3.3 Species cited as used for firewood. This list is by no means exhaustive.

| Species | Vernacular | Info.source |
|---|---|---|
| *Acacia brevispica* | mhereki | K |
| *Acacia goetzi* | msigisigi | S |
| *Acacia mellifera* | mng'orora | D K o |
| *Acacia nilotica* | kigemi | K M |
| *Acacia xanthophloea* | mrera | K M |
| *Acacia tortilis* | mkamahe | K M S o |
| *Aloe sp.* | elambola | S |
| *Aloe sp.* | kihandi | O |
| *Balanites aegyptica* | mjuiya | K |
| *Capparis sp.* | mrera | o |
| *Combretum molle* | mtewamgongo | D |
| *Cordia sp.* | mto | D |
| *Cordia sp.* | mgombeha | D |
| *Croton dictygamous* | mgilalugi | o |
| *Euphorbia candelabrum* | kiroha | D |
| *Euphorbia tirucalli* | kidigho | D M |
| *Ficus sycomorus* | mkoyo | O |
| *Grewia trichocarpa* | esere | K |
| *Haplocoelum folioosum* | egirigirya | K o |
| *Pappea capensis* | kiboboyo | D |
| *Strychnos henningsii* | kibunja | M |
| *Trichilia emetica* | mdaghamira | M |
| *Zanthoxylum chalybeum* | mulongo | o |

**Legend:**
D = DigoDigo
M = Mugholo
O = Oldonyosambu
K = Kisangiro
S = Samunge
Md = Mditu
o = other

frequently include: *Acacia tortilis* (four villages) and *Acacia mellifera* (three villages). *Acacia nilotica*, *Acacia xanthophloea*, *Euphorbia tirucalli* and *Haplocoelum folioosum* were all mentioned in two villages. There are also a few species of plants that are used for specific purposes. *Aloe* species (kihandi and elambola) are used specifically for smoking bees out of beehives when it is time to collect the honey. Species mentioned as most preferred or more highly-valued species were the *Acacia* species (*A. mellifera*, *A. tortilis* and *A. nilotica*).

### 3.3.2 Construction Materials

Construction materials are another major use of wood in the Batemi area. A total of 39 species were mentioned as being used for construction purposes, ranging from house materials, to fences and beehives (Table 3.4).

Building of houses is one of the main construction uses for wood. A traditional house is constructed entirely from indigenous plants (Figure 3.1). Large poles (usually an *Acacia* species, *Haplocoelum folioosum*, *Ozoroa mucranata* or *Mimusops kummel*) are interlaced with smaller poles from a *Cordia* species (mgombeha) or *Strychnos henningsii*. Further south on the plain near Sale, *Cordia gharaf*, or muhabusu, is used. The roof poles are preferably *Dombeya umbraculifera* or *Strychnos henningsii*. Rope, from various trees such as *Sterculia africana* or *Uvaria schlefferi*, or reed species such as *Cyperus alternifolius*, is used to tie the poles together. Various grasses or reeds are then used for thatching the roof. The actual doors are single planks hewed from the roots of large trees. *Ficus sycomorus* is the most commonly used species, as its roots are wide and sprawling. The Batemi leave the majority of the tree intact, cutting out only a section of the root. The other tree commonly used for doors is a *Capparis* species known as mrera.

Table 3.4 List of species used for construction. Given by type of use and place of citation. The category columns are: building poles, beehives, village gates, hyaena traps, house doors, rope, furniture and fences.

| Species | Vernacular | Poles | Beehive | Gates | Traps | Door | Rope | Furn. | Fences |
|---|---|---|---|---|---|---|---|---|---|
| *Acacia senegal* | mhuti | o | | | | | | | |
| *Acacia goetzi* | msigisigi | S | Md | | | | | | |
| *Acacia mellifera* | mng'orora | DKMSMdO | | K | K S | | | | o |
| *Acacia nilotica* | kijemi | M S | | K | K S | | | | o |
| *Acacia tortilis* | mkamahe | S o | | K | K | | | | o |
| *Albizia anthelmintica* | mrira | | o | | | | | | |
| *Balanites aegyptica* | mjuiya | | | | | | | | o |
| *Boscia angustifolia* | munyagu | o | o | | | | | | |
| *Bridelia micrantha* | bara | o | o,o | | | | | | |
| *Capparis sp.* | mrera | | | | | c | | | |
| *Combretum padoides* | mkong'ongi | | | | | | | o | |
| *Combretum molle* | mtewamgongo | o | | | | | | | |
| *Commiphora africana* | kidirigheta | | | | | | | | o,o |
| *Commiphora ellembekii* | mwaraheta | o | KMSMdO | | | | | | |
| *Commiphora pellifolia* | muluba | o | KSMdO | | | | | | o |
| *Cordia africana* | mringaringa | o | DMMdS,2o | | | | | | |
| *Cordia sp.* | mgombeha | DMS | | | | | | | |
| *Cordia gharaf* | muhabusu | o | | | | | | | |
| *Croton dictygamous* | mgilalugi | o | | | | | | | |
| *Croton megalocarpus* | ekitalambu | D | | | | | | | |
| *Dombeya umbraculifera* | gwaretu | O o | | | | | | | |
| *Dichrostachays cinerea* | kiholi | M S o | | | | | | | o |
| *Euclea racemosa* | mraganetu | | K S o | | | | | | |
| *Ficus sycomorus* | mkoyo | | MSMd | | | MSM | | | |
| *Grewia bicolor* | ebusheni | KSOo | | | | | | | |
| *Haplocoelum folioosum* | egirigirya | DKMOoo | | | | | | | |
| *Lannea sp.* | mtoregani | | S Md | | | | | | |
| *Mimusops kummel* | ghanana | DKMo | S Md O | | | | | | |
| *Ozoroa mucranata* | mgalati | MSMd | SMdO | | | | | | |
| *Sterculia quenqulobia* | mugurumetu | o | | | | | O o | | |
| *Strychnos henningsii* | kibunja | M | | | | | | | |
| *Teclea simplifolia* | mwarari | | o | | | | | | |
| *Uvaria schlefferi* | mailimbu | | | | | | o | | |
| *Vangueria apiculata* | mgholoma | | | | | | | | o |
| *Vernonia amygdalina* | mtembereghu | | | | | | | o | |
| *Zanthoxylum chalybeum* | mulongo | o | O | | | | | | o |
| | esughubetu | | S | | | | | | |
| | kijerwe | S Md | | | | | | | |
| | kiteo | | O o | | | | | | |

Legend:

D = DigoDigo
M = Mugholo
O = Oldonyosambu
o = other

K = Kisangiro
S = Samunge
Md = Mditu

Figure 3.1 A traditional Batemi house is round and constructed entirely from local materials.

Some of the newer houses use wood only for the house frames, while mud is used to plaster it. The wood is frequently a cedar bought from the Loliondo area. The most recent type of house structure is made from local bricks. This type of construction seems to be restricted to young people who have jobs and therefore the money to afford such a house as their are labour costs for building bricks and the roof is usually made from tin. The largest portion of houses, however, are still constructed in the traditional style.

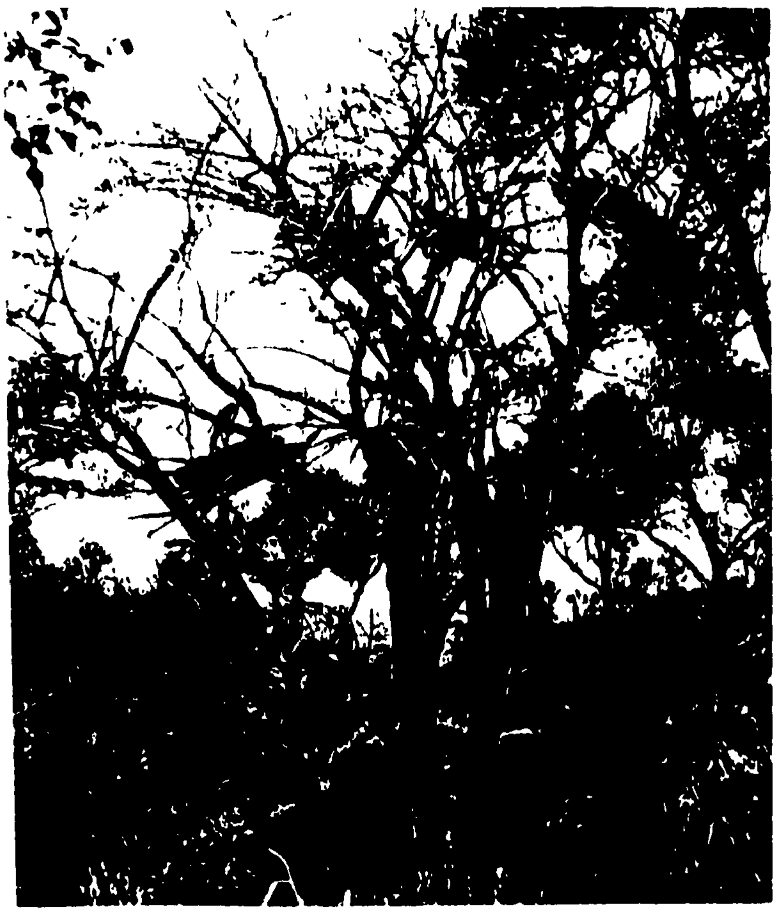
Furniture and platforms inside the houses are also constructed from wood. *Combretum padoides* is used to construct the platforms installed in the houses to hold grains and beans. *Vernonia amygdalina* is used for bedframes.

Wood is also the main material used to construct fences, beehives, village gates and animal traps. Particular species are preferred for many of these uses. Fences are mostly constructed from acacia species, such as *Acacia mellifera*, *Acacia nilotica* or *Acacia tortilis*, along with *Balanites aegyptica* and a few *Commiphora* species. Respondents indicated that branches of acacia trees are preferred for fences around houses and gardens (or shambas) as their thorns make them suitable for barriers. *Zanthoxylum chalybeum* and *Vangueria apiculata* were also mentioned as fence species.

Beehives are an important part of the Batemi culture, with most men having beehives (Gray 1963). They are constructed from hollowed out logs, derived mostly from hardwood species. The beehives are placed in the forks of trees, surrounded by poles to hold them in place (Figure 3.2). A total of 18 species were mentioned as used for beehives. According to respondents, the most sought after tree trunk for beehives is *Cordia africana* (mringaringa), which was mentioned in 4 villages. The use of *Cordia africana* for beehives is quite restricted as they are mainly only found along irrigation channels, where cutting is prohibited except to the Wenamije or elite. As this species is not widely available, a few other species are substituted, including *Commiphora ellembekii* (mentioned in 5 villages) and *Commiphora pelleifolia* (mentioned in 4 villages). Other species mentioned include *Ficus sycomorus*, *Mimusops kummel* and *Ozoroa mucranata*.

Village gates and hyaena traps, for which there is no longer any great need, are made from Acacia species, such as *Acacia tortilis*, *Acacia nilotica* and *Acacia mellifera*. These species are considered to be the most desirable for these uses.

Figure 3.2 Beehives are placed in the forks of trees within bundles of poles. Trees often contain a number of beehives.



### 3.3.2 Household Implements

Implements are generally made from shrubs or smaller trees. A total of seventeen species were mentioned during the course of the interviews and a few of these are used for more than one type of implement or tool (Table 3.5). The types of uses include walking sticks, bows and arrows, digging tools, spoons, and toothbrushes. *Grewia bicolor*, *Acacia mellifera*, a *Cordia* sp. (mto) and *Grewia trichocarpa* are all used for walking sticks, with the first species being the preferred one.

Table 3.5 Species used as implements. Listed by place of reference under specific type of use. The categories are: walking sticks, rungata (authority stick), digging sticks, handles for implements, bows and arrows, toothbrush, and others.

| Genus and Species | vern. | w.stick | rungata | D.stick | handle | bow&arro | tooth | Other | No.ref |
|---|---|---|---|---|---|---|---|---|---|
| *Abrus precatorius* | mnyete | | | | | | o | | 1 |
| *Acacia mellifera* | mng'orora | S O | | | | | | | 2 |
| *Acalypha volkensii* | munyuri | | | | | S | | | 1 |
| *Clausenia anisata* | mnyoka | | | | | | o | | 1 |
| *Clerodendrum rotundifolium* | kijuba | | | | | | o | | 1 |
| *Cordia sp.* | mto | D M | | | | | | | 2 |
| *Croton dictygamous* | mgilalugi | M | | O | | o | | | 3 |
| *Dombeya umbraculifera* | gwaretu | | | | | M S | | | 2 |
| *Euclea racemosa* | msaghanetu | | | | | o | | | 1 |
| *Grewia bicolor* | ebusheni | DKMO o | o | | S | M | | | 8 |
| *Grewia trichocarpa* | esere | K o | | | | | | | 2 |
| *Hibiscus calyphyllus* | kiraraha | | | | | | | | 1 |
| *Jatropha curcus* | ngulungulu | | | | | | | o | 1 |
| *Ricinus communis* | mbono | o | | | | o | | | 1 |
| *Salvadora persica* | msago | | | | | | K O | | 2 |
| *Strychnos henningsii* | kibunja | | | D S o | D | | | | 4 |
| *Zanthoxylum chalybeum* | mulongo | | | | | | | o | 1 |

Legend:

D = DigoDigo
M = Mugholo
O = Oldonyosambu
o = other
K = Kisangiro
S = Samunge
Md = Mditu

Digging sticks, an important implement in the past, are made from *Strychnos henningsii* or *Croton dictygamous*, with the former the most preferred. Bows and arrows are made mostly from *Dombeya umbraculifera*, *Acalypha volkensii*, *Euclea racemosa*, *Grewia bicolor* and *Ricinus communis*. Other types of uses and their species include: toothbrushes (*Salvadora persica*), and hoe handles (*Strychnos henningsii* and *Grewia bicolor*).

## 3.3.2. Services

The Batemi also utilize live trees for a few services, including fences, boundaries and shade. Five species were specifically named (Table 3.6). *Jatropha*

Table 3.6 List of species used for services.

| Genus and Species | Vernacular | Type | Source |
|---|---|---|---|
| *Boscia angustifolia* | munyagu | shade | o |
| *Euphorbia tirucalli* | kidigho | fence | o |
| *Jatropha curcus* | mgulungulu | fence | o |
| *Jatropha curcus* | mgulungulu | boundary | o |
| *Maerua* sp. | kasingiso | shade | O |
| *Mimusops kummel* | ghanana | shade | M |

Legend:

D = DigoDigo
M = Mugholo
O = Oldonyosambu
o = other
K = Kisangiro
S = Samunge
Md = Mditu

*curcus* is used for both live fences and as boundary markers between fields or along ro ı ls. The other species that is highly visible as live fences is *Euphorbia tirucalli*, especially in Samunge and Mugholo (Figure 3.3). A *Maerua* sp. is one of the species used for shade in home compounds, as is *Mimusops kummel*. These species are carefully preserved for shade or planted and managed for purposes such as fences and boundaries. A few other species were also used as fence species, including *Commiphora madaganscensis*.

### 3.4. Discussion

The various non-medicinal uses described above are important for the Batemi. Many of the species derive their value from a range of uses while others are only used for single purposes.

Figure 3.3 *Euphorbia tirucalli* functioning as a live fence. Notice the newer type of house construction in the background.

3.4.1 Multipurpose species

A number of the species can be classed as key multi-purpose species, that is, as trees or shrubs which provide a range of goods or services. Fifteen are used for three or more general purposes, including food and medicine purposes, and forty are used for two or more (Table 3.7).

Many of the most widely-used species, in terms of general use categories, are *Acacia* species. *Acacia mellifera* is probably the most highly-valued amongst the Batemi for its strength and termite-resistant qualities. It is used for medicine, fuel, building (mentioned in all 6 villages) and implements. People continually stressed

Table 3.7 List of species used for multi-purposes. The table lists number of general uses and then the number of uses within the construction and implement categories, as there are eight and seven sub-uses within those two categories respectively.

| Species | Vernacular | # uses | Build | Imp |
|---|---|---|---|---|
| *Acacia goetzi* | msigisigi | 3 | | |
| *Acacia mellifera* | mng'orora | 4 | 4 | |
| *Acacia nilotica* | kijemi | 4 | 4 | |
| *Acacia tortilis* | mkamahe | 3 | 4 | |
| *Capparis* sp. | mrera | 4 | | |
| *Commiphora ellembekii* | mwaraheta | | 2 | |
| *Commiphora pelleifolia* | muluba | | 3 | |
| *Cordia* sp. | mgombeha | 4 | | |
| *Cordia africana* | mringaringa | | 2 | |
| *Croton dictygamous* | mgilalugi | 4 | | 3 |
| *Dombeya umbraculifera* | gwaretu | 3 | | |
| *Euclea racemosa* | msanganetu | 4 | | |
| *Ficus sycomorus* | mkoyo | 3 | 2 | |
| *Grewia bicolor* | ebusheni | 3 | 2 | 4 |
| *Haplocoelum folioosum* | egirigirya | | 2 | |
| *Mimusops kummel* | ghanana | 3 | 2 | |
| *Ozoroa mucranata* | mgalati | | 2 | |
| *Pappea capensis* | mgurumetu | 3 | | |
| *Sterculia quenqulobia* | kiboboyo | | 2 | |
| *Strychnos henningsii* | kibunja | 4 | 1 | 2 |
| *Zanthoxylum chalybeum* | mulongo | 3 | 3 | |

that it was one of the strongest trees and the best for building. Three other acacia species are also widely used: *Acacia tortilis*, *Acacia nilotica* and *Acacia goetzi*. All of these are used for fuel, building and medicine. *Cordia* and *Ficus* are widely used genera, with a *Cordia* sp. (mgombeha) and *Ficus sycomorus* as two of the species that fulfil a number of roles.

Shrubs that are widely used include *Croton dictygamous*, *Croton megalocarpus*, *Grewia bicolor*, and *Strychnos henningsii*. Most of these tend to be used for medicine, fuel, building and implements. A few of them are highly valued for specific purposes, including *Grewia bicolor*, the most prized species for walking sticks.

Some species are also widely used within one general category type (such as construction or implements). For example, *Acacia mellifera, Acacia nilotica* and *Acacia tortilis* are all used for four types of construction purposes. Within the implement category *Grewia bicolor* is used for walking sticks, rungatas, handles and bows and arrows while *Croton dictygamous* is used for walking sticks, digging sticks and bows and arrows. *Strychnos henningsii* is used for digging sticks and hoe handles.

### 3.4.2 Valued, Single-Use Species

There is also a class of species that, although not multi-purpose, are highly valued owing to their suitability for one specific purpose. Notable amongst this category in terms of construction materials is *Cordia africana*, which is the most preferred species for beehives. It was mentioned in five villages as being used for beehives and was referred to as the most valued for this purpose. *Haplocoelum folioosum* is another species that is widely used as one particular material, in this case house poles. Many of the medicinal plants, such as *Harrisonia abyssinica, Warburgia salutaris* and *Myrsine africana* are single-use species.

## 3.4 Conclusion

There are some species and families that can be easily designated "key" social or cultural species, ones whose existence is important to the cultural, social and even economic life of the community. The data in this chapter provide an indication of the more valued or "key" species to the Batemi. The task of identifying key species is discussed further in Chapter 5. But first, biological data, which is also required for conservation and resource planning, is presented in Chapter 4.

## Chapter 4. Woody Vegetation Distribution and Abundance

### 4.1 Introduction

The next step in the research was to conduct a quantitative study of the structure and composition of vegetation resources in the area. Although there have been many vegetation studies conducted in the region, such as in the Ngorongoro Conservation Area (Herlocker and Dirschl 1978), Lake Manyara National Park (Loth and Prins 1986) and the Maasai Mara area in Kenya (Lamprey 1984), there are no baseline data available for the Batemi area. This chapter presents and discusses findings on the woody vegetation, focusing on species composition, abundance and distribution. There are three components to this data. First, there are the basic inventory and spatial distribution data, which provides a general sense of the abundance of the species found in the area. Second, classification and ordination of these data then provide general vegetation types and an idea of the habitats of each type. The final component is a landcover map, which was created from Landsat Thematic Mapper (TM) digital data. The vegetation types from the classification and ordination are depicted on the land cover density classes on the final map.

### 4.2 Methodology

#### 4.2.1 Data Collection

##### 4.2.1.1 Random Samples

In DigoDigo Ward, the areas of most intensive use are the valley floor, the hills occurring within the valley and the lower slopes of the escarpments at the north edge of the valley. These were targeted for study. The limits of the study area

(Figure 4.1) follow the limits of DigoDigo ward, except on the northern-side, where they follow the 1400 meter elevation mark. Random sampling was used, as recommended for ecological and conservational survey work by Usher (1992). One of the main objectives was to investigate the availability of species for all four of the main villages. Therefore, to ensure coverage of the full area, the valley was divided into three adjacent, equal sections (Figure 4.1), each to be sampled separately.

The species-area method was used to determine the optimum area for quadrat size. Five repeated nested quadrats of 25, 100, 225 and 400 m$^2$ showed that 10 x 10 m was an appropriate size (Table 4.1), the size also used in similar environments by many researchers (Fuls *et al.* 1992; Kennenni 1991; Kigomo *et al.*. 1990; Loth and Prins 1986).

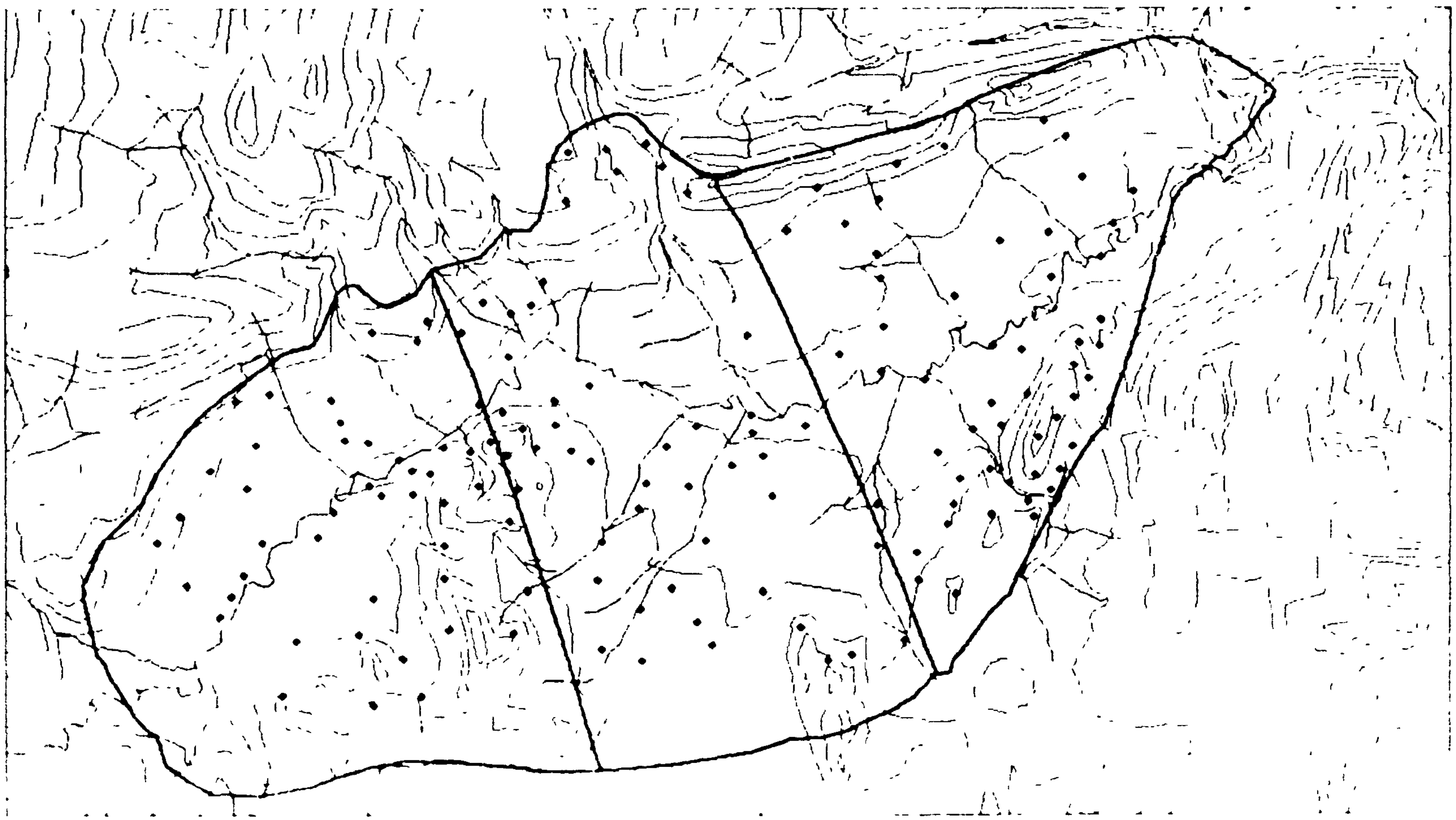
It was initially determined that 150 quadrats would be sampled but that the species-area relationship would be monitored and if the number of species were not approaching an asymptote, the number would be increased.

Locations of samples were marked on a topographic map from coordinates extracted from a random samples table. Locations falling outside of the area were

Table 4.1 Determination of quadrat size using four sizes of nested quadrats with five replicates.

| Size of Quadrat | 5 x 5 m | 10 x10 m | 15 x 15 m | 20 x 20 m |
|---|---|---|---|---|
| Quadrat 1 | 2 | 4 | 4 | 4 |
| Quadrat 2 | 6 | 8 | 9 | 10 |
| Quadrat 3 | 2 | 3 | 4 | 4 |
| Quadrat 4 | 4 | 7 | 7 | 9 |
| Quadrat 5 | 4 | 6 | 7 | 7 |
| Mean | 3.4 | 5.6 | 6.2 | 6.8 |

Figure 4.1. Design of sampling strategy. The three sections of the sample area, the random quadrats, and the irrigation channels inventoried are all shown.



Scale: 1:75,000

Wynet Smith 1993

0 —— 5 KM

Legend:

Elevation

—— Demarcation of sample area and three sections

• - Random quadrats

- Rivers

- Irrigation Channels Inventoried

discarded, as were any quadrats that would have been located within a village or an agricultural field. In the field, the quadrats were located as accurately as possible using the map and aerial photographs. At that point, the exact location of the sample was determined by throwing a rock over the shoulder. The spot where the rock landed was noted by a field assistant and used to mark the northeast corner of the quadrat.

All tree species in the sample plots were recorded or, for any unknown species[3], specimens were collected, described, catalogued and later taken to the University of Nairobi Herbarium for identification. For each individual, height class and diameter at breast height (dbh) for trees were recorded.

4.2.1.2 Additional Data

Although random sampling was the principal method used, these data were supplemented with comprehensive surveys of irrigation channels. These riverine species are distinct and important but have a very low spatial distribution. Complete inventories of four of the principal channels were conducted (Figure 4.1). Additional species information was also collected by noting the presence of species in the village areas and when exploring the more remote escarpment areas. These data are not included in the density and distribution analysis based on quadrats.

[3] An initial inventory list of vernacular and botanical names was available due to the ethnobotanical work underway by Johns (n.d.a, n.d.b).

4.2.2 Data Analysis

Density[4] and frequency[5] of species for the whole area were calculated. The data from the three subsections of the valley were analyzed altogether. These data provide an overall estimate of the availability of the different species.

Classification and ordination of the data were performed to obtain a simplified data structure and to detect patterns of variation (Gauch 1982; cf. Kennenni 1991). Classification was undertaken using the hierarchical two-way indicator species analysis program TWINSPAN (Hill 1979), a polythetic, divisive technique that breaks a sample set down into smaller, associated groups of samples and species. TWINSPAN first constructs a classification of samples and then uses this classification to obtain a classification of species based on ecological preference (Hill 1979). Bredenkamp *et al.* (1991 cited in Fuls *et al.* 1992) found TWINSPAN gave a first good approximation of vegetation communities. The data were ordinated using the detrended correspondence analysis (DCA) option in the computer program CANOCO (ter Braak 1988). The main clusters of the TWINSPAN analysis are compared with the DCA ordination.

Species occurring in less than four percent of the sampling sites were eliminated for the classification and ordination analysis. The final results are based on the default variables in the programs, which were found to provide adequate

[4] Density is defined as the number of individuals per unit area (Kershaw and Looney 1985). This measure was chosen as it allows comparison of different areas and different species and is an absolute measure of the abundance of plants.

[5] Frequency is defined as the proportion or percentage of quadrats containing a species (Goldsmith 1991; Gauch 1982). Frequency is not an absolute measure as values are dependent on quadrat size, plant size and spatial distribution (Kershaw and Looney 1985).

exploration of the data set.

### 4.2.3 Landcover Map Classification

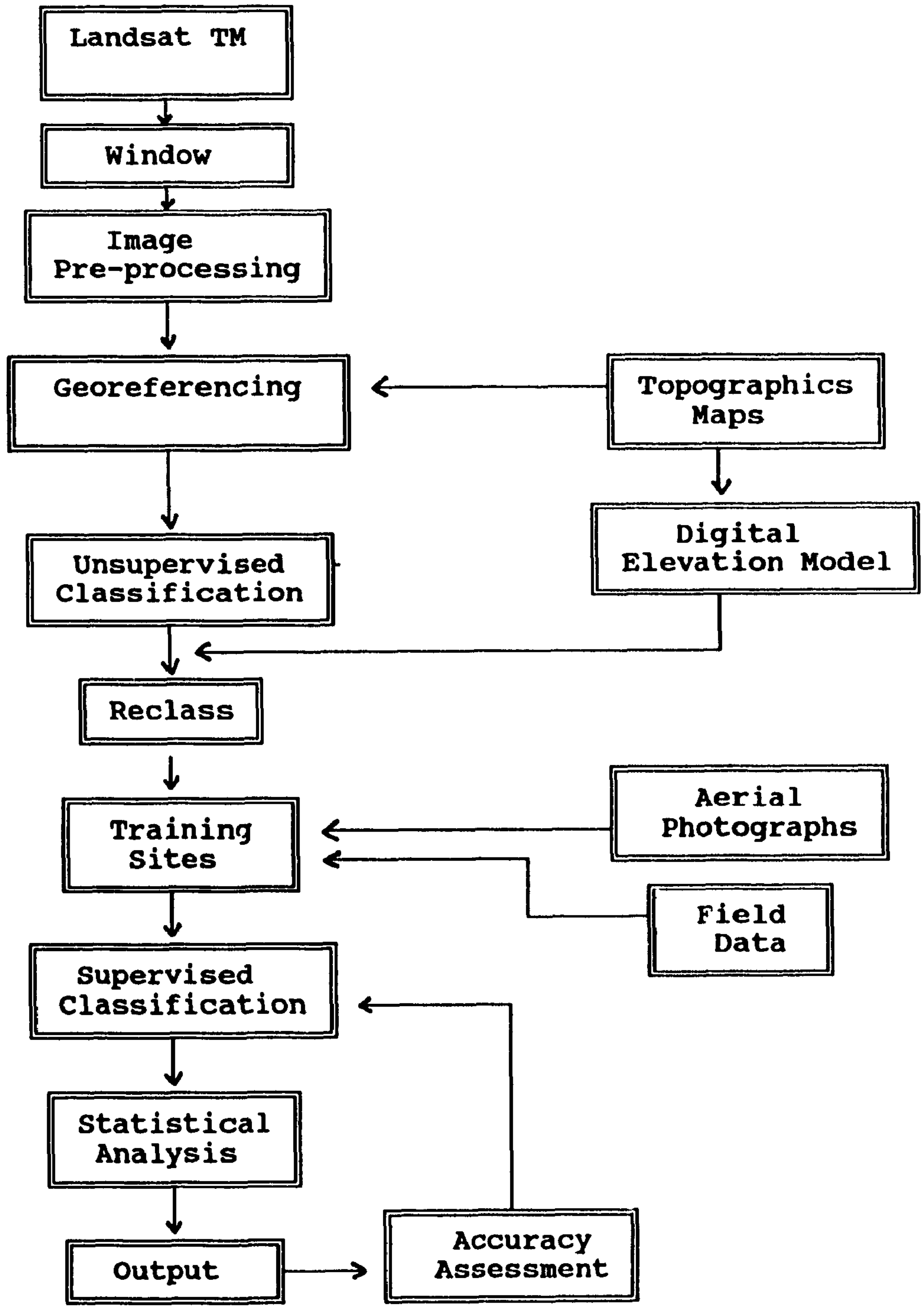
An attempt was made to produce a general landcover map for the area using Landsat Thematic Mapper (TM) digital data. The classes depicted are based on the percentage of woody vegetation in order to provide baseline data for resource management and conservation planning. These types of discrete communities are valuable in the process of mapping areas, assessing value for conservation and in determining plans for management, even if nature does not contain such distinct entities (Cox and Moore 1993).

In areas like the Batemi valley, there are many barriers to classifying land cover including heterogeneity of cover and topography. One possibly important problem in classification of vegetation or soils in semi-arid areas is mixed pixels, which are pixels containing a mixture of surface cover classes (Schowengerdt 1983, 141). As well, there can be variation in spectral characteristics within classes due to factors such as plant health and age. Terrain slope and aspect can also affect spectral reflectance of landcover; the same surface cover can have a wide spectral variation due to slope, aspect and solar inclination and azimuth (Ahman *et al.* 1992; Holbein and Justice 1980 in Civco 1989; Schowengerdt 1984, 139). These factors need to be considered in classification accuracy.

#### 4.2.3.1 Materials and Methods

The materials and procedures used to produce the landcover map are illustrated in Figure 4.2.

Figure 4.2. Flow chart of procedures followed during course of production of Landcover Map.



i) Materials

A range of data were used to investigate and classify the vegetation cover. A Landsat Thematic Mapper (TM) image of March 1, 1991 (scene 169/61) was used for digital analysis. A Landsat TM print (1:100000 scale) for March 1989, aerial photographs for 1958 and 1972, 1:50,000 topographic map sheets (27/1 and 27/2), and field observations were used to aid in the classification process (for a complete list of materials and sources see Appendix 1). The Landsat digital data was an extract from scene D169-061, 1 March 1991.

ii) Pre-processing and image enhancement

A subscene covering DigoDigo Ward (columns 4660-5299 and rows 5360-5839) was extracted from the Landsat image. Initial processing of the digital data included visual and statistical investigation of the separate bands (only 2 and 4-7 were available). Based on the visual interpretability and screening for redundancy in data between the available bands, 2, 4 and 7 were used for the final classification process. The correlation matrix (Table 4.2) shows the high redundancy between a number of the bands. Bands 4 and 7 had one of lowest at 0.4207 and band 2 was chosen to complement these two.

Table 4.2 Correlation matrix for four bands available for the Batemi area.

| Band | Range | Mean | Stand. dev. |
|---|---|---|---|
| 2 | 23-49 | 34.03 | 4.07 |
| 4 | 11-131 | 60.28 | 7.03 |
| 5 | 25-255 | 93.38 | 21.90 |
| 7 | 11-255 | 49.22 | 16.17 |

iii) Geo-referencing

The satellite image was geo-referenced to Universal Transverse Mercator (UTM) coordinates using the rectification process in GRASS. Twelve points on the image were referenced and used to rectify the entire image. The root-mean-square-error (RMSE), usually used to indicate locational error was 27.39 m, an acceptable error given the resolution cell size of 30 meters.

iv) Classification

Initial unsupervised classifications were conducted using IDRISI at the Serengeti Research Institute in the Serengeti National Park. The resultant clusters were investigated with initial field data and aerial photographs and then investigated with further ground truthing.

In Canada, further classification was undertaken on GRASS 4.0 in the McGill University, Department of Geography GIS lab. Unsupervised classification was conducted on a combination of bands 2-4-7, with various numbers of clusters. The influence of topography on the classifications carried out was investigated using a digital elevation model (DEM), derived from digitized topographic maps. This was used to visually interpret effects and to help choose the final classes.

A supervised classification was then undertaken, with training sites (Table 4.3) based on areas of vegetation that were known from initial ground-truthing, aerial photograph interpretation, and pixel clusters identified in the unsupervised classification.

Table 4.3 Training site statistics used for maximum likelihood supervised classification of the Batemi study area.

| | Mean, standard deviation and minimum and maximum spectral values for each of the three bands. | | |
|---|---|---|---|
| Class | Band 2 | Band 4 | Band 7 |
| Bush/ Thicket | 25.2+/-1.5; 23-28 | 46.5+/-3.8; 38-57 | 16.6+/-2.2; 11-19 |
| Woodland | 38.5+/-1.75; 34-42 | 60.7+/-3.3; 53-69 | 75+/-5.8; 58-90 |
| Wooded grassland | 34.8+/-1.46; 32-38 | 54.1+/-3.2; 48-61 | 67.1+/-3.1; 57-75 |
| Grassland | 45.3+/-2.63; 41-49 | 74.9+/-4.2; 68-78 | 83.1+/-4.7; 69-96 |

v) Error Assessment

There are many points at which error can be introduced into the production of a landcover thematic map. Table 4.4 lists the types of error that a user must be aware of in interpreting the reliability of the final map product. The final map is affected by all of the factors.

Table 4.4 Sources of error in the Image Processing and GIS process (derived from Lunetta *et al.*. 1991).

| Stage | Specific error |
|---|---|
| Data Processing | Geometric rectification |
| Data Analysis | Quantitative analysis<br>Classification system<br>Data generalization |
| Data Conversion | Vector to raster |
| Final Product | Spatial error<br>Thematic error |

## 4.3 Results and Discussions

### 4.3.1 Species Composition and Abundance

In all, there were 101 woody species recorded, representing 54 genera and 37 families (Tables 4.5, 4.7 and 4.9). In the 150 random quadrats (Table 4.5), 1208 individual trees and shrubs were counted, representing 74 species (trees, shrubs and a few woody aloes) of 49 genera and 33 families. The four irrigation channels contained 22 species of trees and shrubs in 18 genera and 15 families (Table 4.7). Another 15 species were seen in the area but did not fall within either the random sampling or irrigation channels (Table 4.9). These trees and shrubs represented 13 genera and 11 families.

### 4.3.2 Random Sites Data

The species-area curve (Figure 4.3) suggests that 150 samples was adequate. At 63 quadrats, 64 species had been identified. The number rose only to 74 by 150. Thus, 150 10 x 10 m quadrats (1.5 hectares) were sampled.

The most abundant species in the area are *Croton dictygamous* (168/hectare), *Acacia tortilis* (73/ha.), *Vangueria apiculata* (58/ha.), *Euphorbia tirucalli* (48/ha.) and *Grewia bicolor* (45/ha). Individually, these represent, respectively, 20.9%, 9%, 6.95%, 5.9% and 5.5%, or, together, almost 50% of the total number of trees and shrubs found in the sample set.

Nine species have densities greater than 20 individuals per hectare (Figure 4.4) and account for 767 or 63.5% of the trees and shrubs counted. Eighteen species have densities greater than 10/ha and account for 954 or 79% of the total trees and shrubs. Most of the other species occur only infrequently and often only in restricted

Table 4.5 Random sampling species data.

| Family | Species | Vernacular | Sum | Dens(ha) | %Freq. |
|---|---|---|---|---|---|
| Anacardaceae | *Lannea* | kijombeta | 8 | 5.33 | 2.86 |
| | *Lannea* | mtoregani | 4 | 2.67 | 2.86 |
| | *Lannea stuhlmannii* | msarya | 14 | 9.33 | 7.86 |
| | *Ozoroa mucranata* | mgalati | 1 | 0.67 | 0.71 |
| Annonaceae | *Uvaria schlefferi* | msilimbu | 1 | 0.67 | 0.71 |
| Apocynaceae | *Acokanthera oppositifolia* | msongo | 32 | 21.33 | 3.57 |
| Asclepiadaceae | *Sarcostemma viminale* | minyore | 9 | 6 | 2.14 |
| Balanitaceae | *Balanites aegyptica* | mjulyu | 28 | 18.67 | 14.29 |
| Boraginaceae | *Cordia africana* | mringaringa | 1 | 0.67 | 0.71 |
| | *Cordia sp.* | mgombeha | 4 | 2.67 | 2.86 |
| | *Cordia ghara* | muhabusu | 2 | 1.33 | 1.43 |
| | *Cordia sp.* | mto | 1 | 0.67 | 0.71 |
| Burseraceae | *Commiphora africana* | kidirigheta | 23 | 15.33 | 7.14 |
| | *Commiphora ellembekii* | mwaraheta | 7 | 4.67 | 4.29 |
| | *Commiphora markeli* | kidigho ka mg | 1 | 0.67 | 0.71 |
| | *Commiphora pelleifolia* | muluba | 24 | 16 | 8.57 |
| | *Commiphora schimperi* | msilale/mrunye | 5 | 3.33 | 1.43 |
| Caesalpiniaceae | *Senna didymobotrya* | senetoi | 3 | 2 | 1.43 |
| | *Tamarindus indica* | nsisi | 1 | 0.67 | 0.71 |
| Capparaceae | *Boscia angustifolia* | munyagu | 12 | 8 | 6.43 |
| | *Capparis sp.* | mrera | 2 | 1.33 | 1.43 |
| | *Maerua sp.* | kasingiso | 5 | 3.33 | 3.57 |
| | *Maerua endlichii* | mtrihaje | 1 | 0.67 | 0.71 |
| Combretaceae | *Combretum molle* | mtewamgongo | 5 | 3.33 | 1.43 |
| | *Combretum padoides* | mkong'oni | 2 | 1.33 | 1.43 |
| Compositae | *Solanecio mannii* | ekero | 1 | 0.67 | 0.71 |
| Convolvulaceae | *Ipomea hildebrandtii* | ebungi lya | 5 | 3 33 | 0.71 |
| Cycadaceae | *Encephalalantos hildebrandtii* | esuku | 5 | 3.33 | 1.43 |
| Ebenaceae | *Euclea racemosa* | masaganetu | 1 | 0.67 | 0.71 |
| Euphorbiaceae | *Acalypha volkensii* | munyuri | 58 | 38.67 | 7.14 |
| | *Croton dictygamous* | mgilalugi/msini | 253 | 168.67 | 22 |
| | *Euphorbia candelabrum* | kiroha | 41 | 27.33 | 11.43 |
| | *Euphorbia schefflleri* | kiribaji | 3 | 2 | 0.71 |
| | *Euphorbia tirucalli* | kidigho | 71 | 47.33 | 13.57 |
| | *Euphorbia sp.* | kiheli | 1 | 0.67 | 0.71 |
| | *Ricinus communis* | mubono | 8 | 5.33 | 1.43 |
| Guttiferae | *Garcenia livingstonei* | mbigo | 2 | 1.33 | 1.43 |
| Liliaceae | *Aloe sp* | kihandi | 10 | 6.67 | 0.71 |
| | *Aloe sp.* | elambola | 20 | 13.33 | 2.43 |
| Loganiceae | *Strychnos henningsii* | kibunja | 17 | 11.33 | 2.86 |
| Meliaceae | *Trichilia emetica* | mdaghamira | 9 | 6 | 4.29 |
| | *Turrea robusta* | mnyama | 7 | 4.67 | 4.29 |
| Mimosaceae | *Acacia tortilis* | mkamahe | 109 | 72.67 | 44.29 |
| | *Acacia nilotica* | kijemi | 52 | 34.67 | 17.86 |
| | *Acacia brevispica* | mhereki | 15 | 10 | 8.57 |
| | *Acacia mellifera* | mng'orora | 15 | 10 | 6.43 |
| | *Acacia xanthophloea* | mrera | 6 | 4 | 2.86 |
| | *Acacia goetzei* | msigisigi | 4 | 2.67 | 2.86 |
| | *Acacia senegal* | mhuti | 5 | 3.33 | 2.14 |
| | *Albizia anthelmintica* | mrira | 19 | 12.67 | 2.14 |
| | *Dichrostachays cinerea* | kiholi | 1 | 0.67 | 0.71 |

| Family | Species | Vernacular | Sum | Dens(ha) | %Freq. |
|---|---|---|---|---|---|
| Moraceae | *Ficus sycomorus* | makoyo | 13 | 8 67 | 6.43 |
| | *Ficus sp.* | msaganola | 1 | 0 67 | 0 71 |
| Olacaceae | *Ximenia caffra* | mloma | 4 | 2 67 | 2 14 |
| Papilionaceae | *Abrus precatorius* | mnyete | 2 | 1 33 | 1.43 |
| | *Erythrina abysinnica* | mng'oring' | 1 | 0 67 | 0 71 |
| | *Ormocarpum sp* | ekurehe | 6 | 4 | 3 57 |
| Polygonaceae | *Rumex usambarsis* | nantororu | 1 | 0 67 | 0 71 |
| Rubiaceae | *Canthium setiflorum* | mgogora | 5 | 3 33 | 1 43 |
| | *Hymenodictyon parvifolia* | kirighogho | 5 | 3 33 | 2 14 |
| | *Vangeuria apiculata* | mgholoma | 84 | 56 | 16 43 |
| Rutaceae | *Teclea simplicifolia* | mwarari | 1 | 0.67 | 0 71 |
| | *Zanthoxylum chalybeum* | mulongo | 4 | 2 67 | 2.14 |
| Salvadoraceae | *Salvadora persica* | msago | 1 | 0 67 | 0 71 |
| Sapindaceae | *Haplocoelum folioosum* | egirigirya | 4 | 2 67 | 2 14 |
| Solanaceae | *Withania somnifera* | mjoni | 1 | 0 67 | 0 71 |
| Sterculiaceae | *Dombeya umbraculifera* | gwaretu | 20 | 13 33 | 2.14 |
| | *Sterculia quenqulobia* | mgurumetu | 14 | 9 33 | 8.57 |
| Tiliaceae | *Grewia bicolor* | ebusheni | 67 | 44 67 | 17.86 |
| | *Grewia similis* | mnyiri mseri | 18 | 12 | 7.14 |
| | *Grewia trichocarpa* | esere | 1 | 0 67 | 0.071 |
| Urticaceae | *Obetica pinnatifida* | Kighoghiang'ombe | 1 | 0 67 | 0 71 |
| Verbanaceae | *Clerodendrum rotundifolium* | kijuba | 18 | 12 | 0 71 |
| | *Clerodendrum ternatum* | mhurambura | 2 | 1.33 | 0.71 |
| | | TOTAL: | 1208 | | |

Figure 4.3 Species-area curve used to determine sample size.

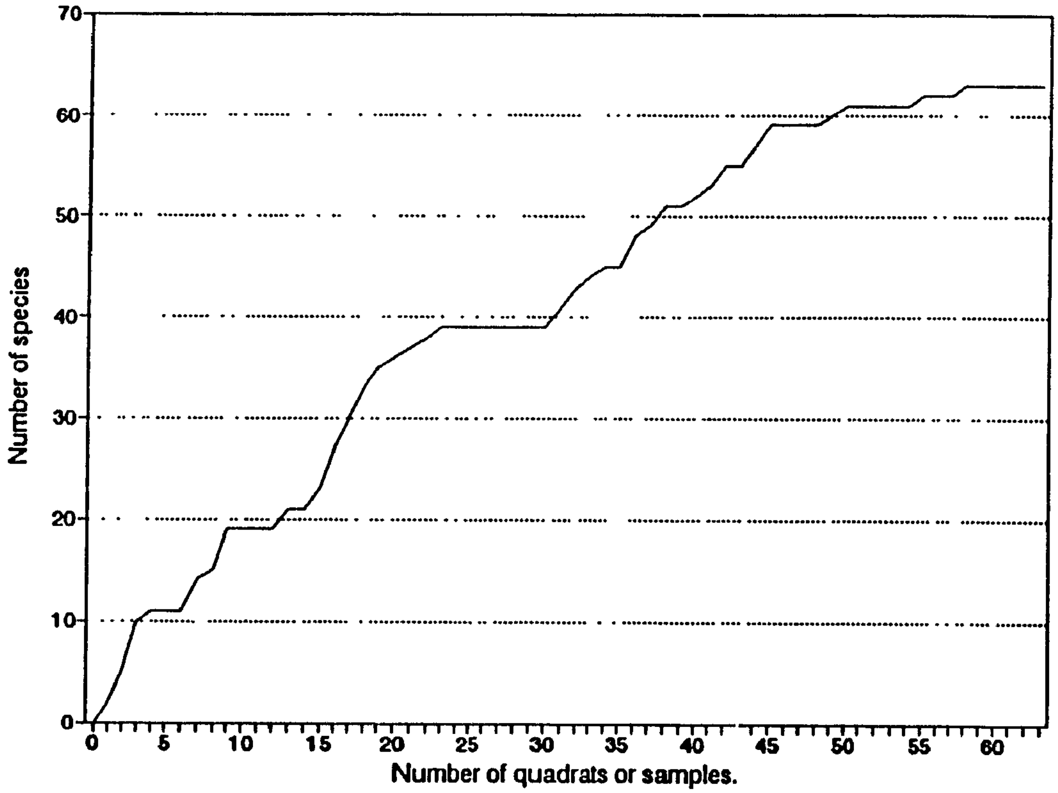
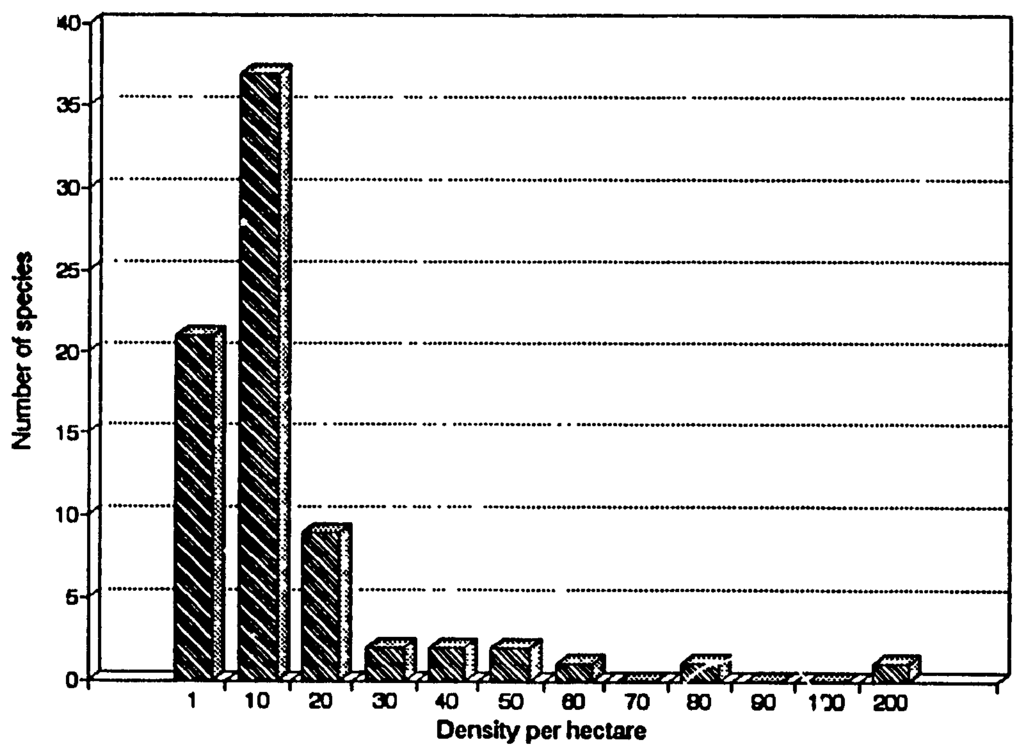



Figure 4.4 Distribution of species density levels.



habitate. Fifty-six species have less than 10 individuals per hectare.

In terms of species numbers, the most widely represented families are Mimosaceae (represented by 3 genera and 9 species) and Euphorbiaceae (with 4 genera and 7 species). All other families are represented by only one or twogenera. In terms of abundance, Euphorbiaceae accounts for 435 (36%) of the 1208 individuals counted and Mimosaceae accounts for 226 (18.7%). Eighty-nine individuals (7.4%) of the Rubicaceae family were counted and 86 individuals (7%) of the Tiliaceae family.

4.3.2.1 Classification

The hierarchical classification of samples and species obtained from TWINSPAN analysis shows the main species and sites clusters identified within the first four levels of division (Table 4.6). Three vegetation types were informally named at the third level of division. The first level of division separated out five species. The sites can be separated into an equal number of clusters. The first level of division separated out 19 samples. The second level divided the remaining samples into groups of 56 and 60. The separation between the various groupings are quite strong. The degree of division amongst groups is often indicated by a high eigenvalue and the values for the separation at levels 1 and 2 are 0.732 and 0.711 respectively.

4.3.2.2 Description of Vegetation types and habitat

From the structured TWINSPAN table (Table 4.6), three main vegetation

Table 4.6 The ordered TWINSPAN table of sites and species. Numbers are transformed density classes. The top margin gives quadrat (printed vertically) grouped into three main clusters. The bottom and right-hand margins show the hierarchical classification of quadrats and woody species respectively, for 4 levels division.

```
                                      SITES AND SITE GROUPS

                      Group III                               Group IIb                 Group IIa           Group I

          1        1               11    1    111   111111111   1111   1          11           1     111111 111 1   1      11     1 11
    28837061992667124615851213445601124313490342460011111111 790002 962  4557899902   387277906 92423333353332131721583333 22 15682822784578 5
    79463077239506496344670513801416763779688350429890124568 7001476124346896924526125285028658 72590346921287340188355719 0187551532392413097

An  ------------------------1--------11112222222211222331111 ---------------------------------- -------------------------- ----------1--------  000
Ec  ---------12232321113------------------------------------ ----------21--------2-1-1--------- -------------------------- -------------------  0010
At  1---11121-111121221122--22221222121111-221-121122322--23 -------1-112-----1--3-1--2--1---1- -1--11---------1-----1---- --------1----------  0011   Type 3
Aa  -------------------2---3---------3---------------------- ---------------------------------- -------------------------- -------------------  0011
Ba  221211111--211------------------------------1---1--2--11 -1----------------------12-------- -------------------------- -------------------  0011
Du  ----------------------------------------3--------------- -------------------------------2-- 4------------------------- -------------------  0011

Am  ----------------1------------------------------1--1-1--- ------------------11------32-----2 -------------------------- -------------------  0100
Ca  ----------------------11------------11---------1-------- ----------1----------------------- -1-22113------------1----- -------------------  0100
Ban ----------1-----------------------------1--------------- ---------------------------------- --------1-------1112-11--- -------------------  0100
Ls  -----------------------1-------------2------------------ --------------------------------1- -1--------1-1-1---1221---- -------------------  0100
Sq  ------------------------1---1--1------------------------ -----------1--2--11--------------- ------1----1112----------- -------------------  0100
Cp  -------------------------------------------------1------ 1---------------1--------2-------- -------1------11----2-2322 -------------------  0100   Type 2
Tr  -------------------------------------------------------- -----------------1--1-----1------- ---11------------------2-- -------------------  0100
Ab  ----1---------------------2----------------------------- ------------------1------1-11221-- -1------1--------------1-- -------------------  0101
Av  --------1----------------------------------------------- -----31----------3---1------4-4332 -------------------------- -------------------  0101
Gs  -------------------1------------------------------------ ------1--------2--------1---212-2- ----------------------11-- -------------------  0101
Cd  -----------------------------------------3-------------- -33343432-444332434444444231----2- ----------------1--143---- -------------------  0101

Et  -------------------------------------------------------- 1233242--2--1-1-32---3-----3--213- 2-----------------1------- -------------------  0101
Sh  -------------------------------------------------------- 3--33---------------------------1- -------------------------- -------------------  0101
Gb  ------1---------------------------2-3--11--------------- ------2-------------------22------ 421-232221212--1---1------ 22---1-------------  011

Ao  --------3------------5---------------------------------- ---------------------------------- -------------------------- 3--------11--------  10
Fs  -------------------------------------------------------- ---------------------------------- -------------------1------ -------1---1211121-  11
Rc  -------------------------------------------------------- ---------------------------------- -------------------------- -----------------32  11
Te  -------------------------------------------------------- ---------------------------------- -------------------------- ---------2-12-111--  11     Type 1
Va  ------------------122----------------------------------- ------2222------------------------ -1-----------------1------ 2213233333222----2-  11

    00000000000000000000000000000000000000000000000000000000 0000000000000000000000000000000000 00000000000000000000000000 1111111111111111111
    00000000000000000000000000000000000000000000000000000000 1111111111111111111111111111111111 11111111111111111111111111 0000000000000000011
    00000000000000000000011111111111111111111111111111111111 0000000000000000000000000000000000 11111111111111111111111111 0000000000011111111
    00000000011111111111110011111111111111111111111111111111 0000000000000000000000000001111111 00000000000000001111111111 0011111111100111111
```

**Species:**

An = *Acacia nilotica*
Ec = *Euphorbia candelabrum*
At = *Acacia tortilis*
Aa = *Albizia anthelmitica*
Ba = *Balanites aegyptica*
Du = *Dombeya umbraculifolia*
Am = *Acacia mellifera*
Ca = *Commiphora africana*
Ban= *Boscia angustifolia*
Ls = *Lannae stuhlmannii*
Sq = *Stercuria quenqulobia*
Cp = *Commiphora pelleifolia*
Tr = *Turrea robusta*
Ab = *Acacia brevispica*
Av = *Acalphya volkensii*
Gs = *Grewia similis*
Cd = *Croton dictygamous*
Et = *Euphorbia tirucalli*
Sh = *Strychnos henningsii*
Gb = *Grewia bicolor*
Ao = *Acokanthera oppositifolia*
Fs = *Ficus sycomorus*
Rc = *Ricinus communis*
Te = *Trichilia emetica*
Va = *Vangueria apiculata*

types (1-3) can be identified, with type 2 having two subgroups. The three main vegetation types are described and related to their habitats or locations as depicted by the quadrat clusters (I-III).

(1) *Vangueria apiculata-Ficus sycomorus-Trichilia emetica* type. Other species present include *Ricinus communis* and *Acokanthera oppositifolia.* The three dominant species all require relatively high soil moisture. *Vangueria apiculata* is usually 1-3 metres in height and often occurs in dense clumps. Ficus trees tend to be tall (8-25 metres) and frequently have diameters at breast height of 300-600 cm. This type of vegetation is found in riverine habitats in the area (Group I) (Figure 4.5). All but one of the nineteen sites included in this cluster group are located along the main river or one of the smaller streams and this sample (Q83) is located close to the main river.

(2) *Croton dictygamous-Euphorbia tirucalli-Grewia bicolor* type (Figure 4.6). These sites generally contain trees and/or shrubs and have higher species richness than found in Vegetation Type 3. This bush or sometimes thicket vegetation is usually found in higher elevation sites (Group II) and the samples of this type tend to have a higher species density.

There are two subgroups of species that tend to occur together. One group (2a) consists of *Euphorbia tirucalli* occurring as emergent trees with a dense understorey of *Croton dictygamous.* Other undergrowth species include *Grewia similis, Acalypha volkensii, Acacia brevispica* and sometimes *Strychnos henningsii* or *Grewia bicolor.* Tree species found include *Sterculia quenqulobia,* with *Acacia tortilis* and *Euphorbia candelabrum* occurring in some of the lower elevation samples.

Figure 4.5 Riverine vegetation in the Batemi area. This photograph depicts the main type of vegetation found along the rivers and streams.

Figure 4.6 Type 2 vegetation, which is found mostly in hill areas. This particular photograph is of dense *Euphorbia tirucalli-Croton dictygamous* vegetation found along the base of the escarpment on the north side of the valley.

This grouping of vegetation is found mainly in the Kirijau hills and along the lower slopes of the escarpments along the north of the valley. The shrubs and bush are rarely more than 1-3 metres tall with trees generally 8 to 10 metres in height.

The second subgroup (2b) consists more of *Grewia bicolor-Commiphora africana-Lannea stuhlmannii.* *Grewia bicolor* in conjunction with *Commiphora africana* or *Sterculia quenqulobia* dominate the vegetation of the Kitoyo hills, in the southeast corner of the study area. This vegetation is not generally as dense as that of type 2a.

(3) *Acacia tortilis-Balanites aegyptica-Euphorbia candelabrum* vegetation type (Figure 4.7). The dominant species is *Acacia tortilis*, which grows to 8-12 meters on average.

Figure 4.7 *Acacia tortilis-Balanites aegyptica-Euphorbia candelabrum* type vegetation, with an undergrowth of an *Aloe* sp. (lugaka).

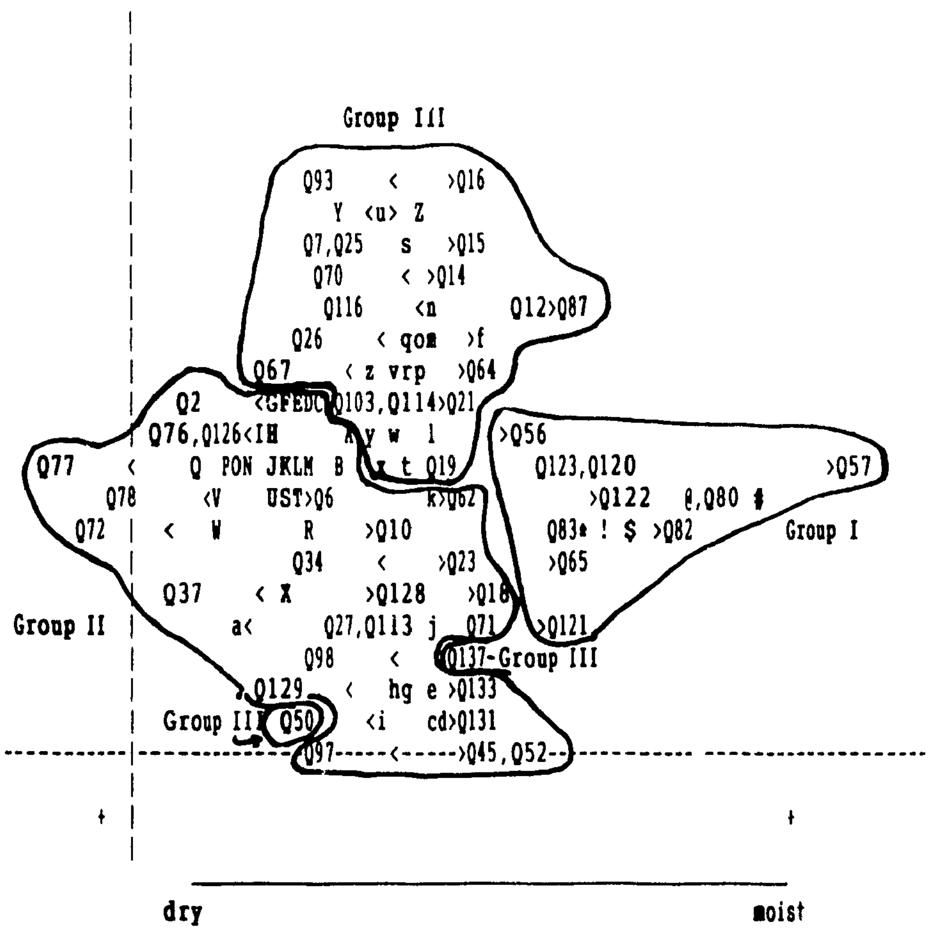
Other species that occur occasionally are *Albizia anthelmintica, Commiphora africana, Acacia mellifera* and *Sterculia quenqulobia.* The underlayer is quite sparse in most places, although clumps of dense vegetation do occur sporadically. This type is scattered throughout the study area, generally on the valley floor or in transition zones from plain to hill areas.

There is a cluster of samples that contain *Acacia nilotica* as opposed to *Euphorbia candelabrum* or *Balanites aegyptica.* This was not separated out as a distinct type because the samples for the two possible subgroupings are geographically interspersed.

4.3.2.3 Ordination

The distribution of quadrats are depicted along the first and second axes of ordination (Figure 4.8). The groups defined from the TWINSPAN analysis are indicated. Most of the samples are located to the left of the diagram, with nineteen sites occurring to the right-side. Those quadrats belonging to samples group II are found more towards the right-side of the diagram and group III quadrats are located in the upper, central position of the diagram. Group I or the river sites are located to the right-side of the diagram. There are a few outliers or samples whose location in the ordination space do not correspond with the TWINSPAN clusters. Quadrats 33, 50 and 137 (Type 3) fall within the lower left-hand side of the ordination diagram. The first axis in these ordinations is probably associated with a soil moisture gradient. Those sites on the left represent areas of drier soil moisture while those on the right are moister (river sites). Also, the quadrats occurring to the left of the diagram are generally areas of higher elevation, which affects soil moisture content.

Figure 4.8 Detrended correspondence analysis (DCA) ordination illustating species space. The TWINSPAN clusters of quadrats are depicted. An environmental interpretation of the first DCA axis is offered.




Legend:

Group I
* - Q8, Q17, Q55, Q81
$ - Q79; ! - Q125; @ - Q51, Q73; # - Q9, Q44

Group II 33=III
a= 96,31,33; c= 135; d= 139; e= 138; g= 130; h = 132; i = 136; j = 22 ; k=124;
A = 91; B = 85; C = 102; D = 4; E = 3; F = 1; G = 5
H = 46, 58, 95; I = 90; J = 94; K = 92; L = 20; M = 32;
N = 100; O = 127; P = 105; Q = 101 104; R = 88;
S = 68 ; T = 53; U = 59; V = 89; W = 75; X = 35

Group III
f =13,40,54,61,117; l = 48, 107; m = 99, 118; n = 43; o = 24, 42, 69, 109
p = 140 q = 112; r = 36, 235, 110, 115; s = 66 ; t= 47
u = 60; v = 111; w = 106, 108; x = 41; y = 38 ; z = 33
Y = 29, 84, 86; Z = 74, 119

Species distributions are indicated in Figure 4.9. The classification of species obtained by the TWINSPAN analysis are obvious here. The species classed as vegetation type 1 are located together to the right side of the diagram. Those species diagnostic of the plain samples are found towards the upper part of the second axis. *Dombeya umbraculifera*, which is included as part of the first TWINSPAN species cluster is shown to be an outlier in the ordination diagram. It only occurs once in a plain quadrat but twice in a hill quadrat.

### 4.3.3 Irrigation Channels

The riverine vegetation in the Batemi area tends to be quite different in species composition and density, as discussed above. A total of 22 species were found along the four irrigation channels inventoried (Table 4.7). Of these 22 species, the most abundant tree species are *Cordia africana*, *Ficus sycomorus*, *Trichilia emetica*, *Ficus sur*, *Capparis* sp. (mrera) and *Vernonia amygdalina*, with 47, 47, 27, 17, 14 and 14 individuals respectively. *Cordia africana* and *Ficus sycomorus* each account for about 25 percent of the trees found in the irrigation channels.

The most represented family in the irrigation channels is Euphorbiaceae, with three genera and four species. Capparaceae is represented by two genera and three species and Moraceae by one genus and three species. In terms of number of individual trees, Moraceae has the highest abundance with 73 trees. Boraginaceae, as represented by *Cordia africana*, is second with 47 and there are 27 individuals of the Meliaceae Family.

Most of the tree species are 15-25 meters in height and many of them have diameter measurements of 300-600 cm at breast height. Most of the trees are quite

Figure 4.9 Detrended correspondence analysis (DCA) ordination displaying samples space. The vegetation types identified in TWINSPAN analysis are indicated. Vegetation types identified in TWINSPAN are indicated. The riverine vegetation species are located to the right of the diagram. For full species names see Table 4.6.

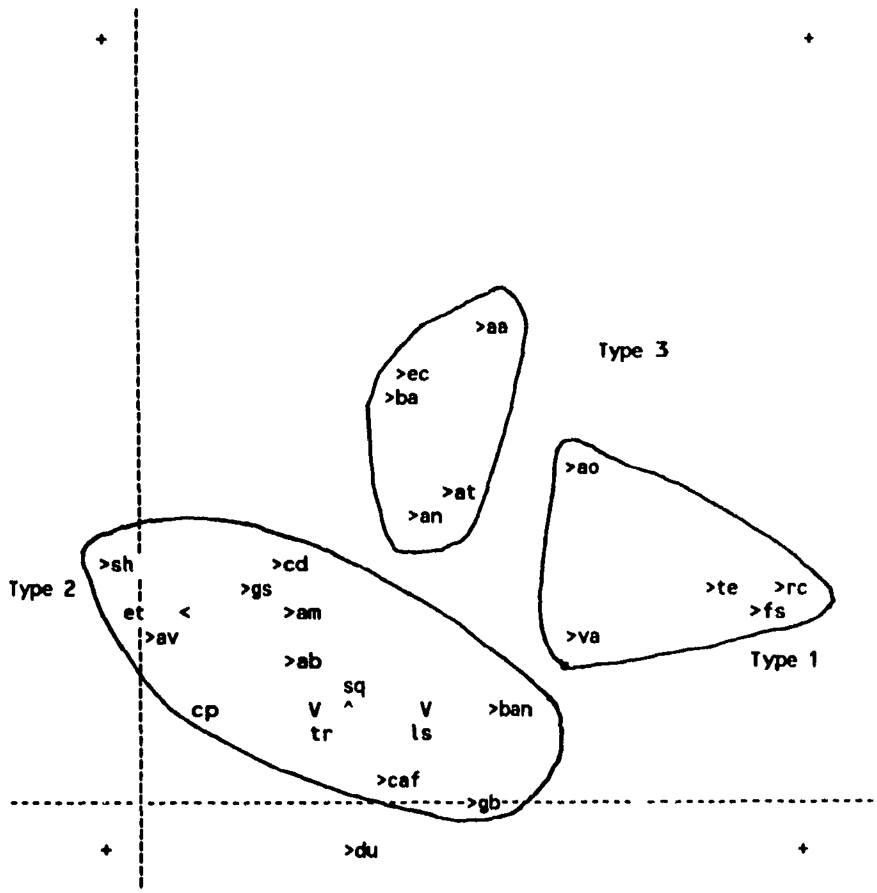


Table 4.7 Inventory of Irrigation Channels.

| Genus and Sp. | Vernacular | DigoDig 1 | 2 | Mugh. 1 | 2 | Tot | Rel. Den. |
|---|---|---|---|---|---|---|---|
| Anacardiaceae | | | | | | | |
| *Lannea* sp. | mtoregani | 1 | | | | 1 | .50 |
| Asteraceae | | | | | | | |
| *Vernonia amygdalina* | mtembereghu | 2 | 1 | 8 | 3 | 14 | 7.04 |
| Boraginaceae | | | | | | | |
| *Cordia africana* | mringaringa | 16 | 15 | 12 | 4 | 47 | 23.62 |
| Capparaceae | | | | | | | |
| *Capparis* sp. | mrera | 14 | | 1 | | 15 | 7.54 |
| *Capparis tomentosa* | mhoroboboi | 1 | | | 1 | 2 | 1.01 |
| Euphorbiaceae | | | | | | | |
| *Bridelia micrantha* | bara | 4 | | 1 | | 5 | 2.51 |
| *Ricinus communis* | mbono | | | 2 | 2 | 4 | 2.01 |
| Guttiferae | | | | | | | |
| *Garcinia livingstonei* | mbigo | 4 | | | | 4 | 2.01 |
| Meliaceae | | | | | | | |
| *Trichilia emetica* | mdaghamira | 19 | 3 | 1 | 4 | 27 | 13.57 |
| Moraceae | | | | | | | |
| *Ficus natalensis* | mgumu | 7 | | | 2 | 9 | 4.52 |
| *Ficus sur* | mtoyo | 1 | 3 | 13 | | 17 | 8.54 |
| *Ficus sycomorus* | mkoyo | 19 | 16 | 8 | 4 | 47 | 23.62 |
| Rubiaceae | | | | | | | |
| *Vangueria apiculata* | mgholoma | 4 | | 2 | 1 | 7 | 3.52 |
| | | 92 | 38 | 46 | 21 | 199 | |
| Capparaceae | | | | | | | |
| *Maerua calophylla* | msoloko | P | | | | | |
| Caesalpiniaceae | | | | | | | |
| *Senna didymobotrya* | senetoi | | | P | | | |
| Euphorbaceae | | | | | | | |
| *Acalypha fruticosa* | msanoni | P | | | | | |
| *Acalypha paniculata* | mnywamayi | P | | | | | |
| Fabaceae | | | | | | | |
| *Cassia bicapularis* | mbenyenye | P | | | | | |
| Malvaceae | | | | | | | |
| *Hibiscus calyphyllus* | kiraraha | P | P | | P | | |
| Rutaceae | | | | | | | |
| *Clausenia anisata* | mnyoka | P | | | | | |
| Sapinadaceae | | | | | | | |
| *Allophyllus abussinicus* | | P | | | | | |
| Verbanaceae | | | | | | | |
| *Clerodendrum rotundifolium* | kijuba | P | | | | | |

old. There are also a number of shrubs found along the channels; two of the major ones being *Clerodendrum rotundifolium* and *Hibiscus calyphyllus.* Typical irrigation channel vegetation is illustrated in Figure 4.10.

Thirteen species found along the irrigation channels were encountered nowhere else in the valley (Table 4.8). Many of these are species that are typically found in moister environments. The species richness along the irrigation channels is high relative to the richness of the surrounding plain vegetation.

Figure 4.10 Typical irrigation channel vegetation. This photograph illustrates a section of one of the irrigation channels in DigoDigo.

Table 4.8 Species found only along Irrigation Channels.

| Species | Vernacular |
|---|---|
| *Acalypha fruticosa* | msanoni |
| *Acalypha paniculata* | mnywamayi |
| *Allophyllus abyssinicus* | |
| *Bridelia micrantha* | bara |
| *Capparis tomentosa* | mhoroboboi |
| *Cassia bicapularsis* | mbenyenye |
| *Clausenia anisata* | mnyoka |
| *Ficus natalensis* | mgumu |
| *Ficus sur* | matoyo |
| *Hibiscus calyphyllus* | kiraraha |
| *Maerua calophylla* | msoloko |
| *Trichilia roka* | mtembereghu |
| *Vernonia amygdalina* | |

4.3.3 Other species

There were also fifteen species that did not fall within either random sample sites or the irrigation channels (Table 4.9). Some of the species, such as *Jatropha curcus* were found within village areas. Others, such as *Warburgia salutaris* were seen during the ethnobotanical surveys and did not fall within the confines of the defined study area (Figure 4.1). Many of the species (for example, *Pappea capensis*, *Rhus quantiniana*) are found within the plains but are not common and thus were not encountered in a quadrat.

4.3.5 Landcover Map

The resultant thematic map depicts four landcover classes (Figure 4.11). These classes are: 1) bushland and woodland thicket, 2) woodland 3) wooded grassland, and 4) grassland with scattered trees, which includes agricultural areas and

Table 4.9 Species encountered but not counted in any of the methods.

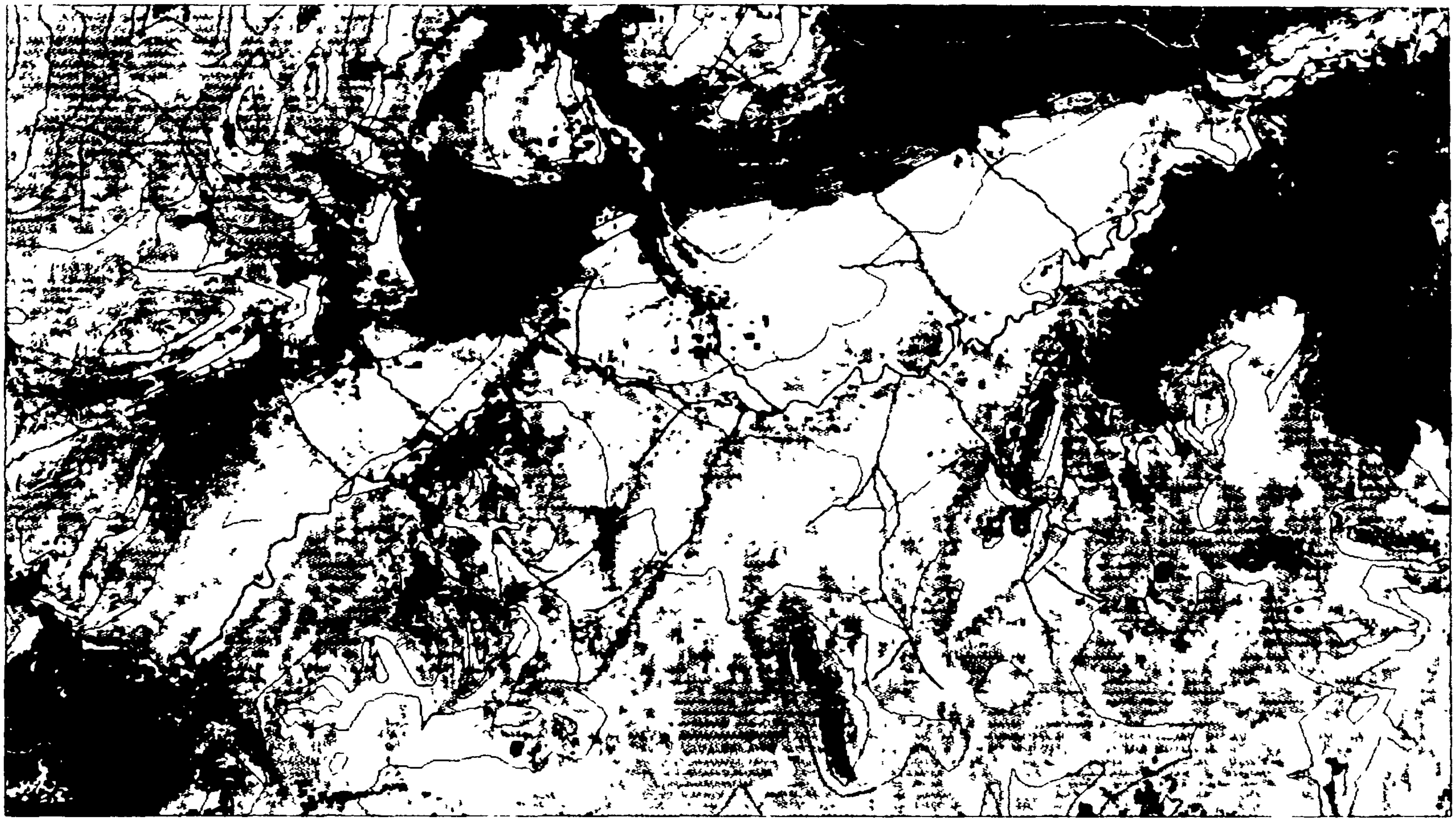
| Family | Species | Vernacular |
|---|---|---|
| Anacardaceae | *Lannea schimperi* | mginkinywa |
| | *Rhus natalensis* | mbwensha/msigiyo |
| | *Rhus quantiniana* | msymbeuhembe |
| Burseraceae | *Commiphora markei* | kidingho ka mgongo |
| Canellaceae | *Warburgia salutaris* | msega |
| Combretaceae | *Combretum* sp. | msaghu |
| Euphorbiaceae | *Croton megalocarpus* | ekitilambu |
| | *Jatropha curcus* | mgulungulu |
| Liliaceae | *Aloe* sp. | elongo |
| Mimosaceae | *Acacia* sp. | mzironi |
| | *Acacia nubica* | oldebe |
| Moraceae | *Ficus populifolia* | mgagatya |
| Papilionaceae | *Ormocarpum kirkii* | mlemenjagu |
| Sapindaceae | *Pappea capensis* | kiboboyo |
| Tiliaceae | *Grewia* sp. | msabasabwa |

villages. The classes are described below.

The bushland and woodland thicket class consists of vegetation cover of either woodland or bushland type but with the woody plants in such close density that this type is often impenetrable. When vegetation forms locally impenetrable patches it is termed thicket (White 1983; Lind and Morrison 1974). Bushland can be defined as areas with more than 40 percent bush cover. Bushes are woody plants intermediate between a shrub and a tree, that is, usually between three and seven meters tall (White 1983). The appearance of the bushland and thicket varies, as does the actual plant shape, according to the rainfall it receives (Lind and Morrison 1974).

The woodland contains trees of up to 18 m in height, with an open or continuous but not thickly interlaced canopy (Pratt *et al.* 1966). Woodland is similar to bushland but with a taller and more closed canopy (White 1983).

Figure 4.11 Landcover map for the Batemi area.



Scale 1:75,000 0 — 5 KM Wynet Smith 1993

Legend:

- Bushland and woodland thicket
- Woodland
- Wooded grassland
- Grassland and scattered trees
- Elevation
- Rivers
- Villages

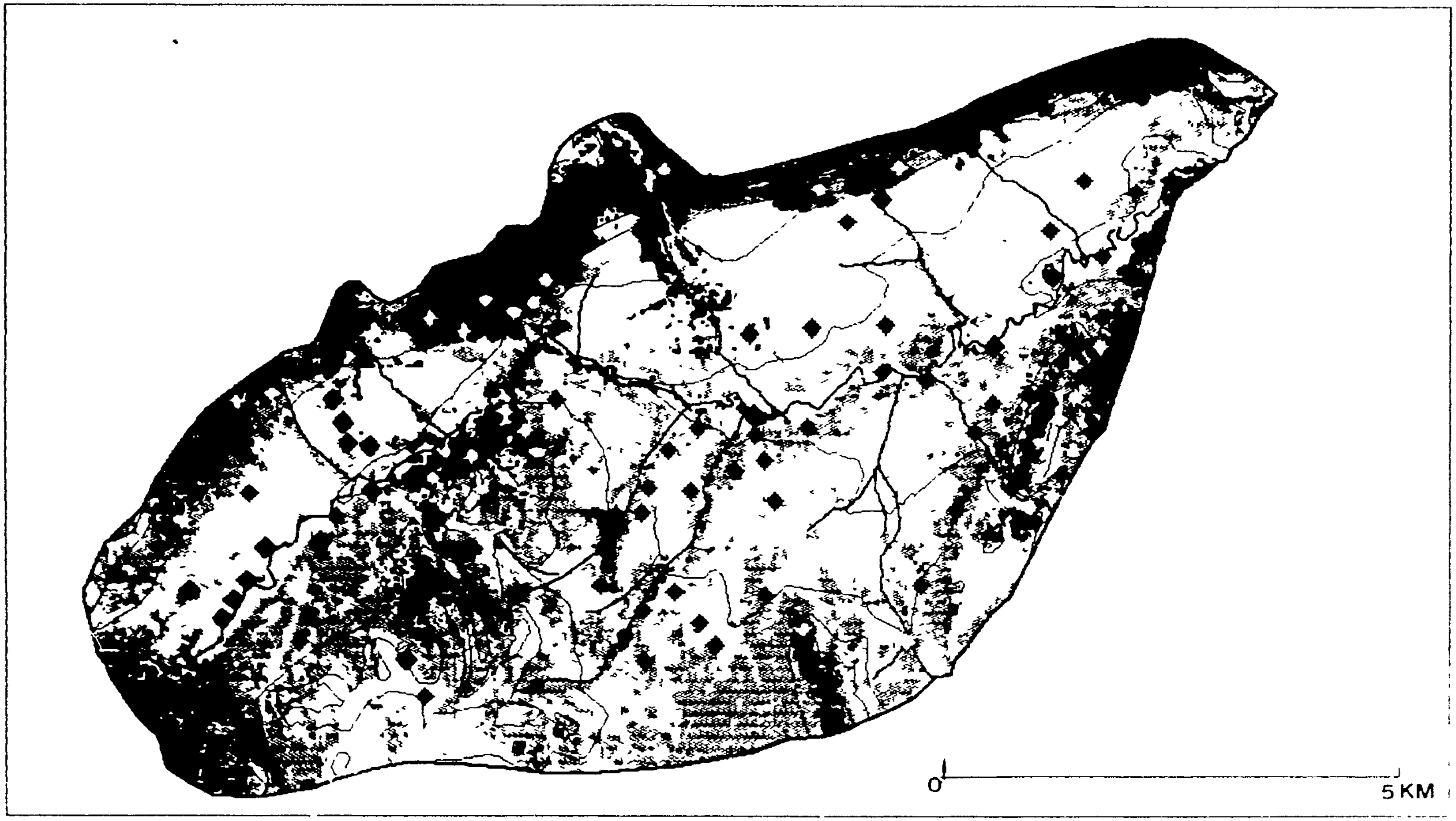
Wooded grassland is defined as areas with 10-40% canopy cover (White 1983), or less than 20% according to Pratt *et al.* (1966). These figures are somewhat arbitrary, however, as this type grades into grassland and woodland (White 1983).

Grassland is usually defined as consisting of less than 10 percent woody cover (White) or 2%(Pratt *et al.* 1966). This class also contain village and agricultural areas.

Figure 4.12 depicts the study area, with the random sample sites (grouped into three vegetation types) overlayed on the supervised classification. This overlay reveals that there is fairly good correlation between vegetation site types and the landcover density classes. Most of the *Acacia tortilis* vegetation type falls within the wooded grassland or grassland classes while most of the *Euphorbia tirucalli-Croton dictygamous* sites are shown to fall within the thicket or woodland areas. Type 1 vegetation is found near river sites as already discussed.

The locations of the villages are also depicted in Figure 4.11. This illustrates that all of the villages do not have the same access to the various vegetation types. The sub-villages of Eyasi, Mgero and Mgundu do not have easy access to bushland and woodland thicket, which is the source of much of the firewood used by villagers. All of the villages have reasonable access to woodland and wooded grassland cover, where there is still a reasonable abundance of species for fuelwood and timber.

Figure 4.12 Masked Landcover map showing the distribution of the random quadrats in terms of the three vegetation types.




Scale 1:75,000

Wynet Smith 1993

Legend:

- ◆ - Type 1
- - Type 2
- ◆ - Type 3
- Bushland and woodland thicket
- Woodland
- Wooded Grassland
- Grassland and scattered trees
- Elevation
- Irrigation Channels
- Rivers and streams

## 4.4 Conclusions

The Batemi area consists of three main vegetation types that are associated with three different types of habitat. The distribution of the various vegetation types and individual species is essential for identifying and monitoring species vulnerability. These data provide a baseline inventory that can be used with the species use data to identify species that may require attention in conservation or resource planning. The landcover map may assist in this process. The next chapter examines the process of assigning use values and assesses the abundance of key socioeconomic or valued species.

# Chapter 5. Identifying Conservation Priorities

## 5.1 Introduction

In marginal or semi-arid areas, such as the Batemi valley, where vital resources are under increasing demand, sustainable use and conservation of resources will require identification and study of valued ecosystem components or key socioeconomic species. From the Batemi perspective, this approach will assist in protecting the integrity of the resource base for their continued use. This is one of the goals of KIPOC in designing a sustainable resource plan. On a macro-level, the regional and national governments require such information to ensure equity in land-use and resource management planning and to understand use pressures on the environment. The international conservation movement recognizes the need for people-oriented conservation information because of failures of past efforts.

In order to identify conservation priorities, it is first necessary to assess locally important resources. If no attempt is made to somehow index relative values, the default is that all uses and all species are treated as equal. Treating all species as equal will not address local pressures on the environment and local vulnerabilities to environmental change, nor will it help to identify more endangered species. Value indices can be used in relation to availability or abundance information to identify possible conservation priorities. If all species were of equal use value, it would be expected that common species will be used more while rare ones are used less. Deviations from this pattern may reveal significant situations where species that are highly valued and intensively used are ecologically rare and perhaps vulnerable, or where species that are abundant are ignored or underused, perhaps reflecting untapped resources.

This chapter records qualitative local information on species value and conservation priorities but it also attempts to use field data to generate qualitative indices that could be useful in conservation work. It is exploratory and is intended to show how factors could be used rather than to show definitively what priorities should be. Nonetheless, the exploration is discussed in light of field knowledge of the conservation situation and some recommendations are made.

### 5.2 Salient Issues

While some conservation priorities are established by the international scientific community, locally important species and ecosystem components can be identified only through a local perspective. Various studies have shown that local knowledge and traditional management practices are important sources of information for conservation programs (see Alcorn and Oldfield 1991a; Boom 1987; Johannes and Halter 1986). Most studies of plant use, however, merely record use without attempting to assign value. Frequently, species of value are named but there is little information on methods of determining the value and there is no quantitative basis for comparative assessment. This offers little on which to establish priorities.

Little work has been done on assigning non-economic values to components of the biophysical environment.[6] Where markets exist for commodities, it is often

[6] Valuation of natural resources is a field receiving much attention (see Brown 1990; McNeeley 1988). Most theories attempt to assign economic values to uses. This is not the interest or intent of the type of use-value being discussed here. Rather, the goal is a non-economic index of the relative importance of various species in an attempt to identify species that may require more attention because of greater demand.

assumed that the market works to establish values for those commodities[7]. Supply should balance with demand through competitive bidding for scarce commodities that drive prices up and thereby encourage producers to produce more and protect sources of supply. But assuming this mechanism will protect ecological resources that do not have significant market value can lead (and has led) to ecological catastrophe. Some other strategy has to be developed to recognize the real value that ecological resources may have in non-market economies.

Factors influencing utility value of a commodity or service are 1) the importance of the need that is being met and 2) the range of options for meeting that need. The value would be directly proportional to the importance of the need being met and inversely proportional to the range of alternatives for meeting that need. Thus, if value is V, I is importance of the need and S the number of substitutes, then V is a function of I/S. The vulnerability of a renewable resource is related to the rate of production or availability (A) relative to the rate of consumption (C). Thus, vulnerability or endangerment (E) is a function of C/A. Establishing conservation priorities based on local cultural needs would involve relating the value (V) to the degree of endangerment (E). Important species with high vulnerability would be priorities; low value species with low vulnerability would not be. Thus conservation priority (P) is a function of E x V or C/A x I/S.

Is this conceptualization useful? It may be in an abstract way for formalizing ideas about conservation priorities, but it may also help to highlight practical concerns or note significant change where sufficient data exist. Quantifying these parameters,

---

[7] Note that this does not deal with the "deep-ecology" issue of inherent or intrinsic value of species independent of their utility value. It attempts only to address the step beyond market valuation, where commodities do have utility value but, for various reasons, do not have appropriate market values.

however, is difficult, perhaps impossible, in practice partly because importance is a subjective assessment that will vary culturally and, probably, between individuals. Availability and number of substitutes will change with economic, technological and environmental circumstances. Nonetheless, the difficulty of determining precise values should not preclude attempts to examine the issues.

Practical examples of evaluations, such as those that assign values to key socioeconomic species, are in an early stage of development. One possibility is to assume a relationship between number of times a species is cited and its importance for that use. Johns *et al.* (1990), although not attempting to assign a use value, do limit their reporting of indigenous plant use to species that are cited a minimum number of times.

Another possibility is to assign use values. Prance *et al.* (1987) outline a method which assigns a major use value of 1.0 or a minor use-value of 0.5 to each use of a species. The criteria for assigning a major or minor use-value is based on respondent information and authors' observations but the exact method of doing this is not well-explained. This is a coarse scale of evaluation. The method of totalling all use values highlights those species that are multi-purpose but undervalues those which may be highly-valued for one specific use. The authors, however, do recognize the importance of species that can not be substituted and the need to pursue identification and conservation of these species. Despite obvious flaws, Pinendo-Vasquez *et al.* (1989) have used this system in an attempt to quantify, on a comparative level, resource use patterns.

Another method involves the assigning of a hierarchy of usefulness by the villagers or respondents themselves (Joint Forest Management 1992a, 1992b). In this technique, the interviewers have respondents indicate the value of a species for a given use. Differing numbers of seeds or other small objects are used to demonstrate the relative importance of species. Although more time-consuming than the appr... ...ring value based on responses, this system offers good potential as the ... ...ctly indicated by the local respondents.

The met... explored in this study are number of citations, a scaling of use values, as well as a factor for intensity of use. The intention is to see how the inclusion of each of ... factors influences the analysis.

## 5.3 Met...

### 5.3.1 ... practices

Data ... local ... ...edge and conservation practices were collected during informal interviews with the village groups (discussed in Chapter 3) and with village leaders in August 1992. The information from these interviews is qualitative in nature and is discussed as such. Particular types of data collected include local conservation practices, knowledge about woody vegetation distribution and local views on declining species.

### 5.3.2 Assigning Quantitative Values

The use data from Chapter 3 provides the basic information upon which to explore methods for assigning value. Food and medicine are not included in these calculations as the method of collecting data was different.

i) Citations

A count was made of the number of times a given species was mentioned for a given use in one of the group interviews. The first analysis was simply to record the number of classes of use for which a species was cited regardless of the number of citations. The second analysis weights the results according to the number of citations for each use.

ii) Use values

The second approach was to assign an importance value to the need that a species is fulfilling as done by Prance *et al.* (1987). To overcome some of the limits of this method, the approach taken here is to consider how important an use is and how many alternatives there are for achieving or meeting the same need. This can be done by giving each species a weighting proportional to its use in meeting that need.

Rather than using two values as Prance *et al.* (1987) did, a need value was assigned to each use category or sub-use category, ranging from 0 to 100 percent (Table 5.1) rather than treating all uses as equally important. For example, in construction, 60 was assigned to house poles, 20 to fences, five to furniture and two to hyaena traps. Species are not all considered to be equally important for a given use and so are assigned a weighting proportional to the number of citations for that use. The number of citations per species per use was taken to be proportional to the importance of that species that use. If there are six species cited as contributing to a specific need and one accounts for 75% of the citations for that use, it is assumed that it is of greater importance than one that accounts for 10%. For each species, the use importance value, such as 60 for poles, is multiplied by its citation proportion number. This effectively addresses the I/S component in the model proposed above. The resulting number is termed the <u>use-species value</u> for that given use. This procedure is carried out for each sub-category and then aggregated to obtain an overall category use-value for each species. This procedure is then applied to each general category of use to obtain a final overall use value for each species.

One potential problem with this approach is that it only includes woody species. High values may be assigned to woody species based on low substitutability while there may be herbaceous or succulent species that are employed for the use. This is certainly the case for rope.

5.3.3 Method for Investigating Endangerment and Conservation Priorities

In order to explore the endangerment or vulnerability of species, it is necessary to examine consumption levels relative to production or abundance. As no quantitative information on amounts of consumption was collected during the field work, consumption values are estimated on an ordinal scale between one and four, with one indicating low use and four a high volume use. For example, within construction uses, poles require higher amounts of wood and thus are assigned a three, while furniture or rope is given a one. On the general level of use, firewood accounts for the highest volume of woody vegetation use and thus receives a four, while implement use will be quite low and thus receive a one (Table 5.1). These consumption values (C) are then multiplied by the use values (V) already calculated for the construction categories and for the aggregate use value. This is done as conservation priorities are likely to include those species that are highly valued and are consumed at a high rate relative to their abundance.

The conservation status of various species is investigated by plotting each of the different types of "values" (citation, V, V*C) for construction use, as well as for the overall V*C values, against the abundance data presented in Chapter 4. Medicinal citation data (from Johns *et al.* n.d.b) are plotted against density as well.

Table 5.1 Numbers used to calculate values for the various types of use. Construction and implement uses subdivided into their respective categories.

| Use | # citations | Importance | Consumption |
|---|---|---|---|
| Construction | | | |
| Poles | 53 | 60 | 3 |
| Bee | 39 | 10 | 1 |
| Gate | 3 | 2 | 1 |
| Trap | 5 | 2 | 1 |
| Door | 5 | 5 | 1 |
| Rope | 3 | 5 | 1 |
| Furniture | 2 | 5 | 1 |
| Fences | 10 | 20 | 3 |
| Implements | | | |
| w. stick | 13 | 5 | 1 |
| rungata | 1 | 1 | 1 |
| d. stick | 4 | 1 | 1 |
| handle | 2 | 2 | 1 |
| Bow & A | 7 | 2 | 1 |
| Tooth | 5 | 1 | 1 |
| Other | 2 | 1 | 1 |
| Firewood | 32 | 75 | 4 |
| Services | 7 | 15 | 1 |

## 5.4 Results and Discussion

### 5.4.1 Traditional conservation practices

The Batemi practice certain forms of conservation; they are well aware of the importance of trees to their environment and have rules governing use of certain areas. The Batemi have distinct management strategies for woody vegetation. This applies mostly to the well-forested irrigation channels that are found within the areas around the four main villages and the subvillage of Eyasi. The irrigation channels are extremely important to the Batemi as explained in Chapter 2. In interviews with various villagers, the conservation of trees along the watercourses was consistently discussed. Villagers confirmed the traditional practice of leaving the trees along the watercourses as these were considered important for preserving water flow and thus ensuring continued irrigation. Cutting of trees along the streams or the main river is allowed but is prohibited along the irrigation channels. This strict control has been a traditional Batemi law for many generations and severe fines are levied against transgressors of the prohibition. Only the traditional Wenamije class, who have hereditary entitlement to the channels, have the right to cut trees or give permission for others to do so.

These sanctions demonstrate a de facto conservation program that may reflect recognition of priority species or the hydrological importance of protective vegetation along irrigation channels. If there are not sanctions against use elsewhere, it may reflect a tradition in which the intensity of the impact of human use was not significant relative to the availability of ecological resources.

As discussed in Chapter 3, the Batemi utilize a large range of woody species found in the fields and hills surrounding their villages. The 102 species used by the Batemi (Chapter 3) represent a large portion of the total number of species encountered in the area. Some of the species that were mentioned were not encountered during the survey work (Table 5.2). Of the 101 species actually inventoried during the biological survey, 84 (83%) were mentioned as fulfilling some function.

The Batemi possess an intimate knowledge of the habitats of various species and this can be helpful, especially in the cases of rare or less-widely distributed species. Most villagers were able to describe the general location or habitat type for the less common species or for species not found in their immediate area (Table 5.2). For instance, Batemi villagers at the west end of the valley were able to describe the

Table 5.2 Species indicated as used by the Batemi but which were not encountered during sampling. The locations are those given by villagers, or in a few cases observed first hand by Johns (1992).

| Species | Vernacular | Location |
|---|---|---|
| *Boscia coriacea* | jugumetu | Sale plain |
| *Carissa edulis* | lumeme | Bush (seen near Mditu) |
| *Clerodendrum myricoides* | mgutugutu | woodland in mtn. |
| *Commiphora madagacacensis* | msisiyo | Soutn of bwelo |
| *Dichrostachays cinerea* | kiholi | hillside |
| *Euphorbia cuneata* | mrumye | hillside |
| *Ficus glumosal* | mbugi | |
| *Harrisonia abysinnica* | toro | high elev.(Mditu) |
| *Myrsine africana* | ngashe | Loliondo |
| *Plumbago zelanica* | lughiri | |
| *Typha* sp. | kiroya | (Oldonyosambu) |
| | kijerwe | far in Bwelo |
| | lorieni | mountain areas |

location of a species such as *Salvadora persica* which is only found in the Kisangiro area. Other species (e.g. *Croton megalocarpus*, *Mimusops kummel* and *Ormocarpum kirkii*) were described as being "mountain" or "bush" species which were not easily accessible. Some areas in the valley are named after species that occur in dense numbers. For example, there is an area to the east of the Kirijau hills that is known as *makurehendane* after the vernacular ekurehe or makurehe (plural) tree (*Ormocarpum* sp.) that used to be found there.

In a few villages, locals discussed the problem of disappearing species. Mugholo and Samunge villagers named *Acacia mellifera* and *Cordia africana* as two species that were becoming less common. The first species, as already discussed, is a highly-valued, multi-purpose species while the second is highly-valued as a beehive material. In Oldonyosambu, *Cordia gharaf* and *Ozoroa mucranata* were the two main species regarded as being noticeably more difficult to find. Each of these species are multi-purpose, being used for at least two general purposes.

The Batemi display an in-depth knowledge of their environment. Any sound conservation strategy for the area must recognize their use of resources, and would benefit greatly by incorporating their knowledge and resource use practices.

5.4.2 Use-values

The range of values for the different methods (citation, V and V*C) for the construction category, and for the overall value with consumption (V*C) are given in Table 5.3. Figures 5.1 to 5.6 indicate the relationship between these values and abundance. These diagrams isolate species that may warrant special conservation attention

5.4.2.1 Citations

Figure 5.1 illustrates the number of use categories of each species against abundance. The figure shows that there are many multi-purpose species that do not appear to be all that abundant in the area. *Acacia mellifera*, although one of the most prized species only has a density of 10 individuals per hectare. Many of the multi-purpose species have low densities of under 20 individuals per hectare. Only *Croton dictygamous*, and then *Acacia tortilis*, *Acacia nilotica*, and *Grewia bicolor* have relatively high densities in relation to the number of citations.

Based on the second method of totalling all citations, the most valued or key local species for construction purposes is *Acacia mellifera*, which has ten citations. The other frequently mentioned species are: *Mimusops kummel*, *Cordia africana*, and *Ficus sycomorus*, all with seven citations. When examining these numbers in relation to abundance (Figure 5.2), there are obvious differences in the abundance of species

Table 5.3 List of values for various construction species based on the two methods of assigning value. The columns of values are: building citation number, builing (V), building (V*C), implement (V*C), fire (V*C), service (V*C) and an aggregate value (V*C).

| Abbr. | Genus and species | Vernacular | B.Cit. | B.Value | Build-V*C | Impl | Fire | Serv | Total |
|---|---|---|---|---|---|---|---|---|---|
| Abp | *Abrus precatorius* | mnyete | | | | 0 5 | | | 0 5 |
| Ab | *Acacia brevispica* | mhereki | | | | | 9 | | 9 |
| As | *Acacia senegal* | mhuti | 1 | 1 13 | 3 4 | | | | 3 4 |
| Ag | *Acacia goetzi* | msigisigi | 2 | 1.4 | 3 65 | | 9 | | 12.65 |
| Am | *Acacia mellifera* | mng'orora | 10 | 10.3 | 27.8 | 0 769 | 28 | | 56 569 |
| An | *Acacia nilotica* | kijemi | 6 | 5 7 | 14 3 | | 18 | | 32.3 |
| At | *Acacia tortilis* | mkamahe | 5 | 5.3 | 13.9 | | 37 | | 50.9 |
| Ax | *Acacia xanthophloea* | mrera | | | | | 18 | | 18 |
| Ac.v | *Acalypha volkensii* | munyuri | | | | 0 28 | | | 0 28 |
| Aa | *Albizia anthelmitica* | mrira | 1 | 0 3 | 0 26 | | | | 0 26 |
| A1 | *Aloe sp.* | elambola | | | | | 9 | | 9 |
| A2 | *Aloe sp.* | kihandi | | | | | 9 | | 9 |
| Ba | *Balanites aegyptica* | mjuiya | 1 | 2 | 6 | | 9 | | 15 |
| Ban | *Boscia angustifolia* | munyagu | 2 | 1.4 | 3.65 | | | 2 14 | 5.79 |
| Bm | *Bridelia micrantha* | bara | 3 | 1.6 | 3 9 | | | | 3.9 |
| C | *Capparis sp.* | mrera | 1 | 0 4 | 0.4 | | 9 | | 9.4 |
| Cl.a | *Clausenia anisata* | mnyoka | | | | 0.5 | | | 0 5 |
| Cl.r | *Clerodendrum rotundifolium* | kijuba | | | | 0.5 | | | 0.5 |
| Cp | *Combretum padoides* | mkong'ongi | 1 | 1.5 | 1 5 | | | | 1.5 |
| Cm | *Combretum molle* | mtewamgongo | 1 | 1.13 | 3 4 | | 9 | | 12.4 |
| Cm.a | *Commiphora africana* | kidingheta | 2 | 4 | 12 | | | | 12 |
| Ce | *Commiphora ellembekii* | mwaraheta | 6 | 2.41 | 4.68 | | | | 4 68 |
| Cm.p | *Commiphora pellifolia* | muluba | 6 | 4 2 | 10 4 | | | | 10.4 |
| Caf | *Cordia africana* | mringaringa | 7 | 2 7 | 4.93 | | | | 4.93 |
| Cd.s | *Cordia sp.* | mgombeha | 3 | 3 4 | 10.18 | | 9 | | 19.18 |
| Cd.m | *Cordia sp.* | mto | | | | 0.77 | 9 | | 9.77 |
| Cd.g | *Cordia gharaf* | muhabusu | 1 | 1.13 | 3.4 | | | | 3.4 |

| Abbr. | Genus and species | Vernacular | B Cit. | B.Value | Build-V*C | Impl. | Fire | Serv. | Total |
|---|---|---|---|---|---|---|---|---|---|
| Cd | *Croton dictygamous* | mgilalugi | 1 | 1.13 | 3 4 | 0.92 | 9 | | 13 32 |
| Cr.m | *Croton megalacarpus* | ekitalambu | 1 | 1.13 | 3.4 | | | | 3.4 |
| Dc | *Dichrostachays cinerea* | kiholi | 4 | 5.4 | 16.2 | | | | 16 2 |
| Du | *Dombeya umbraculifolia* | gwaretu | 2 | 2 3 | 6.79 | 0.57 | | | 7 36 |
| Er | *Euclea racemosa* | mraganetu | 3 | 0 77 | 0.77 | 0.29 | | | 1.06 |
| Ec | *Euphorbia candelabrum* | kiroha | | | | | 9 | | 9 |
| Et | *Euphorbia tirucalli* | kidigho | | | | | 18 | 2 14 | 20 14 |
| Fs | *Ficus sycomorus* | mkoyo | 7 | 2.4 | 2.37 | | 9 | | 11.37 |
| Gb | *Grewia bicolor* | ebusheni | 4 | 4.5 | 13 58 | 4.2 | | | 17.78 |
| Gt | *Grewia trichocarpa* | esere | | | | 0.77 | 9 | | 9 77 |
| Hf | *Haplocoelum folioosum* | egirigirya | 6 | 6 8 | 20 4 | | 18 | | 38.4 |
| Hc | *Hibiscus calyphyllus* | kiraraha | | | | 0.1 | | | 0.1 |
| Jc | *Jatropha curcus* | mlemanjagu | | | | 0 2 | | 4 28 | 4 48 |
| L | *Lannea sp.* | mtoregani | 2 | 0 51 | 0.51 | | | | 0 51 |
| M | *Maerua sp.* | kasingiso | | | | | | 4 28 | 4 28 |
| Mk | *Mimusops kummel* | ghanana | 7 | 5.3 | 14.35 | | | 2 14 | 16 49 |
| Om | *Ozoroa mucranata* | mgalati | 6 | 4 2 | 10 96 | | | | 10 96 |
| Pc | *Pappea capensis* | kiboyoyo | | | | | 9 | | 9 |
| Rc | *Ricinus communis* | mbono | | | | 0.67 | | | 0 67 |
| Sp | *Salvadora persica* | msago | | | | 1 | | | 1 |
| Sq | *Sterculia quenqulobia* | mugurumetu | 3 | 4.5 | 6 73 | | | | 6 73 |
| Sh | *Strychnos henningsii* | kibunja | 3 | 3.4 | 10 19 | 1 8 | 9 | | 20 99 |
| Ts | *Teclea simplifolia* | mwarari | 1 | 0 36 | 0 26 | | | | 0 26 |
| Te | *Trichilia emetica* | mdaghamira | | | | | 9 | | 9 |
| Uv | *Uvaria schlefferi* | msilimbu | 1 | 1 7 | 1 67 | | | | 1 67 |
| Va | *Vangueria apiculata* | mgholoma | 1 | 2 | 6 | | | | 6 |
| Vam | *Vernonia amygdalina* | mtembereghu | 1 | 1 5 | 1 5 | | | | 1 5 |
| Zc | *Zanthoxylum chalybeum* | mulongo | 3 | 3 4 | 9 65 | 0 2 | 9 | | 18 85 |
| es | | esughubetu | 1 | 0 36 | 0 26 | | | | 0 26 |
| kj | | kijerwe | 2 | 2 3 | 6 79 | | | | 6 79 |
| k | | kiteo | 2 | 0.51 | 0 51 | | | | 0.51 |

Figure 5.1 Multi-purpose values plotted against availability.

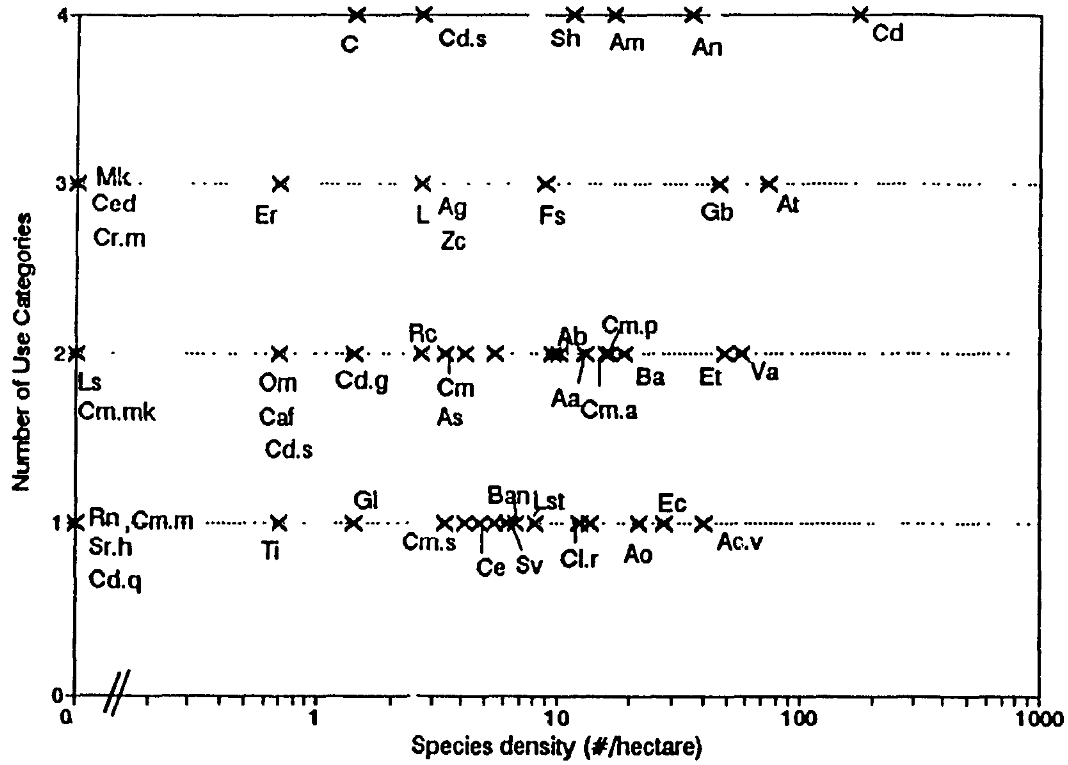
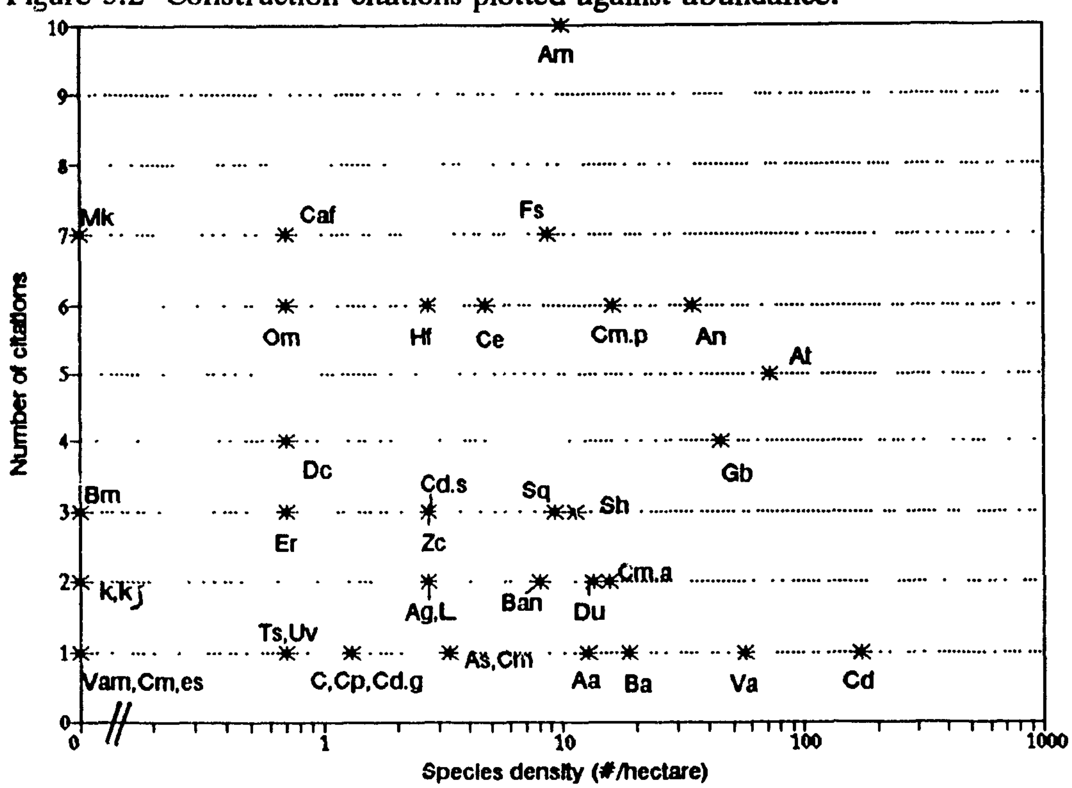



Figure 5.2 Construction citations plotted against abundance.



that have the same citation number. For example, *Ficus sycomorus* has a density of 8.7/hectare as opposed to *Cordia africana*, which has a density of 0.7/hectare or *Mimusops kummel* which was not seen during the sampling. The latter two species may therefore require more attention than *Ficus sycomorus*. Other species that may be considered as warranting special attention are *Ozoroa mucranata*, *Haplocoelum folioosum* and *Dichrostachays cinerea*.

5.4.2.2 Value

The use-values (V) for the various categories are given in Table 5.3. Figure 5.3 illustrates the construction values in relation to abundance. There is a scattering of species in the diagram. Species that have high values but low densities are *Acacia mellifera*, *Haplocoelum folioosum*, *Mimusops kummel* and *Dichrostachays cinerea*. Other species that may warrant attention include *Ozoroa mucranata*, *Cordia africana* and possibly *Cordia* sp. (mgombeha) and *Zanthoxylum chalybeum*. There are also species, including *Croton dictygamous*, *Acacia tortilis*, *Grewia bicolor* and *Vangueria apiculata*, that are quite abundant but have relatively low value. These species would therefore be low on the list of species requiring attention.

5.4.2.3 Endangerment and Priorities

When a volume-of-use coefficient is added to the equation (V*C), the resultant values are slightly different (Figure 5.4). The most highly valued and used species are basically the same as in Figure 5.3, with *Acacia mellifera* having the highest value, followed by *Haplocoelum folioosum*. *Dichrostachays cinerea* is slightly higher than *Acacia nilotica* using this approach. A few other species also change positions relative to each other, including *Sterculia quenqulobia* - *Strychnos henningsii*

Figure 5.3 Construction use-values versus availability (I/S=V).

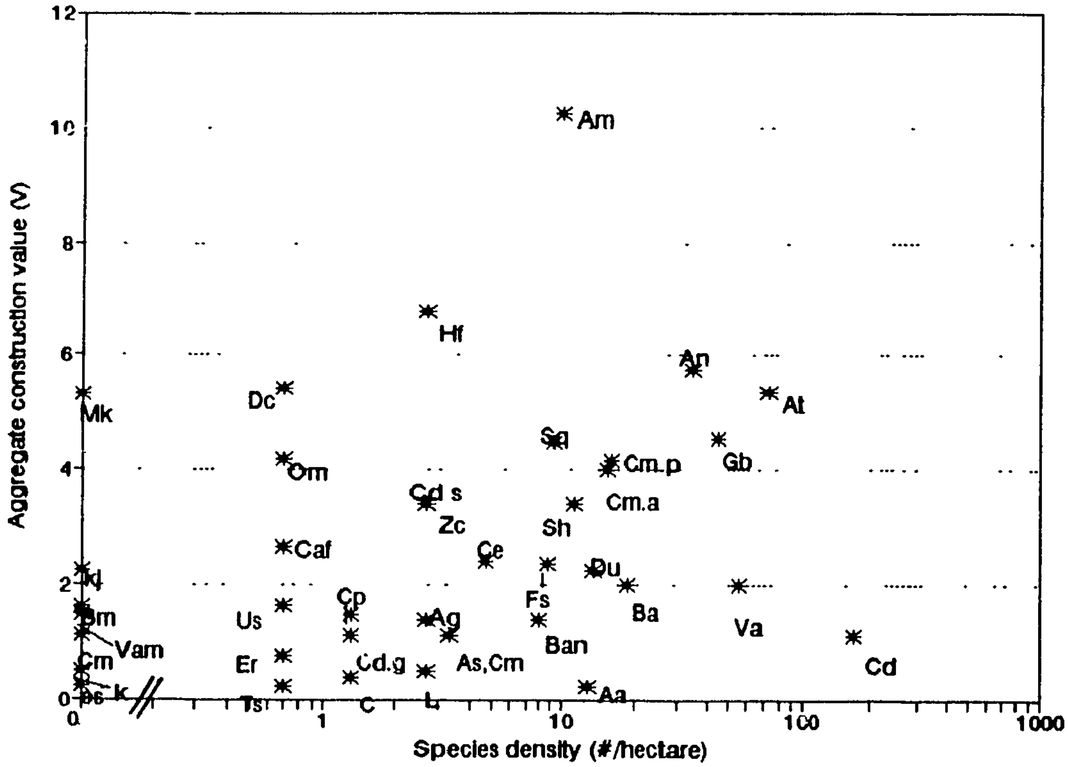
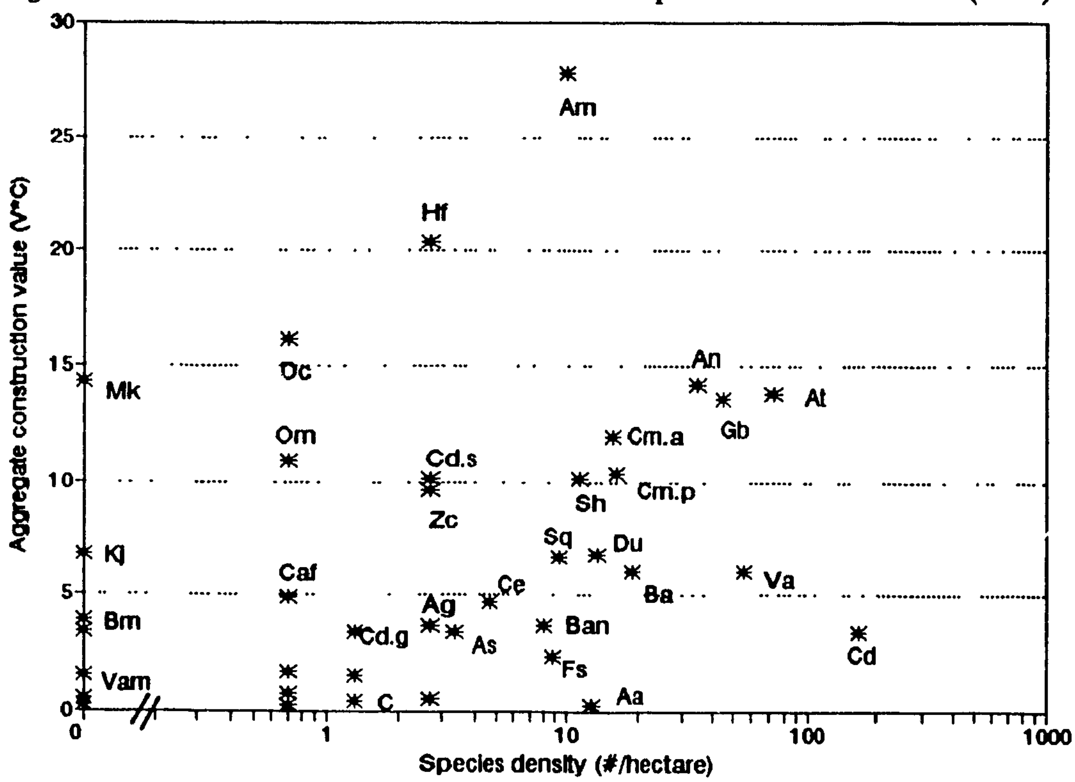



Figure 5.4 Construction use-value with consumption factor included. (V*C)



and *Commiphora africana - Commiphora pelleifolia.*

The overall aggregate values for species (based on four categories of use) are listed in Table 5.3 and their relationship to availability is illustrated in Figure 5.5. The species indicated as valuable are generally consistent with the previous figures. *Acacia mellifera, Acacia tortilis, Acacia nilotica* and *Haplocoelum folioosum* are all species that have high values. They do not, however, have the same abundance in the area and therefore there are some species that may require more attention. For instance, *Acacia mellifera,* which has a higher use value than *Acacia tortilis* (56.6 vs. 50.9), has a much lower density (10/ha vs 72.7/ha). *Haplocoelum folioosum* and *Acacia nilotica* have the same relative relationship, with the former having a higher use value (38.4 vs 32.3) but a much lower density (2.7/ha vs 34.7/ha).

All of the figures illustrate a range of values per density and no linear relationship to abundance. This marked deviation from a linear relationship between use and abundance suggests differences in the way the species should be viewed from a conservation standpoint. Do the often cited species that are rare require special attention? Is their rareness due to rates of exploitation? Is abundance stable? What would be the social consequences of local extinction?

Analysis of the density of "key" species reveals a number of interesting factors. These include low densities for a number of species, with some not even found in the immediate vicinity of the villages, such as *Mimusops kummel.* Other species, such as *Haplocoelum folioosum, Dichrostachays cinerea* and *Mimusops kummel* have relatively high use-values but lower densities. Many species that have high construction use-values, such as *Haplocoelum folioosum* and *Dichrostachays cinerea* have quite low species density. Certain species, such as *Acacia tortilis* and *Acacia nilotica* are shown to possess high use values and relatively high densities. Still others,

Figure 5.5 Aggregate use-value plotted against availability.

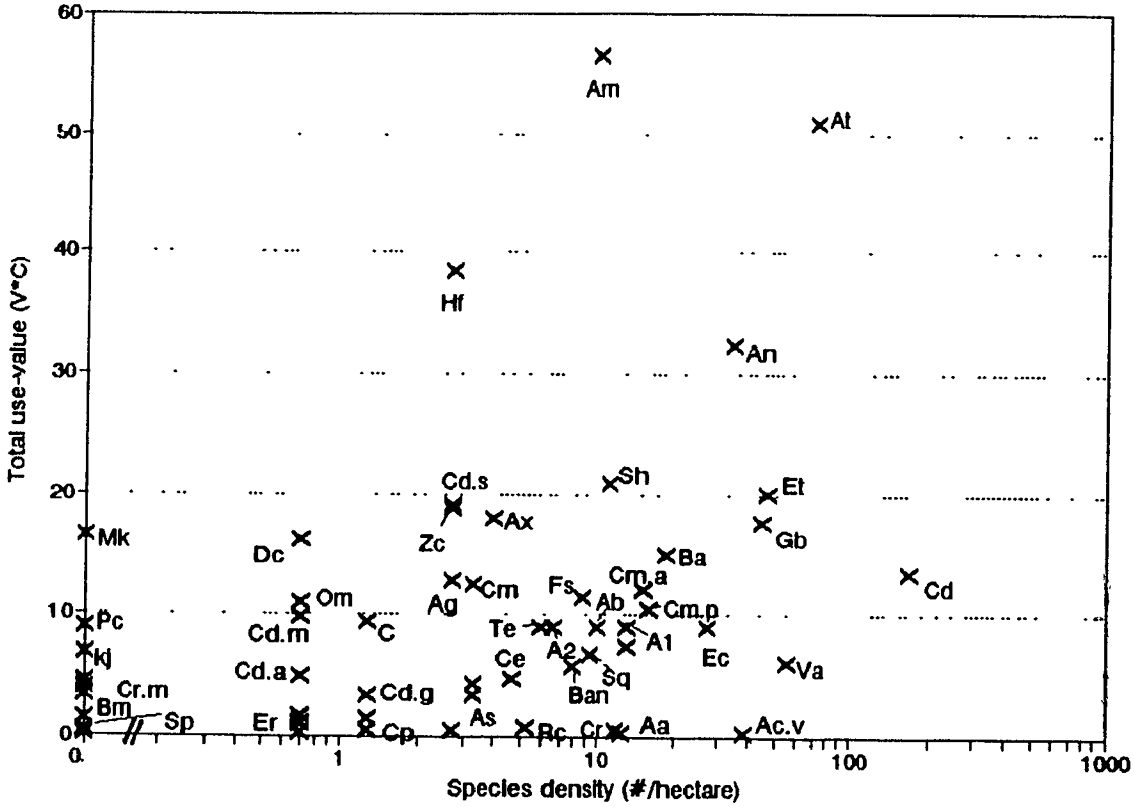
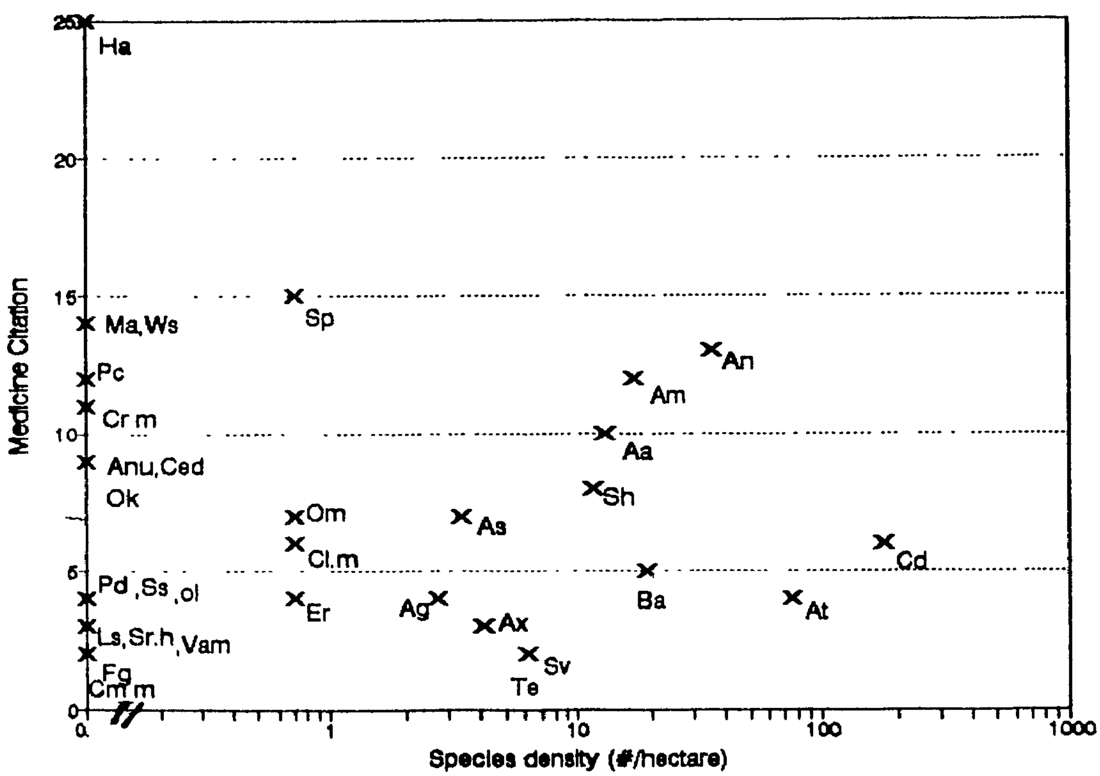



Figure 5.6 Availability of medicinal plants.



such as *Salvadora persica* and *Euclea racemosa* have both low densities and low use-values and thus presumably lower priorities. Overall, the most highly valued species is *Acacia mellifera*, which the locals consider a strong, resistant wood. As this species does not have a high abundance, it may be a suitable species to single out for special attention. The identification of this species as potentially vulnerability reflects the information provided by the local residents (see Section 5.4.1) in terms of species that are most highly valued and declining.

There are a few further notes of interest regarding species availability and use. The restricted use of species such as *Euphorbia tirucalli* is usually related to their distribution. *Euphorbia tirucalli* is abundant along the escarpment and in the Kirijau hills and this is reflected in its use in Digodigo and Mugholo where it provides easy access to abundant fuelwood. This species is also a common live fence in these two villages.

Only four of the species found only along the irrigation channels are used by the Batemi and these are all fairly minor uses. *Ficus sur* is used only for food; *Clausenia anisata* is used for toothbrushes. *Vernonia amygdalina* is used for building and medicine. *Bridelia micrantha* is the only species that has a higher use value due to its use for construction. The low usage of these species -- 30.7% of species as compared to 83% species usage overall -- may be a reflection of the restrictions on cutting along irrigation channels.

The distribution and abundance of a number of the medicinal species provides some interesting insight into their use (Figure 5.6). Most of the species used for medicinal purposes are either extremely rare or are not found in the area altogether. For example, some of the most widely used medicinal species, *Harrisonia abyssinica* and *Warburgia salutaris* are not found near the villages. *Myrsine africana* is only found in Loliondo, about 30 kilometres away. *Harrisonia abyssinica* is found to the west of the study area, near the Samunge subvillage of Mditu (Johns 1992) while *Warburgia salutaris* is found in the hills, about an one and a half hour walk behind Mugholo. *Commiphora madagascar* is found to the south of the study area, near Ghamasa Hill, about ten kilometres from DigoDigo and Mugholo.

### 5.4.3 Assessment of Methods

A number of difficulties became apparent during the exploring of methods to assign use-values. For example, the division of the need-importance coefficient by the number of substitutes greatly affects the importance of each use-species importance value. This is problematic in many ways. Within the construction category, for example, the range of species cited for house poles may reflect the importance of the need, while furniture, with a much lower need-importance, involves only a few species. The range of species used for poles reduces the overall importance value for that column below that for furniture, a less important need.

The differences between using the number of citations versus the generated values can easily be seen by examining the placement of species in Figure 5.1 versus Figure 5.3. The positions of some species, such as *Acacia mellifera* or *Croton dictygamous*, do not change greatly between methods, while others species are affected quite dramatically. *Ficus sycomorus* and *Cordia africana* which appear quite high in terms of the citation numbers have much lower positions based on the calculated use-values (V). *Haplocoelum folioosum*, however, is placed relatively higher in Figure 5.3 as opposed to Figure 5.1. The relative positions of *Ozoroa mucranata* and *Dichrostachays cinerea* also change, with the former being more "valued" in the citation system and the latter being more important in terms of the calculated value. In this respect, the use of a calculated value seems worthwhile, as highly valued species such as *Ficus sycomorus* and *Cordia africana* are actually not used much at present, either due to restrictions on their habitat or low availability.

The difference created by adding a volume coefficient is evident in the relative position of a number of species. Higher use volumes add to the value or intensity of use of a species and therefore increases its overall use-value. The resultant difference is obvious in comparing the change in the position of *Ficus sycomorus*, which as a very valuable, but not high volume use species, has a lower vulnerability when volume is taken into account. Certain species, such as *Strychnos henningsii*, increase in vulnerability with the addition of the volume of use coefficient, as does *Zanthoxylum chalybeum* to a slight degree.

Overall, the differences between the various methods seem adequate to justify further exploration of the possibilities of such approaches for attempting to identify possible conservation priorities. Refinements should include work on the means of assigning relative use values and levels of consumption coefficients. Possibilities for solving the present problem of subjectivity would be to collect more quantitative use values and to quantify the local consumption of different species and different categories of use. Attention to variations in local use patterns in relation to species distribution would serve to identify species that may require more attention in a localized area.

## 5.5 Conclusion

The management and conservation of these species must be addressed within the socioeconomic and ecological context of the area. Baseline data as collected in this research can assist local communities and governments in planning for sustainable use and conservation of these resources. Local knowledge and traditional conservation practices such as the conservation areas in the Batemi area, provide baseline structures that can be built upon in resource and conservation planning. Ignoring these local practices and values would only jeopardize any plans that would be implemented. Further investigation of local ecological knowledge about species habitats, ecological preferences and species interactions would bolster this process.

The results of the different methods for assigning use value, as explored in this chapter, suggest that further work and refinement on the means of assigning values would be worthwhile. Methods of having locals assign quantitative values, actual quantified consumption levels, and variations in use patterns are all factors that would bolster these types of approaches to identifying conservation priorities. Based on the methods as followed in this chapter, species such as *Acacia mellifera*, *Haplocoelum folioosum* and *Strychnos henningsii* may be species that require further study and attention.

## Chapter 6. Conclusions

> In view of the interrelationship between the natural environment and its sustainable development, and the cultural, social, economic and physical well being of indigenous people . . . efforts to implement . . . sustainable development should recognize, accommodate, promote and strengthen the role of indigenous people and their communities.
>
> United Nations, Agenda 21: Section 26.1

Addressing the goals of Agenda 21 will require great advances in our ability to translate ecological requisites and cultural aspirations into practical management strategies. The great challenge of protecting biodiversity must be faced by recognizing the range of culture systems and resource use practices that co-exist with the world's biodiversity. This thesis has attempted to explore one way of promoting and strengthening the role of the Batemi in protecting their irreplaceable resource base. The three specific goals were to:

1) investigate local use of vegetation

2) study the abundance and distribution of woody vegetation in the area

3) experiment with assigning use-values to species and with using these values to identify conservation priorities.

As discussed in Chapter 2, there are a number of pressures in the area, including a growing population and changing social and political structures that affect land use and resource management. The conversion of land into cultivated fields and gardens is taking place primarily on the plains, so the resources from this community may come under increased stress as population growth continues to increase the demand for agriculture. Firewood reserves are largely on hillsides, so as the demand for firewood grows the problem of hillside erosion may increase. There is evidence, such as widespread gully erosion and localized areas of bush yclearing, that these pressures may have an increasingly adverse effect on the area. It is therefore important that a resource and conservation plan be designed and implemented. A local group, KIPOC, and the District Council are in the process of working towards this goal, a goal that must incorporate local needs and practices.

Chapter 3 has shown that the Batemi make use of a large percentage of the "natural" vegetation found in their environment. They use over one hundred woody species found in the surrounding areas, which constitutes 83 percent of the species encountered during the random sampling. The Batemi have definite preferences for various species, depending on the specific use. For example, valued construction species include *Acacia mellifera*, *Haplocoelum foliolosum* and *Cordia africana*, while valued implement species include *Grewia bicolor* and *Strychnos henningsii*.

Chapter 4 presented data on the biological area that the Batemi inhabit. The area contains a large number of woody species (over 100), most of which are used by the Batemi for at least one purpose. The natural vegetation can be divided into three communities that are found within hillside, plain and riverine habitats. In addition, there are the irrigation channels, which can be considered as more diverse, dense examples of the riverine vegetation, which seems to be due to their special conservation status as well as higher moisture availability.

This range of habitat types allows access to a broad array of plant species. The placement of the villages with respect to the spatial distribution of vegetation types shows that each village, with some exceptions, has reasonable access to each community. The irrigation vegetation is accessible to all villages in the valley. It is valued for its ecological role in preservation of the irrigation system and hence cutting is restricted and the use of the woody species is practically nil. Similar vegetation is found in Type 1 or riverine vegetation, which is found scattered throughout the valley. Type 2 vegetation is the major source for fuel and building timbers and it contains many valued, scarcer species, such as *Acacia mellifera* and *Warburgia salutaris*. Because it is restricted mainly to thickets on hill sites, it is not equally accessible to all the villages. The sub-villages of Eyasi, Mgero and Mgundu, have less access to the bush and woodland thicket. Type 3 vegetation, which occurs mostly in "woodland" or "wooded grassland" formations, is widely accessible. Species found in Type 3 are also used for fuelwood and construction, although these areas do not seem to be as heavily exploited as Type 2 for these purposes.

There is enough spatial variation in the plant community that variations in resource use practices were seen to vary from village to village. Villagers tended to cite a higher reliance on plants that were close, such as the high use of *Euphorbia tirucalli* for fuel and live fences in DigoDigo and Mugholo. The exception to this is the practice involving medicinal species, where some of the most valued ones, such as *Warburgia salutaris* and *Harrisonia abyssinica*, are particularly rare and only available at great distances. People will travel long distances in search of these varieties.

In Chapter 5, Batemi conservation knowledge and traditional practices were discussed and shown to be relevant to designing and implementing a conservation strategy or sustainable resource plan. Their knowledge of the economic properties of available resources, their traditional conserving strategy for local irrigation channels and their knowledge of species habitats would have benefits if incorporated into any regional or national plan. Their dependence on the resources suggests a strong interest in maintaining the viability of the ecosystem and their historical record of interaction with the ecosystem suggest that they do have ways -- implicit or explicit -- of ensuring coexistence with a large range of naturally occurring species.

Chapter 5 also explored methods for incorporating local values and practices into a quantitative index of resource valuation. The assigning of use-values to various species illustrates the difficulties involved in establishing objective or at least consistent conservation priorities. By showing the range of species that are valued for specific uses, the work did highlight the importance of effective conservation. By combining biological data on the abundance and distribution of the various woody species with use data, key socioeconomic species that may represent conservation priorities have been identified. Certain species, including *Acacia mellifera* and *Haplocoelum folioosum* were identified as being of potential concern, or priorities for further work. The quantitative values presented in Chapter 5 are debatable of course, but they do serve as a way of integrating information and they do appear to be effective in identifying species that should at least receive closer scrutiny as conservation strategies are developed.

The data used in this study were gathered at a single time, but repeated studies at later times or at other places could help show change over time or differences between places. These too could be important signals for conservation planners. It is hoped that the data that has been presented in this thesis can be of assistance in the Batemi area, in terms of providing baseline data, illustration of spatial extent of use of habitats, and in identification of species of potential interest or concern. Further work on identification of key ecological species would also beneficial.

It is clear that the goals set by Agenda 21 and by many international conservation agencies will only be achieved if present approaches to resource management and development are radically modified. Among the many changes that are required is a recognition of the ecological system of indigenous populations. The Batemi have an extensive knowledge of the land they occupy, use a large array of the native species and have resource-use practices that have allowed them to co-exist sustainably with their environment for generations. As their population grows and economic relationships change, they will undoubtedly alter their relationship to the land. Successful conservation will require their being able to meet their aspirations without undermining their resource base.

Clearly related to this issue is the requirement of establishing conservation priorities in settings where market forces cannot be assumed to be adequate to identify valued assets and regulate their management. The life sustaining natural resources of the Batemi have a utilitarian worth that exists entirely outside of markets or cash economies. Yet the value of building materials is clearly as great here as it is anywhere.

Given the pressures of "economic rationalization" that are reshaping many developing countries, it is vital that some method be established for identifying and codifying valued resources. Where conservation priorities are being determined at least in part by the needs ot the local population, the encoded values will help establish conservation priorities. This thesis has experimented with various ways of linking local use data with estimates of consumption and measures of abundance to raise questions about conservation priorities. The convergence between the results of this approach and the priorities cited in interviews with local people, suggests the methods are worth pursuing. It is hoped, therefore, that this thesis can provide insight into reorienting approaches to conservation and development.

## References Cited


Ahman, W., L.B. Jupp and M. Numez. 1992. Landcover mapping in a rugged terrain area using Landsat MSS data. International Journal of Remote Sensing 13(4): 673-683.

Alcorn, Janis B. 1989. Process as resource: the traditional agricultural ideology of Bora and Huastec resource management and its implications. Advances in Economic Botany 7: 63-77.

Altieri, M.A., M.K. Anderson, and L.C. Merrick 1987. Peasant agriculture and the conservation of crop and wild plant resources. Conservation Biology 1(4): 49-58.

Anderson, A.B. and D.A. Posey 1989. Management of a tropical scrub savanna by the Gorotire Kayapo of Brazil. Advances in Economic Botany 7:159-173.

Atlas of Tanzania 1967. Government of Tanzania, Dar es Salaam.

Beanlands, G.E. and P.N. Duinker. 1983. An Ecological Framework for Environmental Impact Assessment in Canada. Institute for Resource and Environmental Studies, Dalhousie University, Halifax, N.S.

Berlin, B., D.E. Breedlove and P.H. Raven 1974. Principles of Tzeltal Plant Classification: An Introduction to the Botanical Ethnography of a Mayan-Speaking People. Academic Press, New York.

Biswas, A.K. 1979. Management of traditional resource systems in marginal areas. Environmental Conservation 6(4):257-264.

Boom, Brian M. 1989. Use of plant resources by the Chacobo. In D.A. Posey and W. Balee (eds.), Advances in Economic Botany 78, Resource Mangement in Amazonia: Indigenous and Folk Strategies, 78-96.

Bowander, B. 1986. Deforestation in developing countries. Journal of Environmental Systems 15:171-192.

Bowander, B. 1987. Environmental problems in developing countries. Progress in Physical Geography 11(2):246-259.

Brokensha, D., D.M. Warren and O. Werner (eds.) 1980. Indigenous Knowledge Systems and Development. University Press of America, Washington, D.C.

Brown, G.M. 1990. In G.H. Orians, G.M. Brown Jr., W.E. Kunin and J.E. Swierzbinski (eds.), The Preservation and Valuation of Biological Resources, 203-229. University of Washington Press, Seattle, London.

Brown, Michael and Barbara Wyckoff-Baird. 1992. Designing Integrated Conservation and Development Projects. Biodiversity Support Program, World Wildlife Fund, Nature Conservancy and World Resources Institute, Washington, D.C.

Carroll, C.R. 1992. Ecological management of sensitive natural areas. In P.L. Fiedler and S.K. Jain (eds.), Conservation Biology, 347-372. Chapman and Hall, New York.

Christiansson, C., I.S. Kikula and W. Ostberg 1991. Man-land interrelationship in semiarid Tanzania: a multidisciplinary research program. Ambio 20(8): 55-61.

Civco, Daniel. 1989. Topographic normalization of Landsat Thematic Mapper digital imagery. Photogrammetric Engineering and Remote Sensing 55(9): 1303-1309.

Cox, C.B. and T.D. Moore. 1993. Biogeography: An Ecological and Evolutionary Approach. 5th ed. Blackwell Scientific, Oxford.

Dasmann, R.F. 1991. The importance of cultural and biological diversity. In M.L. Oldfield and J.B. Alcorn (eds.), Biodiversity: Culture, Conservation and Ecodevelopment, 7-15. Westview Press, Boulder, San Franscisco.

Denevan, W.M and C. Padoch 1988. Swidden fallow agroforestry in the Peruvian Amazon. Advances in Economic Botany 5:1-107.

Dorm-Adzobu, C. 1982. Impact of utilization of natural resources on forest and wooded savanna ecosystems in rural Ghana. Environmental Conservation 9(2):157-162.

Douthwaite, R.J. 1987. Lowland forest resources and their conservation in Southern Somalia. Environmental Conservation 14(1):29-35.

FAO (Food and Agriculture Organization). 1983. Food and fruit-bearing forest species 1: examples from eastern Africa. FAO forestry Paper 44/1. Food and Agriculture Organization of the United Nations, Rome.

FAO. 1988. Traditional food plants. FAO Food and Nutrition paper 42, Food and Agriculture Organization of the United Nations, Rome.

Farnsworth, N.R. 1988. Screening plants for new medicines. In E.O. Wilson (ed.), Biodiversity, 83-97. National Academy Press, Washington, D.C.

Fleuret, A. 1979. The role of wild foliage plants in the diet: a case study from Lushoto, Tanzania. Ecology of Food and Nutrition 8: 87-93.

Fleuret, A. 1980. Nonfood uses of plants in Usambara. Economic Botany 34(4):320-333.

Fries, J. 1991. Management of natural forests in the semiarid areas of Africa. Ambio 20(8):395-400.

Fuls, E.R., G.J. Bredenkamp and N. van Rooyen. 1992. Plant communities of the rocky outcrops of the northern Orange Free State, South Africa. Vegetatio 103: 79-92.

Gauch, H.G. 1982. Multivariate Analysis in Community Ecology. Cambridge University Press, New York.

Goldsmith, B. 1991. Vegetation monitoring. In B. Goldsmith (ed.), Monitoring for Conservation and Ecology, 77-86. Chapman-Hill, New York.

Government of Tanzania. 1957. 1957 Census of Tanzania. Bureau of Statistics, United Republic of Tanzania, Dar es Salaam.

Government of Tanzania. 1967. 1967 Census of Tanzania. Bureau of Statistics, United Republic of Tanzania, Dar es Salaam.

Government of Tanzania. 1978. 1978 Census of Tanzania. Bureau of Statistics, United Republic of Tanzania, Dar es Salaam.

Government of Tanzania. 1988. 1988 Census of Tanzania. Bureau of Statistics, United Republic of Tanzania, Dar es Salaam.

Gray, A. 1991. Between the Spice of Life and the Melting Pot: Biodiversity Conservation and its Impacts on Indigenous Peoples. International Working Group for Indigenous Affairs, Copenhagen.

Gray, R.F. 1963. The Sonjo of Tanganika: an anthropological study of an irrigation-based society. Oxford University Press, New York.

Griffiths, J.F. 1969. Climate. In W.T.W. Morgan (ed.), East Africa: its peoples and its resources. Oxford University Press, New York.

Grivetti, L.E. 1978a. Kalahari agro-pastor-hunter-gatherers: the Tswana example. Ecology of Food and Nutrition 7: 235-256.

Grivetti, L.E. 1978b. Nutritional success in a semi-arid land: examination of Tswano agro-pastoralists of the eastern Kalahari, Botawana. Am. J. Clin. Nutr. 31:1204-1220.

Herlocker, D.J. and H.J. Dirschl 1978. Vegetation of the Ngorongoro Conservation Area, Tanzania. Canadian Wildlife Service Report Series # 19, Ottawa.

Hill, M.O. 1979. TWINSPAN: a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, N.Y.

Hutchinson, C.F. 1991. Uses of satellite data for famine early warning in sub-Saharan Africa. International Journal of Remote Sensing 12(6): 1405-1421.

IUCN (International Union for the Conservation of Nature and Natural Resources). 1980. World Conservation Strategy. World Wildlife Fund, Washington, D.C.

Johannes, R.E. and B.G. Hatcher. 1986. Shallow tropical marine environments. In Michael E. Soule (ed.), Conservation Biology: The Science of Scarcity and Diversity, 371-382. Sinauer Associates, Sunderland, MA.

Johns, T. 1992. Personal communication.

Johns, T. and J.O. Kokwaro 1991. Food plants of the Luo of Siaya District, Kenya. Economic Botany 45(1): 103-113.

Johns, T., J.O. Kokwaro and E.K. Kimanani. 1990. Herbal remedies of the Luo of Siaya District, Kenya: establishing quantitative criteria for consensus. Economic Botany 44(3): 369-381.

Johns, T., E.B. Mhoro, and P. Sanaya. n.d.a. Quantitative appraisal of the herbal remedies of the Batemi of Ngorongoro District, Tanzania. Manuscript prepared for sumbission to Economic Botany.

Johns, T., E.B. Mhoro, P. Sanaya and E.K. Kimanani. n.d.b. Plant foods and food additives of a traditional subsistence community, the Batemi of Ngorongoro District, Tanzania. Manuscript in Preparation.

Joint Forest Management. 1992a. Field Methods Manual, Vol I: Diagnostic Tools for Supporting Joint Forest Management Systems. Joint Forest Management Support Program, New Delhi.

Joint Forest Management. 1992b. Field Methods Manual. Vol II: Community Forest Economy and use Patterns: Participatory Rural Appraisal (PRA) Methods in South Gujarat, India. Joint Forest Management Support Program, New Delhi.

Kapoor-Vijay, P. 1992a. Biological Diversity and Genetic Resources The Programme of the Commonwealth Science Council. The Commonwealth Secretariat, London.

Kapoor-Vijay, P. 1992b. Choice of species for conservation. In P. Kapoor-Vijay and J. White (eds.), Conservation Biology: A Training Manual for Biological Diversity and Genetic Resources, 45-60. Commonwealth Secretariat, London.

Kasperson, R.E., B.L. Turner, J.X. Kasperson, R.C. Mitchell and S.J. Ratick. 1991. A preliminary working paper on critical zones in global environmental change. In T.Meredith, C. Marley and W. Smith (eds.), Defining and Mapping Critical Environmental Zones for Policy Formulation and Public Awareness, 37-62. Canadian Global Change Program, Montreal.

Keay, R.W.J., Aubreville, A., P. Duvigneaud, F.A. Merdonca and R.E.G. Pichi-Sermolli 1959. Vegetation map of Africa: south of the tropic of cancer. Cook, Hammond and Kell, London.

Kennenni, L. 1991. Geography and phytosociology of Acacia tortilis in the Sudan. Afr. J. Ecol. 29: 1-10.

Kershaw, K. and Looney. 1985. Quantitative plant ecology. 3rd ed. Edward Arnold, Baltimore, Maryland.

Kigomo, B.N., F.S. Savill and S.R. Woodell. 1990. Forest composition and its regeneration dynamics; a case study of semi-deciduous tropical forests in Kenya. Afr. J. Ecol. 28: 174-188.

Klee, G.A. (ed.). 1980. World Systems of Traditional Resource Management. V.H. Winston and Sons, London.

Lamprey, R.H. 1984. Maasai impact on Kenya savanna vegetation: a remote sensing approach. University of Aston, Birmingham. Unpublished PhD Thesis.

Lawesson, J.E. 1990. Sahelian woody vegetation in Senegal. Vegetatio 86: 161-174.

Lind, E.M. and M.E.S. Morrison 1974. East African Vegetation. Longman, New York.

Loth, P.E. and H.H. Th Prins 1986. Spatial patterns of the landscape and the vegetation of Lake Manyara National Park. ITC Journal 1986(2) 115-130

Lunetta, Ross S., Russell G. Congalton, Lynn K. Fernstermaker, John R. Jensen, Kenneth C. McGuire, and Larry R. Tinney. 1991. Remote sensing and geographic information systems data integration: error sources and research issues. Photogrammetric Engineering and Remote Sensing 57(6): 677-687.

McNeeley, J.A. 1988. Economics and Biological Diversity: Developing and Using Economic Incentives to Conserve Biological Resources. IUCN, Gland, Switzerland.

Milne-Redhead, E. and W.B. Turrill (eds.) 1952. Flora of Tropical East Africa. Crown Agents, London.

Nabhan, G.P., D. House, S.A. Humberto, W. Hodgson, L. Hernandez and G. Malda. 1991. In M.L. Oldfield and J.B. Alcorn (eds.), Biodiversity: Culture, Conservation and Ecodevelopment, 127-146. Westview Press, Boulder, San Fransisco.

National Research Council (NRC). 1992. Biodiversity. National Academy Press, Washington D.C.

Nietschmann, B. 1973. Between Land and Water: The Subsistence Ecology of the Miskito Indians, Eastern Nicaragua. Seminar Press, New York.

Newby, J.E. and J.F. Grettenberger 1986. The human dimension in natural resource conservation: a Sahelian example from Niger. Environmental Conservation 13(3):249-256.

Oldfield, M.L. and J.B. Alcorn. 1991a. Conservation of traditional agroecosystems. In M.L. Oldfield and J.B. Alcorn (eds.) Biodiversity: Culture, Conservation and Ecodevelopment, 37-58. Westview Press, Boulder, San Franscisco.

Oldfield, M.L. and J.B. Alcorn. 1991b. Introduction. In M.L. Oldfield and J.B. Alcorn (eds.) Biodiversity: Culture, Conservation and Ecodevelopment, 119-126. Westview Press, Boulder, San Franscisco.

Palmberg, Christel. 1992. Criteria on choice of species for conservation: woody plants. In P. Kapoor-Vijay and J. White (eds.), Conservation Biology: A Training Manual for Biological Diversity and Genetic Resources, 51-60. Commonwealth Secretariat, London.

Peters, C.M., M.J. Balick, F. Kahn and A.B. Anderson 1989a. Oligarchic forests of economic plants in Amazonia: utilization and conservation of an important tropical resource. Conservation Biology 3(4): 341-349.

Pichi-Sermolli, R.E.G. 1955. Tropical East Africa (Ethopia, Somalia, Kenya and Tanganyika). In Plant Ecology: Reviews of Research, 302-360. Unesco, Paris.

Pinendo-Vasquez, M., D. Zarin, P. Jipp and J. Chota-Inuma 1990. Use-values of tree species in a communal forest reserve in northeast Peru. Conservation Biology 4(4): 405-416.

Porter, P.W. 1976. Climate and agriculture in East Africa. In C.G. Knight and J.L. Newman (eds.), Contemporary Africa - Geography and Change, 112-139. Prentice-Hall, Englewood Cliffs, N.J.

Posey, D. 1984. A preliminary report on diversified management of tropical forest by the Kayapo Indians of the Brazilian Amazon. Advances in Economic Botany 1:112-126.

Posey, D. 1983. Indigenous ecological knowledge and the development of the Amazon. In E.F. Moran (ed.), The Dilemna of Amazonian Development, 225-258. Westview Press, Boulder, CO.

Potanski, T. n.d. The Irrigation System of the Batemi. Unpublished manuscript.

Prance, G.T., W. Balee, B.M. Boom, and R.L. Carneiro. 1987. Quantitative ethnobotany and the case for conservation in Amazonia. Conservation Biology 1(4): 296-310.

Pratt, D.J., P.J. Greenway and M.D. Gwynne. 1966. A Classification of East African Rangeland, With an Appendix on Terminology. Blackwell Scientific Publications, Oxford.

Prince, Stephen D. 1986. Monitoring the vegetation of semi-arid tropical rangelands with the NOAA-7 Advanced very high resolution radiometer. In M.J. Eden and J.T. Parry (eds.) Remote Sensing and Tropical Land Management, 307-334. John Wiley and Sons Ltd, London.

Reid, N., J. Marroqur and P. Beyer-Munzel 1990. Utilization of shrubs and trees for browse, fuelwood and timber in the Tamaulipan thornscrub, northeastern Mexico. Forest Ecology and Management 36:61-79.

Reuss, R.W. and F.L. Halter. 1990. The impact of large herbivores on the Seronera woodlands, Serengeti National Park, Tanzania. African Journal of Ecology 28: 61-79.

Rowe, R., N.P. Sharma, and J. Browder. 1992. Deforestation: problems, causes and consequences. In N.P. Sharma (ed.), Managing the World's Forests: Looking for Balance Between Conservation and Development, 33-45. Kendall House Publishing, Dubokue, Iowa.

Ryan, John C. 1992. Life Support: Conserving Biological Diversity. Worldwatch Institute, Washington, D.C.

Schowengerdt, R.A. 1983. Techniques for Image Processing and Classification in Remote Sensing. Academic Press, New York.

Sinclair, A.R.E. 1979. Dynamics of the Serengeti ecosystem: process and pattern. In A.R.E. Sinclair and M. Norton-Griffiths (eds.) Serengeti: Dynamics of an Ecosystem, 1-30. University of Chicago Press, Chicago.

Skarpe, C. 1990a. Shrub layer dynamics under different herbivore densities in an arid savanna, Botswana. J. Appl. Ecol. 27: 873-885.

Skarpe, C. 1990b. Structure of the woody vegetation in disturbed and undisturbed arid savanna, Botswana. Vegetatio 87: 11-18.

Ter Braak, C.J.F. 1988. CANOCO: a FORTRAN Program for Canonical Community Ordination by (Partial) (Detrended) Canonical Correspondence analysis, P.C.A. and Redundancy Analysis.

Timberlake, Lloyd. 1986. Africa in Crisis: the Causes, the Cures of Environmental Bankruptcy. Earthscan, London.

Toledo, V.M. 1991. Patzcuano's lesson in nature, production and culture in an indigenous region of Mexico. In M.L. Oldfield and J.B. Alcorn (eds.), Biodiversity: Culture, Conservation and Ecodevelopment, 147-171. Westview Press, Boulder, San Franscisco.

Trapnell, C.G. and I. Langdale-Brown 1969. Natural Vegetation. In W.T.W. Morgan (ed), East Africa: its peoples and resources, 127-139. Oxford University Press, New York.

Trotter, Craig M. 1991. Remotely-sensed data as an information source for geographical information systems in natural resource management: a review. International Journal of Geographic Information Systems 5(2): 225-239.

UNCED (United Nations Conference on Environment and Development). 1992a. Agenda 21. United Nations document, New York.

UNCED (United Nations Conference on Environment and Development). 1992b. Convention on Biological Diversity. United Nations document, New York.

Usher, Michael B. 1992. Quantitative aspects of the collection and analysis of inventory data. In P. Kapoor-Vijay and J. White (eds.), Conservation Biology: A Training Manual for Biological Diversity and Genetic Resources, 71-86. Commonwealth Secretariat, London.

Vasquez, R. and A.H. Gentry 1989. Use and misuse of forest-harvested fruits in the Iquitos area. Conservation Biology 3(4): 350-361.

WCED (World Commission on Environment and Development) 1987. Our Common Future. Cambridge University Press, New York.

White, F. 1983. The Vegetation of Africa: a descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. Unesco, Paris.

World Resources Institue (WRI), The World Conservation Union (IUCN) and United Nations Environment Programme (UNEP). 1992. Global Biodiversity Strategy. Washington, D.C.

Appendix 1 : Materials used in land-use analysis.

| Material | Details | Source |
|---|---|---|
| Aerial photographs | February 1958, 1:40,000 35TN8, 62 and 63 and 35TN10, 146 and 147 | Fairy Air Survey, held at Mapping Office in Dar es Salaam, Tanzania |
| Aerial photographs | January 1972 - 2-35 L19-S | Geosurvey, held at Mapping Office in Dar es Salaam, Tanzania |
| Landsat TM print | March 1, 1990, Scene 61 | Photograph of print held at the Serengeti Research Institute, Serengeti National Park |
| Landsat TM digital data | March 1, 1991, Scene 169-061, Path 16. | Data from Serengeti Research Institute, Serengeti National Park |
| Topographic maps | 1:50000, Sheets 27/1 (1968 and 1979) and 27/2 (1978 and 1991) | Mapping Office, Dar es Salaam, Tanzania |