MORE USERS AND MORE USES:

CHOOSING BETWEEN LAND AND FOREST IN MALAWI'S PROTECTED AREAS

by

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Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

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SIGNED: ____________________

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I dedicate this work to my wife and best friend,

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and to the memory of those who passed before,

well before their time…

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ABSTRACT

Local inhabitants risk the loss of ecological resources when land is cleared for cultivation as population densities and the demand for land resources increase. This dilemma is investigated through an interdisciplinary socioeconomic and ethnoecological assessment of 427 households in communities adjacent to four protected areas in Malawi. This study introduces a multidimensional approach that captures baseline socioeconomic information and resource utilization in a quantitative, integrated manner. Household income was derived from a "sum of the parts" aggregation of income elements including species-level agricultural production and resource utilization data. Regression analysis ($R^2 = 0.84$) demonstrated that poorer households are more reliant on protected area-based income than are wealthy households. Lorenz curve analysis demonstrated that income distribution equality improves when proceeds from protected areas are included in household income. Poverty threshold analysis indicates that exploitation of protected area resources is a livelihood strategy that halved the number of households that otherwise would have remained beneath a basic needs poverty threshold. Ecological resources are shown to meet demand for more people and for a longer time frame than converting the same lands to agriculture. However, conversion is more likely because per hectare values are 2 to 3.5 times greater for agriculture than for consumptive ecological resource use. Spatial analysis suggests points of negative land cover change (1984-94) were not associated with the proximity of population but with the agricultural suitability of the land. The results suggest the kinds of decisions people will make under extreme stress, when

consideration of potential impacts is overwhelmed by the need to survive. This study demonstrates that protected area resources play a pivotal role in poverty alleviation, and by extension, efforts to make sustainable use and sustainable development compatible.

CHAPTER 1: INTRODUCTION

EXPLANATION OF THE PROBLEM AND ITS CONTEXT

Developing nations with predominantly agrarian economies face a difficult natural resource dilemma. Food and Agriculture Organization (FAO) estimates suggest these countries lost 14.9 million hectares of forest area annually between 1980 and 1995 (FAO 1997). Particularly in Africa, the driving force was generally the expansion of subsistence agriculture. As population densities and the demand for *land* resources increase, local inhabitants risk the loss of *ecological* resources when land is cleared for cultivation. This dilemma has direct bearing on efforts to alleviate poverty, encourage sustainable development, and promote community-based natural resource management, particularly where currently protected land is being considered for conversion to agriculture.

As the amount of total forested land declines, natural resources in protected areas become pivotal for both conservation and sustainable development. Poor rural households rely on natural resources extracted from protected parks and reserves, despite the potential for detrimental ecological impact. This deliberate livelihood strategy is intended to balance income against expenditure in normal times (Arnold and Falconer 1989) while providing a final safety net in times of crisis (Garine and Koppert 1988). Despite the importance of wild resources in household economies, baseline assessments of livelihood security often fail to capture their role in anything other than broad or aggregate terms. Conversely, ethnoecological research that might meet this need is often conducted at a spatial and temporal scale unsuitable for sustainable development planning.

Evolving societal concerns have increased pressure to meld the goals of conservation and sustainable development. The desire to improve upon conventional "fences and fines" approach to conservation (Barrett and Arcese 1995) has coincided with a more general trend towards including local communities in research, planning, and management of development initiatives (Brandon and Wells 1992). This has fostered interdisciplinary research that integrates socio-economic and ecological perspectives where concerns for protection of natural areas and economic development of local communities converge (Munasinghe 1992).

Although the potential of community-based management of natural resources has come under increased scrutiny (Wainwright and Wehrmeyer 1998), the long-term financial benefits of conservation to local people have the potential to outweigh those of agriculture or logging (e.g. Kremen *et al.* 2000). In spite of potential benefits, local populations in developing countries tend to receive a small share of the use and non-use benefits assessed by outsiders (Godoy *et al.* 2000).

To rectify this inequality, community-based natural resource management and integrated conservation and development projects (IDCPs) have become widespread. Their goal is to exploit the role that human consumption of protected natural resources can play in both conservation and development by directing the returns derived from conservation back into the community (Brandon and Wells 1992). This would suggest the potential for harmony between ecological and livelihood sustainability, and indeed IDCPs are viewed as having greater appeal than the exclusionary, "fences and fines" conservation strategies that preceded them (Barrett and Arcese 1995). Nevertheless, they require far more ecological, economic, social, and institutional monitoring, an investment difficult for developing nations and their inhabitants to make. Moreover, the ecological and socioeconomic aspects of sustainability are not always compatible.

This research presents a methodology to capture the role of protected area resources in rural household economies that integrates ethnoecological resource valuation techniques (Godoy, Lubowski, and Markandya 1993) with a combination of rapid and participatory, livelihood security assessment tools (Chambers 1990; 1994, Campbell, Luckert and Scoones 1997; Finan 1996; Woodson 1997). The methodology was tested over 12 months between 1996 and 1997 as part of the Malawi Public Lands Utilization Study. The data gathered were then used answer three fundamental questions:

(1) What are the per capita quantities and consumptive use-values of each species used for various uses, whether agriculturally produced or collected from the protected area?

(2) Are poorer households more reliant on protected area-based income?

(3) Do protected area proceeds influence the overall equality in the distribution of household income?

(4) Does the current supply of protected area resources meet current demand?

(5) Based on current patterns of use and population growth, when will demand outstrip sustainable supply?

(6) If protected area land suitable for agriculture was opened to cultivation, when would it be consumed, based on current patterns of land use and population growth?

(7) What is the per hectare value of protected area land used for a) natural resource product utilization, and b) agriculture?

(8) Does spatial analysis of land cover change suggest negative impacts are associated with proximity to higher population densities (as would be the case if fuelwood extraction dominated the process) or with the distribution of agriculturally suitable land?

STUDY SITE DESCRIPTION

The study sites used for this research are all in Malawi, in southeastern Africa (Figure 1.1 and 1.2). Each Appendix is a manuscript that includes a description of Malawi and the four protected study areas in a manner appropriate to the manuscript's theme. Sites are more thoroughly described in this introductory chapter to provide a more comprehensive geographic context for the entire study.

MALAWI

In 1997, 19% of Malawi's 94,000 km^2 of land was under protection in the form of four wildlife reserves, five national parks, and seventy-seven forest reserves (Orr *et al.* 1998). This percentage is not exceptional in Africa or elsewhere. However, in the same year, 86% of the country's 9.65 million people lived in rural areas (Malawi Government 1998). Malawi's average population density of 103 persons/km^2 of land was three times that of its neighbors (United Nations Population Division 2000), resulting in twice the per capita pressure on both protected and non-protected wooded areas. With a mean land holding size at or below 1.0 ha for a family of five in rural Malawi (BDPA/AHT 1998; House and Zimalirana 1992) and the importance of traditional agriculture in the dominant livelihood systems, the demand for agricultural land is substantial. Furthermore, 98% of rural and 94% of urban energy demand is satisfied through fuelwood and charcoal (Arpaillange 1996), a level of dependence exceeded internationally only by Nepal (Pearce and Turner 1990).

As a result of this population pressure, the forested area in Malawi was reduced by half between 1946 and 1996 (FAO 1981; FAO 1999; Millington *et al.* 1989; Openshaw 1996, Willan 1947). This has had the effect of increasing the importance of remaining protected area resources as both common resource base and potential agricultural land (Mwafongo 1994; Mwafongo and Kapila 1999).

The population of Malawi is predominantly rural, with smallholder farmers (averaging 1.0 ha of land under cultivation) constituting 90% of the nation's poor (World Bank 1998).The agroecosystems in Malawi are dominated by a sub-humid tropical, uni-modal rainfall system (ranging from 700 to 1400 mm annually), with loamy sand soils characterized as having "low" to "sufficient" nutrient levels (Snapp 1998). High population growth rates have led to small land holdings (House and G. Zimalirana 1992), and continuous cultivation (limited or no fallow), whereas in 1938, plots were farmed only 3 to 5 years before extended rest (Berry and Petty 1992).

In response to the acknowledged population pressure to convert protected areas to agricultural lands, the Government of Malawi commissioned a Public Lands Utilization Study (PLUS) in 1996 to study both the environmental risks of conversion and the importance of the reserves and their resources to adjacent communities (Orr *et al.* 1998). The study was guided by a national Steering Committee on Land, which was made up of 60 government and non-government stakeholder agencies. The Committee selected four protected areas for intensive study, including Mulanje Forest Reserve, Liwonde National Park, Dzalanyama Forest Reserve and Ranch, and Vwaza Wildlife Reserve.

MULANJE FOREST RESERVE

Mulanje Mountain was first gazetted as a forest reserve in 1927, with the nearby Michesi Mountain added in 1929. Centered on 15°57'S, 35°39'E, the reserve now covers 56,314 ha of mostly mountainous terrain. Geologically, the massif consists of a large syenitic intrusion, rising from the surrounding plain from 600m to 3,000m above sea level. Steep slopes and shallow dystric-fersialic soils limit the agricultural suitability of the forest to some lowlands on the southern and eastern edge of the reserve (Paris 1991a; Pike and Rimmington 1965).

The miombo woodland (mesic-dystrophic savanna, here dominated by *Julbernardia* and *Brachystegia* species) on the lower slopes has a mean annual rainfall of 800 mm and a mean annual temperature of 21°C. By contrast, the montane forests and grasslands of the plateau average 2500mm rainfall and 16°C, dropping to an average minimum of 5°C in the montane forests and grasslands on the plateau and southern slopes. The reserve protects a number of catchment sources from erosion. It also shelters considerable biological diversity that includes a greater variety of wildlife than any other forest reserve in Malawi and over thirty endemic flora species (Chapman 1962; Edwards 1985; Wild 1964), including the threatened *Khaya anthotheca* (Welw.) C. DC., *Philippia nyasana* Alm and T.C.E. Fries (IUCN Species Survival Commission 2000).

The reserve also serves as a tourist attraction and a source of high quality timber, including the *Widdringtonia whytei* Rendle, which is now considered endemic to Mulanje (Pauw and Linder 1997) "Mulanje Cedar is Malawi's national tree and is considered "vulnerable" on the 2000 IUCN Red List (IUCN Species Survival Commission 2000). *Pinus patula* Schiede ex Schltdl. & Cham., an exotic originally planted for timber, is part of the threat as it was become invasive on the mountain.

A large *Eucalyptus* plantation in the southeastern portion of Mulanje was intended to supply fuelwood and charcoal locally and to urban centers, though the high cost of transport has limited progress towards reaching objectives. The average population density around the reserve in 1996 was 211 persons km^{-2}, with the greatest concentration on the southern side of the reserve near Malawi's most productive tea estates. This population was 46% male in 1996, and 21% had attended school beyond junior primary. Household size averaged 5.3 persons holding 0.8 ha of land, and 29% of these households were female-headed. The dominant ethnic groups were Lomwe (58%) and Manganga (29%).

LIWONDE NATIONAL PARK

In the Upper Shire River valley, the riverine-lacustrine Liwonde plain, originally defined as a Controlled Area for managed game hunting, was constituted as a National Park in 1972. In 1976 a corridor was added in the northeast to facilitate elephant movements to and from Mangochi Forest Reserve In addition, a 1 km wide by 35 km long strip was added to the western bank of the Shire to act as a buffer for wildlife. Centered on 14°50'S, 35°21'E, today the Park encompasses 54,633 ha of predominantly flat topography, broken by the Chiunguni Hills, a foyaitic ring-complex rising from 450m to 900m above sea level in the southern end of the Park. Along the Shire, Liwonde has extensive marsh and floodplain areas that include both palm (*Borasus aethiopum* Mart.) and reed (*Phragmites mauritianus* Kunth.) communities. In the main body of the Park, mopanic and gleyic soils ill suited for agriculture cover alluvium and gravelly colluvium underlain by Pre-Cambrian gneiss (Pike and Rimmington 1965; Venema 1991). The mean annual rainfall in the Park is 1000mm, while the mean annual temperature is 24°C, with a minimum average of 14°C. Liwonde protects wildlife in the Upper Shire and is a Malawian example of Mopane Woodland, broad-leafed, lowland, drought deciduous woodland and savanna dominated by mopane (*Colophospermum mopane* (Kirk ex Benth.) Kirk ex Léonard). Three years after being declared extinct in Malawi, the first black rhinoceros (*Diceros bicornis* L. *minor*) were introduced to a sanctuary within the Park in 1993 (Bhima and Dudley 1997), and in 2000 the population is five. Once in decline, the Park is home to the only elephant (*Loxodonta africana* Blumenbach) population in the country that has grown significantly in the past 20-25 years (Bhima and Bothma 1997). Tourism is the official primary use of the park, with a primary objective to attract high revenue tourists to Malawi. A wire fence on the more densely populated western edge of the Park and security measures combine to enforce stricter protection in Liwonde than in all other protected areas in Malawi. The Park also serves a critical catchment protection role for the Shire River, the primary source of the country's electricity. The average population density around the Park in 1996 was 166 persons km^{-2}, with heavier concentrations along the northeastern corridor. The boundary population was 48% male in 1996, and 14% had attended school beyond junior primary. Household size averaged 4.7 persons holding 0.9 ha of land, and 28% of these households were female-headed. The Yao ethnic group accounted for 78% of the boundary population in 1996.

DZALANYAMA FOREST RESERVE AND RANCH

The history of protection in Dzalanyama, which means "full of wild animals" in Chichewa (the primary indigenous language), actually began with the creation of a game reserve called Central Angoniland in 1911. The decline in big game and concern over water shifted protection emphasis to water and soil, and the Dzalanyama Forest Reserve was constituted in 1922. In 1966 the Malingunde dam was built, the first of two dams fed from Dzalanyama tributaries that account for 30% of all water needs for Lilongwe. Four years later Dzalanyama became the largest protected area in Malawi to be managed by two different government agencies when 66,574 ha of its lowlands were opened to a livestock scheme called Dzalanyama Ranch. Centered on 14°20'S, 33°22'E, the reserve today encompasses 98,827 ha of terrain ranging from low lying, open Miombo and dambo areas (grasslands in seasonally inundated drainage lines) at 1,100m, to the more closed-canopy Miombo of the Dzalanyama Hill Range that peak at nearly 1,700m in elevation (Ngalande 1995). Eutric-fersialic soils cover much of the alluvium and colluvium that is underlain by a Precambrian Basement Complex of granulites, gneiss and schists (Brown and Young 1965; Lorkeers and Venema 1991). The lowland soils outside the dambos are largely suitable for agriculture (Orr *et al.* 1998). The lowlands of Dzalanyama average

1050mm in annual rainfall, while the highlands average 1350 mm. The mean annual temperature for the reserve is 20°C, with a minimum average of 10°C. The natural woodland and almost 5,000 ha of mainly plantations in *Pinus kesiya* Royle ex Gordon, *Eucalyptus camaldulensis* Dehnh., and *E. tereticornis* Sm. supply fuelwood locally and to the Lilongwe metropolitan area. The western edge of the reserve runs along a forested area in Mozambique that has seen limited use over the past 25 years. The rest of the reserve is bounded by a population averaging 119 persons km^{-2}, with heavier concentrations near tertiary roads that lead to the main Mchinji-Lilongwe-Dedza highway. The boundary population was 47% male in 1996, and 19% had attended school beyond junior primary. Household size averaged 5.1 persons holding 1.6 ha of land, and 22% of these households were female-headed. The Chewa ethnic group accounted for 99% of the boundary population in 1996.

VWAZA MARSH WILDLIFE RESERVE

Originally a controlled hunting area, what is today Vwaza Marsh Wildlife Reserve was officially constituted in 1977. Centered on 11°00'S, 33°28'E, four major landscape classes have been identified within Vwaza's 98,214 ha. From east to west, these include: (a) a hills with shallow, rocky, paralithic soils, underlain by a biotite gneiss basement complex; (b) gently sloping pediments of Karroo sediments, biottite gneiss and dolerite dykes, covered by sandy, eutric-ferralic soils; (c) alluvial plains that are inundated most of the year, comprised of mostly fine textured, gleyic and mopanic soils; and (d) plateau areas underlain by deeply weathered gneiss and quartzite, forming high infiltration, eutric-ferralic soils (McShane 1985; Paris 1991b; Young and Brown 1962). Elevations in Vwaza range 1050m in elevation at Lake Kazuni to over 1600 m at Mohohe Hill in the northeast. Rainfall in the south and west of the reserve averages at 800mm, and reaches 1,100 in the northeast. . The mean annual temperature for the reserve is 20°C, with a minimum average of 10°C.

The majority of Vwaza Marsh is made up of *Brachystegia-Julbernardia* Miombo woodland, though some montane woodland, dambo grassland, mopane woodland, and thicket associated with perched water tables are also present. The reserve is rich in both flora and fauna, with 1,200 plant, 427 bird, 85 mammal, 34 reptile, and 22 amphibian species. Vwaza has a long history of trade related to wildlife dating back to the 18th century. The elephant population, estimated at 250 in 1985 has declined to the point that sighting assessments are no longer considered valid. Vwaza also contains the tsetse fly species *Glossina morsitans* and *G. pallidipes*, though Trypanosomiasis of cattle is endemic and an increasing number of sleeping sickness cases among humans have been reported since 1980 (McShane 1985). The eastern, Zambian side of the reserve is sparsely populated, while the land surrounding the Malawian boundary averaged 95 persons km^{-2} in 1996, a density due in part to the creation of numerous tobacco estates over the past 20 years, limiting customary land expansion. The boundary population was 48% male in 1996, and 39% had attended school beyond junior primary. Household size averaged 5.5 persons holding 1.8 ha of land, and 25% of these households were female-headed. The Tumbuka ethnic group accounted for 95% of the boundary population in 1996.

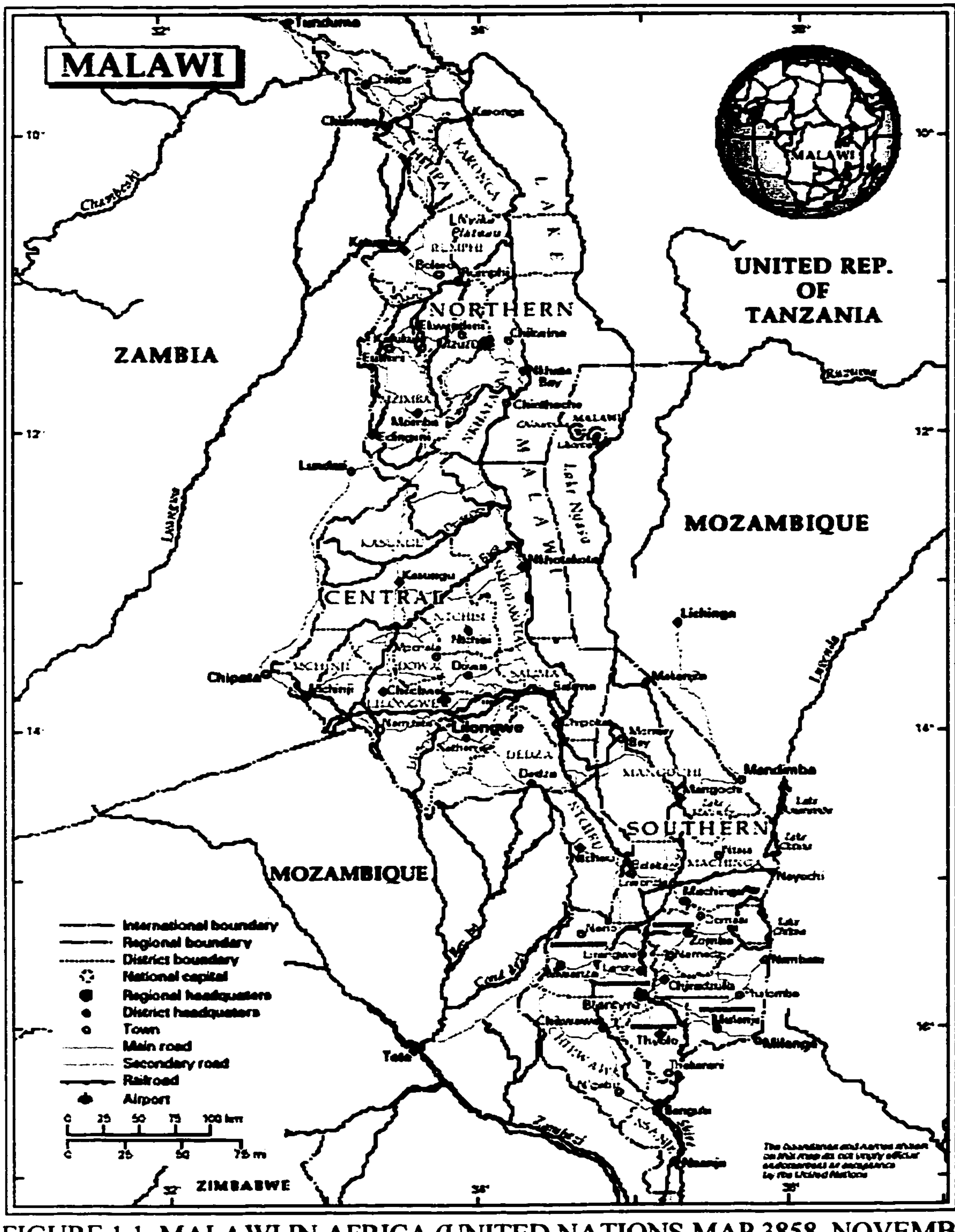

FIGURE 1.1. MALAWI IN AFRICA (UNITED NATIONS MAP 3858, NOVEMBER 1994).

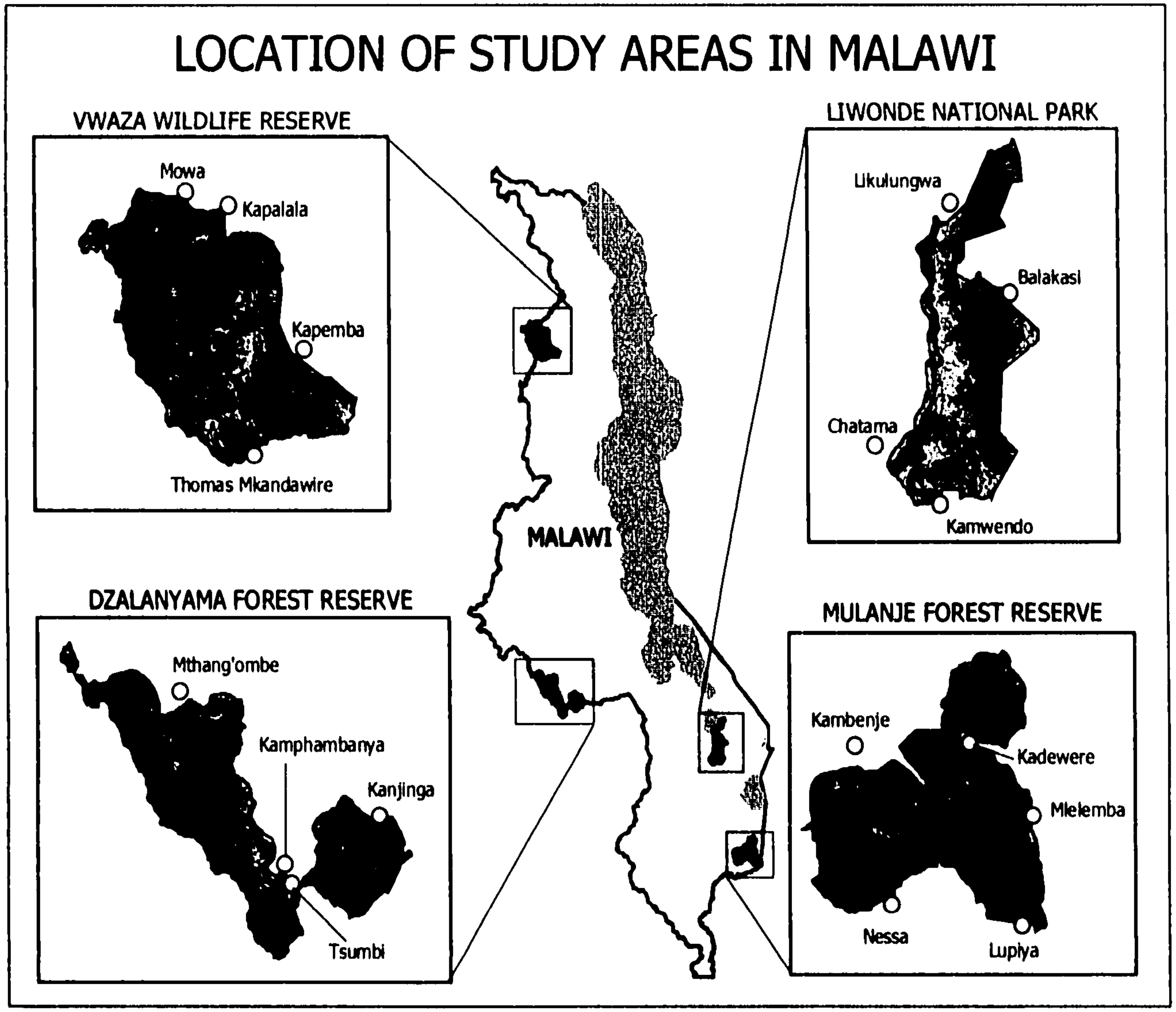

FIGURE 1.2. LOCATION OF STUDY AREAS WITHIN MALAWI.

EXPLANATION OF DISSERTATION FORMAT

The main body of this dissertation is contained in three appendices (A, B, and C). These are individual research manuscripts that are logically connected and integrated into the dissertation as a whole. All three manuscripts are based on data collected from 17 communities adjacent to four protected areas in Malawi (Figure 1.1) between 1996 and 1997, as well as spatial analysis of digital data layers that were created for the Public Lands Utilization Study over the same time frame.

RELATIONSHIP OF THE APPENDED MANUSCRIPTS

The first manuscript details the multidimensional field methodology that provided both baseline socio-economic information concerning household production and detailed, species level protected area resource utilization. It documents how the annual harvests of agricultural and protected area natural resource products were a) identified, b) measured (by volume in local units of measure), converted to weights in scientific units (kg), verified against on-site physical measurements and ancillary, key respondent interviews, and then valued.

The methodology represents a unique blend of tools used to gather livelihood security information and ethnoecological data. This combination permitted the assessment of the role protected area resources play in the livelihoods of those living in adjacent communities. In particular, the first manuscript assesses how the proceeds derived from protected area resource utilization impact equity in the distribution of income, and provide a means to overcome poverty for the poorest households.

The second manuscript focuses on how protected area resources represent a bridge between the goals of sustainable development and efforts to promote community-base natural resource management. It expands on the documentation of methods in the first manuscript by summarizing the quantity (kg) and value (Malawian Kwacha) of both agricultural production and protected area resource utilization. These results are presented on per capita basis, by species for each category of use for the four protected areas under study. They are then aggregated and analyzed in conjunction with projected population totals and then compared with an assessment of sustainable protected resource supply. The results demonstrate how the methodology can be useful in providing critical resource demand information at the species level, while also contributing to defining the context within which a resource management system that permits controlled extraction can be implemented.

The third manuscript brings the results of the first two manuscripts together into a Malawian case study application of the Boserup (1965) hypothesis on how higher population densities may spur spontaneous agricultural intensification, and the Tiffen, Mortimore, and Gichuki (1994) extension of this hypothesis that suggests community-initiated environmental amelioration may also result. It demonstrates how, despite high population densities, conditions in the Malawian context are not ripe for spontaneous agricultural intensification. Instead, poor smallholder households are basing both farming and resource utilization decisions on the absolute, short-term need to survive.

The strategy for poverty alleviation identified in the first manuscript proves, *ceterus peribus*, to have the potential for sustainability, as demonstrated in the second article. The third article applies the valuation results of the first two articles on a per hectare basis, comparing proceeds from agricultural against those derived from protected area use. Though protected area proceeds are clearly a strategy being used by poor households to overcome poverty, converting the land beneath those ecological resources into agriculture would provide much higher returns. The choice between land and forest proves to be obvious in short term economic terms, but far more costly in the long run, because agriculturally suitable land would be exhausted by the growing population in relatively short order, and the option of alleviating poverty through the exploitation of protected area resources would not longer be available.

CONTRIBUTION OF THE AUTHOR

All three papers were the result of research conducted in the framework of the Malawi Public Lands Utilization Study (PLUS), which the author of the dissertation coordinated from 1996 to 1998. PLUS provided a rich and comprehensive database of biophysical and socioeconomic data used throughout the dissertation. However all analysis, results and conclusions in the dissertation are original and unique, extending beyond those reported in the PLUS final report (Orr *et al.* 1998) submitted to the Malawian government and the study sponsor, the U.S. Agency for International Development.

With guidance from the dissertation committee, the research design, methodology, field logistics, data analysis, and interpretations for all three manuscripts were original contributions provided entirely by the author. The author collaborated with the co-authors of the first two manuscripts in data collection, supported by a team of eight enumerators and two vegetation specialists from the Forestry Research Institute of Malawi. The author collaborated with the co-author on conceptual design of the third manuscript. The staff of the Arizona Remote Sensing Center conducted the primary satellite image processing and spatial database construction that was used as a foundation for the analysis in the third manuscript. Finally, the author collaborated with the co-authors of all three manuscripts in the verification of results.

CHAPTER 2: PRESENT STUDY

SUMMARY

The literature review, data, methods, results, discussion and conclusions of this study are presented in the appended papers. The following is a summary of the most important findings.

METHODS

To capture the quantity and value of protected area resource demand, it was necessary to develop a multidimensional approach that documented baseline socioeconomic information and resource utilization in a quantitative, integrated manner. This approach involved the integration of qualitative and quantitative ethnobiological and socioeconomic information concerning household agricultural production and the use of plant and animal species from protected areas, as well as spatial analysis of biophysical data (see Appendix A for detailed summary). Central to this effort was a quantitative survey conducted in 1996-97 of 427 households comprised of 2,205 individuals in across the four protected areas. The survey was based on respondent recall of production and resource utilization activities, particularly at the species level. A coincident market survey was done to permit conversion of local volumetric measures to weights, and to establish retail prices for each species. Overlapping key respondent interviews captured specialized resource use (i.e., small enterprises involving fuelwood, charcoal, wild foods, hunting, handicrafts, tool making, healing, etc.). Data were collected through interviews conducted in the villages and in the protected areas during resource extraction. These surveys were essential in linking the size and price of final products back to the physical quantity of species used. This was particularly important for uses where the relationship between the weight of raw materials were greater than the weight of the product actually sold, or the unit of sale included the services of a specialist (i.e., a healer converting roots into a cure for an ailment and then selling both that cure and advice).

With the exception of the single formal survey, data were gathered through participatory methods: local inhabitants carried out the investigation, presentation, and preliminary analysis under the guidance and training of the research team (Campbell, Luckert, and Scoones 1997; Chambers 1990, 1994). The field research team was made up of four Malawian male and female enumerators conversant in the key local languages (primarily Chichewa, Chiyao, and Chitumbuka). The resulting data were coded and entered in the SPSS (Statistical Package for the Social Sciences 1998), where all aggregation and statistical analysis was conducted.

Species reported by households were physically verified (where possible) in 136 resource assessment plots (eight per village). A field botanist was present at all the assessment plots, working with local inhabitants to confirm all local names and match them to scientific equivalents for each species identified. Because scientific species names did not always correspond directly with local (and sometimes polysemic) names, a particular effort was made to incorporate local perceptions and classifications into all instrument responses and into how survey questions were posed (Martin 1995). The Forestry Research Institute of Malawi (FRIM) and the National Herbarium provided indispensable assistance with local species names. Other national experts, and Malawi's rich tradition of gathering ethnographic biological information, proved invaluable where local confirmation was not possible. The extensive plant dictionary of Binns (1972) was used for confirming Latin names. The works of Williamson (1975), Morris and Msonthi (1996), and Morris (1990) were essential for addressing gaps in local plant, fruit, and mushroom descriptions, and provided the foundation for evaluating species use.

The socio-economic analysis was intended to capture two key variables. The first addressed *household well being*, expressed in terms of both direct and non-direct household income. The second addressed *household protected area natural resource utilization*, broken into seven major use categories: food, fuelwood, fiber, tools, medicinal plants, and both wood and thatch for construction. Income estimates from all sources (direct and indirect) were compiled for each individual household and converted into per capita values (15 Malawi Kwacha = 1 USD).

For the first manuscript, the aggregate results provided an estimate of household income including that associated with protected area resources for1996. From this it was possible to calculate "reliance," or the proportion of total income derived from resources taken from the protected area. Variability in reliance among households was then analyzed to determine the role of protected area resources as an income generating activity, and its impact on poverty and the distribution of income. Reliance was obtained by assessing the distribution of income *without* protected area proceeds first, and then comparing that with an assessment *with* those proceeds. The specific tools used were standard quantitative methods for measuring inequality and poverty. These included a Lorenz curve, a Gini coefficient and polarization index derived from the Lorenz curve, and three poverty indices. The mathematical methods selected to parameterize the Lorenz curve and determine the underlying indices are defined in Appendix A. The actual calculations were conducted in POVCAL software, developed specifically for this purpose by the World Bank (Chen, Datt, and Ravallion 1992).

In the second manuscript, the results were evaluated at the species level by use. They were also aggregated to create a per capita estimate of protected area resource demand. A geographic information system (ESRI 1997; 2000) was employed to assess the sustainability of use over time. Rural population estimates based on population totals and growth trends derived from the 1998 census were mapped in a 5 km zone of influence adjacent to each protected area. Total protected area resource demand equaled the total population in the zone of influence multiplied by the mean per capita resource utilization estimates (kg) for 1996.

The threshold for sustainable protected area resource extraction was defined as the volumetric (m^3 ha^{-1} yr^{-1}) mean annual increment (MAI) of all woody biomass in the protected area, based on a roundwood equivalent (wood in its natural state as felled or otherwise harvested). Vegetation classifications created from 1994 Landsat Thematic Mapper satellite imagery during PLUS (Orr *et al.* 1998) were converted into biomass maps using MAI estimates for each vegetation type developed by FRIM (Masamba and Ngalande 1997). The threshold for sustainable extraction was the total of the MAI estimates for each vegetation class multiplied by the total hectares for each class across the protected area.

Estimates for total protected area resource demand per capita in 1996 were held constant and applied to population estimates based on 1987 through 1998 growth rates (Malawi Government 1998). The total demand for protected area resources was compared to the estimated sustainable supply through time to determine when that sustainable supply would be exhausted.

The third manuscript involved the spatial comparison of the value per hectare that could be derived from using protected area land for ecological resources versus the value that could be obtained from cultivating agriculturally suitable land. This involved the spatial integration of the results obtained in the first two manuscripts and an additional spatial analysis of agricultural suitability. The latter involved analysis of PLUS Maps of the agricultural suitability of land in all four protected areas that were generated from a Land Resources Evaluation Project (LREP) model and data produced by the Government of Malawi and FAO (Eschweiler *et al.* 1991; Orr *et al.* 1998). This manuscript also took advantage of vegetation classifications for 1984 and 1994 and a change detection analysis, both products of PLUS (Orr *et al.* 1998).

Analysis for the third manuscript involved three key comparisons: (1) resource utilization vs. agricultural land use values; (2) sustainability of ecological vs. land resources in the face of population pressure and competing uses; (3) the spatial correlation of negative change with points of high population pressure vs. sites of agriculturally suitable land within each protected area.

RESULTS

Each manuscript is appended (Appendices A, B, and C) Their findings are summarized here in direct reference to the seven fundamental research questions posed.

(1) *What are the per capita quantities and consumptive use-values of each species used for various uses, whether agriculturally produced or collected from the protected area?*

In all, 694 unique "used" species were identified in the formal survey. The quantities and values associated with that use are reported on a per capita basis for each category of use for the most important species in Appendix A. The result are presented graphically so that each of the four protected areas can be compared.

(2) *Are poorer households more reliant on protected area-based income?*

Regression analysis demonstrated that poorer households are more reliant on protected area-based income than wealthy households. The relationship between income and reliance was exponential, with a reasonable fit ($R^2 = 0.84$). On the basis of the high probability of significance of the t-statistic, the null hypothesis that per capita income (independent variable) has no impact on reliance was rejected. The shape and direction of the exponential curve fit suggests an inverse income–reliance relationship. On average, for every 100 MK increase in per capita income, the portion of income that is protected area-based can be expected to decline by 0.1%.

(3) *Do protected area proceeds influence overall equality in the distribution of income?*

Equality in the distribution of income, with and without protected area proceeds were evaluated with the Gini index (derived from a Lorenz curve), and then compared. When proceeds from protected areas are excluded from the rest of household income, the pattern of income distribution among households results in a Gini index of 56.3%. The ratio declines to 50.9% (more equity) when the protected area proceeds are included in the income totals.

(4) *Does the current supply of protected area resources meet current demand?*

The current demand of protected area ecological resources more than meets demand in all four protected areas.

(5) *Based on current patterns of use and population growth, when will demand outstrip sustainable supply?*

Using 1996 as a base year, and hold current utilization rates constant, the sustainable supply of protected area ecological resources can be maintained for 50 years in Mulanje, Liwonde, and Vwaza, and 100 years in Dzalanyama.

(6) *If protected area land suitable for agriculture was opened to cultivation, when would it be consumed, based on current patterns of land use and population growth?*

Using 1996 as a base year, the results show rapid conversion of agriculturally suitable land in Mulanje (5 years), despite low population growth rates, because only a small percentage of the mountainous reserve is suitable for agriculture. Liwonde's agriculturally suitable land would last only 8 years, while much larger Vwaza and Dzalanyama (which also have much larger per capita land holdings) would last 30, and 58 years, respectively.

(7) *What is the per hectare value of protected area land used for a) natural resource product utilization, and b) agriculture?*

The per hectare value of protected area natural resource product utilization ranges from 44.78 USD in Dzalanyama to 67.64 USD in Mulanje. The agricultural values are significantly higher, ranging from 188.84 USD in Liwonde to 316.23 USD in Dzalanyama.

(8) *Does spatial analysis of land cover change suggest negative impacts are associated with proximity to higher population densities (as would be the case if fuelwood extraction dominated the process) or with the distribution of agriculturally suitable land?*

Spatial analysis of land cover change between 1984 and 1994 shows limited spatial association between concentrations of high population adjacent to sites of negative land cover change. By contrast, there is a high association between agriculturally suitable lands and negative land cover change.

CONCLUSIONS

This research introduces a multidimensional field methodology that can provide both baseline socio-economic information concerning household production and detailed, species level protected area resource utilization. Using the example of four protected areas in Malawi, I have demonstrated how the annual harvests of agricultural and protected area natural resource products were: (a) identified; (b) measured (by volume in local units of measure); (c) converted to weight units, (d) verified against on-site physical measurements and key respondent interviews; and (e) valued in monetary units.

When collected data are aggregated to the household level, the importance of protected area-based income is evident. Poor households are generally more reliant on protected area resources than other households. In turn, that reliance has a major influence on the distribution of income between poor and rich households. Exploitation of protected area resources is a livelihood strategy that halved the number of households that would have remained beneath the basic needs poverty threshold. These findings have major policy ramification, not only for environmental management and conservation, but also for poverty alleviation.

In a society that is almost entirely dependent on agriculture households, and in particular poor households, low income households have created income-generating alternatives to maintain livelihood security. That these alternatives are based on protected area proceeds represents a challenge and an opportunity to those attempting to balance sustainable use and sustainable development simultaneously.

The methodology described here represents a unique blend of tools used to gather livelihood security information and ethnoecological data that have not been used traditionally to capture the role of protected area resources in household economies. This provides the opportunity to address and monitor the influence of those resources on local communities and gauge the ecological impact of resource demand.

The quantity and consumptive use value of protected area species can be used to inform natural resource management. Knowledge of the level of demand for individual species can be compared with field survey analysis of its ecological status to estimate the impact of extraction. Where rates of demand are deemed excessive, use of alternative species in the protected area can be promoted. Moreover, the role individual species plays in overall household income can be assessed. Substitutes among agricultural crops or livestock can be identified and, where desired, alternative income generating activities can be promoted to reduce pressure on specific species.

Variation was high among four Malawian protected areas in products extracted from them and the species that were used. In some cases this was due to biophysical conditions that favored specific species, or protection policies that target selected species, such as large mammals. In other cases, local preferences or the availability of alternatives explained the variation.

Despite this variation, for each use category, a few species dominated, none more than the multipurpose fruit tree, masuku (*Uapaca kirkiana* Müll. Arg.). This species was the most important protected area source of food, was very important for fuelwood, and was used for construction, fiber, and medicinal purposes. Our findings support the conclusion of both Ngulube (1995) and Malembo, Chilanga, and Maliwichi. (1998) who both found the pervasive use of masuku in the wild as in important factor supporting its candidacy for domestication as an agroforestry species.

Aggregation of woody species utilization data can also provide an estimate of overall protected area resource demand. In three of the protected areas studied, demand will exceed the sustainable supply of woody biomass within 50 years, and within 100 years in the fourth. This suggests that, barring any additional demand pressure, there is time to enhance community-based natural resource initiatives that are promoted for all four protected areas. In addition to their inherent institutional and management complexities, community conservation efforts must take these time constraints into account.

An analysis of aggregate sustainable use provides a context for natural resource decision making. The analysis, particularly when combined with species-level demand assessments and physical resource inventories, provides a set of monitoring tools for community management and conservation. Without regularly updated estimates of protected area resource demand, threats to individual species can only be assessed by impact on the resource, a metric applied only after damage is done. Providing resource demand information enhances management options and offers an understanding of the problem from the perspective of the user. Working without this information where managed use is encouraged limits the tools available to resource managers to find alternatives for threatened resources.

Poor households who actually use protected area proceeds to overcome poverty would still choose to covert those protected area land base to agriculture if given the option. There is strong indication in both the qualitative and quantitative data that those surveyed were aware of the longer term risks of converting protected areas to agriculture, and that they are equally aware of the immediate differences in consumptive use values of both the land and the ecological resources. This would seem to refute Carrasco's (1993) position that knowledge of the value of ecological resources might lead to conservation is unlikely when the difference between the value of land cultivation and consumptive use of natural resources is so large. The fact that protected area resources provide a critical income flow that compensates for insufficient land in many cases does not compensate for short-term risk. Our findings are more in line with Reardon (1998)– that poor households in Malawi are thinking about survival first, that they recognize conditions are not ripe for agricultural intensification as a solution, that they are aware that protected area resources may be only a stop-gap. The short-term risk in investing in either farming innovation or conservation overwhelms longer-term considerations.

Unfortunately, using protected area-based income for poverty alleviation has longer-term limitations as a livelihood strategy. The protected area results assume a system limited to those living within a 5 km zone of influence around each protected area. Yet supply and demand pressures on both land and ecological resources at the national-level suggest unsustainable demand, undermining the notion of a closed system. . Protected areas supply products not only to local populations, but society as a whole. Moreover, the total value of protected area resources to the whole of Malawi goes beyond the economics of simple consumptive use, to include genetic diversity, cultural, religious, aesthetic, and intrinsic natural value (Rolston 1985).

Demand for land and the demand for ecological resources will result in difficult choices at the local level. Reliance on protected area resources can provide much-needed alternatives to agricultural income in the short run where land is scarce. But in the longer term, this reliance may expose poorer households to the strong possibility that land demand will eventually overtake the resource base providing the alternative income stream. Government and donor environmental policies and their prescriptive interventions must consider replacing the poverty-alleviation function of protected area resources with income alternatives that are neither land nor forest-based. Furthermore, community conservation initiated by donor projects that do not address the large financial differences between the value of land and the value of ecological resources may actually accelerate the risk faced by the very communities to gain from such measures. As suggested by Shyamsundar and Kramer (1997), proceeds from protection (ecotourism, etc.) need to be reinvested in local communities to compensate for the value of foregone agricultural lands and secondary protected area products. In a country like Malawi, where conditions are not ripe for autonomous agriculture intensification, and income diversification is often through the exploitation of natural resources, investment must be directed towards the development of alternative income streams that give poorer households options. It is essential that these options are not entirely dependent on natural resources, and that they do not exacerbate already critical land shortages.

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A. APPENDIX A. INTEGRATING METHODOLOGIES FOR LIVELIHOOD SECURITY AND ETHNOECOLOGICAL ASSESSMENTS IN RURAL MALAWI

A.1 ABSTRACT

Orr, Barron J. *(Office of Arid Land Studies, University of Arizona, 1955 E. 6th Street, Tucson, AZ 85719, USA, barron@ag.arizona.edu)*, **L.N. Malembo, and Humphrey T. Chapama** *(Forestry Research Institute of Malawi, P.O. Box 270, Zomba, Malawi, frim@malawi.net)*. INTEGRATING METHODOLOGIES TO MEASURE THE ROLE OF PROTECTED AREA RESOURCES IN LIVELIHOOD SECURITY. *This study introduces a multidimensional approach that captures baseline socioeconomic information and resource utilization in a quantitative, integrated manner. It was based on a quantitative survey of 427 households across four protected areas in Malawi. Household income was derived from a "sum of the parts" aggregation of income elements including species-level agriculture production and resource utilization data. Regression analysis (R^2 = 0.84) demonstrated that poorer households are more reliant on income derived from protected resources than wealthy households. Lorenz curve analysis demonstrated that income distribution equity improves when proceeds from protected areas are included in household income. Poverty threshold analysis indicates that exploitation of protected area resources is a livelihood strategy that halved the number of households that otherwise would have remained beneath the basic needs poverty threshold. This study demonstrates that protected area resources play a pivotal role in poverty alleviation, and by extension, efforts to make sustainable use and sustainable development compatible.*

Key Words: protected area resources; valuation; livelihood security; inequality; income distribution; reliance; poverty threshold, participatory appraisal; Malawi.

A.2 INTRODUCTION

Poor rural households rely on natural resources extracted from protected parks and reserves, despite the potential for detrimental ecological impact. This deliberate livelihood strategy is intended to balance income against expenditure in normal times (Arnold and Falconer 1989; Guijt, Hinchcliffe, and Melnyk 1995). When basic livelihood security is threatened by unanticipated economic events, wild resource utilization also serves as a final safety net survival strategy (Garine and Koppert 1988; Luoga, Witkowski, and Balkwill 2000; Nurse 1975; Luckert *et al.* 2000; Zinyama, Matiza, and Campbell 1990). Despite the importance of wild resources in household economies, baseline assessments of livelihood security often fail to capture their role in anything other than broad or aggregate terms (Giuliano, Ilahiane, and Orr 1998), or ignore them altogether (Fleuret 1979).

Livelihood security assessments would benefit from a basic understanding of ethnobiological and economic aspects of ecological systems. Equally, biological conservation assessments would be enhanced by an understanding of the immediate causes of environmental degradation through analysis of regularly available, locally relevant socio-economic data (Bawa and Dayanandan 1997). Baseline livelihood security assessments and follow-up monitoring studies are conducted routinely in many developing nations for decision making or as a diagnostic tool for projecting and monitoring the impact of development projects. These assessments tend to target large areas, with relatively brief visits to study sites and thus could not replace long-term site and resource-specific ethnobiological research. However, methodologically integrated, regularly updated livelihood assessments could provide a unique and essential monitoring component to resource utilization and valuation studies

The data gathered in baseline livelihood security assessments are commonly used to measure poverty. By integrating methods to value plant and animal use, it is possible to quantify the relative impact of proceeds derived from protected areas on the distribution of income among a population. It also permits the assessment of the importance of protected area resources in the poverty alleviation strategies pursued by the poorest households.

Within this framework we developed a multi-dimensional approach to maximize the rapid collection of baseline socio-economic data drawn from livelihood security assessment methodology (Woodson 1997) and participatory rapid appraisal (Campbell, Luckert, and Scoones 1997; Chambers 1990, 1994) and combine them with ethnobiological resource valuation methods (Godoy, Lubowski and Markandya 1993). The approach was tested in communities around four protected areas in Malawi. The data collected permitted us to address four essential questions:

(1) What are the per capita consumptive use-values of agricultural production and protected area resource utilization among rural households?

(2) What is the relationship between protected area proceeds and all other major income components within rural households?

(3) Are poorer households more reliant on protected area-based income?

(4) Do protected area proceeds influence overall equality in the distribution of income?

A.3 STUDY AREAS

In 1997, 86% of Malawi's 9.65 million people lived in rural areas, translating into an average population density of 103 persons/km^2 of land, three times that of its neighbors (United Nations Population Division 2000). At the same time, 19% of Malawi's 94,000 km^2 of land is under protection in the form of four wildlife reserves, five national parks, and seventy-seven forest reserves (Orr *et al.* 1998), resulting in twice the per capita pressure on both protected and non-protected, wooded areas

To better understand the ramifications of this pressure, the Government of Malawi commissioned a Public Lands Utilization Study (PLUS) in 1996 to study both the environmental risks of converting protected land to agriculture and the importance of the reserves and their resources to adjacent communities (Orr *et al.* 1998). Four of the areas selected for intensive study are the subject of this research: Mulanje Forest Reserve, Liwonde National Park, Dzalanyama Forest Reserve and Ranch, and Vwaza Wildlife Reserve.

A.3.1 MULANJE FOREST RESERVE

Mulanje Forest Reserve, located in southeastern Malawi (centered on 15°57'S, 35°39'E, covering 56,314 ha of mostly mountainous terrain) has vegetation ranging from montane woodland and grassland on the plateau to miombo woodland (mesic-dystrophic savanna, dominated by *Julbernardia* and *Brachystegia* species) on the lower slopes. Steep slopes and shallow dystric-fersialic soils limit the agricultural suitability of the forest to some lowlands on the southern and eastern edge of the reserve (Pike and Rimmington 1965; Paris 1991a). The reserve protects a number of catchments from erosion and supplies both hard and softwood timber. It also shelters considerable biological diversity that includes a greater variety of wildlife than any other forest reserve in Malawi and over thirty endemic flora species (Edwards 1985). Mulanje lies in the most densely populated area of the four reserves (211 km^{-2} in 1996), with the greatest concentration on the southern side of the reserve near Malawi's most productive tea estates. This population was 46% male in 1996, and 21% had attended school beyond junior primary. Household size averaged 5.3 persons holding 0.8 ha of land, and 29% of these households were female-headed. The dominant ethnic groups were Lomwe (58%) and Manganga (29%).

A.3.2 LIWONDE NATIONAL PARK

Liwonde National Park is located in south central Malawi (centered on 14°50'S, 35°21'E, encompassing 54,633 ha) in the Upper Shire River valley, on a predominantly flat, riverine-lacustrine plain covered in mostly mopanic and gleyic soils ill suited for agriculture (Venema 1991). Liwonde protects biodiversity and wildlife in the Upper Shire and one of the few Malawian examples of mopane woodland (a broad-leafed, drought deciduous woodland and savanna dominated by *Colophospermum mopane (Kirk ex Benth.) Kirk ex Léonard*) (Bhima and Dudley 1997). It is the most important location for ecotourism in Malawi. Enforcement of protection is stricter in Liwonde than anywhere else in Malawi, due in part to a wildlife fence on the more densely populated western edge of the Park. It is also the base of operation for the nation's wildlife scout training program.

The average population density around the Park in 1996 was 166 persons km^{-2}, with heavier concentrations along the northeastern corridor. The boundary population was 48% male in 1996, and 14% had attended school beyond junior primary. Household size averaged 4.7 persons holding 0.9 ha of land, and 28% of these households were female-headed. The Yao ethnic group accounted for 78% of the boundary population in 1996.

A.3.3 DZALANYAMA FOREST RESERVE AND RANCH

Dzalanyama Forest Reserve is located in the central, western part of Malawi, (centered on 14°20'S, 33°22'E). It is Malawi's largest forest reserve, encompassing 98,827 ha of terrain. The western third of this area is close-canopy, upland miombo that borders a forested area of Mozambique that has seen limited human use over the past 25 years (Ngalande 1995). The rest is shared with a government agricultural scheme called Dzalanyama Ranch, located in a mostly low lying area of open miombo and dambo (grasslands in seasonally inundated drainage lines). The lowlands are dominated by eutric-fersialic soils that are suitable for agriculture (Lorkeers and Venema 1991). The portion of the reserve boundary facing into Malawi is bounded by a population averaging 119 persons km^{-2}, with heavier concentrations near tertiary roads that lead to the main Mchinji-Lilongwe-Dedza highway. The boundary population was 47% male in 1996, and 19% had attended school beyond junior primary. Household size averaged 5.1 persons holding 1.6 ha of land, and 22% of these households were female-headed. The Chewa ethnic group accounted for 99% of the boundary population in 1996.

A.3.4 VWAZA MARSH WILDLIFE RESERVE

Vwaza Marsh Wildlife Reserve (centered on 11°00'S, 33°28'E) primarily serves to protect biodiversity and wildlife, and to promote ecotourism (though current levels are well below that of Liwonde). Vwaza also serves to contain the tsetse fly; *Trypanosomiasis* of cattle is endemic and an increasing number of sleeping sickness cases among humans have been reported since 1980 (McShane 1985). The majority of Vwaza Marsh is situated on eutric-ferralic soils that are suitable for agriculture (Paris 1991b. Vegetation consists of mostly miombo woodland, though some montane woodland, dambo grassland, mopane woodland, and thicket are also present. The eastern, Zambian side of the reserve is sparsely populated, while the land surrounding the Malawian boundary averaged 95 persons km^{-2} in 1996. This density is greater than much of northern Malawi, due in part to the creation of numerous tobacco estates over the past 20 years, limiting customary land expansion. The boundary population was 48% male in 1996, and 39% had attended school beyond junior primary. Household size averaged 5.5 persons holding 1.8 ha of land, and 25% of these households were female-headed. The Tumbuka ethnic group accounted for 95% of the boundary population in 1996.

A.4 METHODS

A.4.1 APPROACH

This study was conducted with a multidimensional approach using on baseline livelihood security data collection methods developed in the Sahel and Haiti (Finan 1996; Woodson 1997), and then adapted to evaluate the flow of protected area resource product utilization as part of the Malawi Public Lands Utilization Study (Orr *et al.* 1998). A livelihood security approach uses a "rapid" survey of individuals and groups within an area that is conducted over a period of weeks. It is intended to capture both a quantitative and qualitative picture of household food stocks, flows, and patterns of consumption. While sufficient and useful for studying relatively large areas quickly, it is subject to some limitations associated with respondent recall over the period about which questions are asked. (Bernard *et al.* 1984; Nachman 1984).

In this study, rather than strictly food, we focused on natural resource utilization. This allowed us to develop a "multidimensional" approach that was based on other independent observations of resources and behaviors to corroborate survey respondent responses (Table A.1). We used a mix of overlapping qualitative and quantitative techniques both inside the home (where both male and female members participated), and inside the protected area, where activities could be observed and measured. Ultimately, results based on respondent recall were calibrated with an inventory analysis of resource utilization zones. Other than the formal survey, data collection was participatory in nature: local inhabitants carried out the investigation, presentation, and preliminary analysis under the guidance and training of the research team (Campbell, Luckert, and Scoones 1997; Chambers 1990, 1994).

TABLE A.1. SUMMARY OF DATA COLLECTION METHODS.

Data Gathering Activity	Primary Objectives
Rapid Appraisal (138 villages)	
Interviews with traditional officials	• Village list, locations, resource patterns
Community meetings	• Access to infrastructure, services, resources • Agricultural calendar • Off-farm income generating activities • Patterns of protected area use • Crop, livestock, wild species list
Focus group interviews (men and women separately)	• Qualitative specialized use • Land and resource tenure • Attitudes towards protection • Changes in resource availability/access
Intensive study (17 villages)	
Participatory mapping (men and women separately)	• Village spatial extent and infrastructure • Protected area vegetation • Present and past resource utilization
Key respondent interviews	• Quantitative specialized use *(223 respondents)* • Land and resource tenure • Village history/crisis/environmental change • Alternatives to protected area resources • Local unit volume and weight conversions • Local market retail prices
Resource assessment *(136 plots)*	• Total canopy cover • Ground cover (point frequency) • Species identification and use • Local name / Latin name verification • Woody species: Diameter at breast height (DBH) Height, species abundance • Herbaceous species Species cover
Formal survey *(427 households)*	• Intra-household variability • Demographics • Income (agriculture production, livestock, remittances, off-farm activities, etc.) • Protected area resource utilization

Data collection began in April 1996 with a three month pilot study at Zomba and Malosa Forest Reserves, and was completed in March 1997. The socio-economic research team included four men and four women to reduce gender bias. All members of the research team spoke Chichewa, as did all the respondents in Dzalanyama and Mulanje, and the majority in Liwonde. The team also included one Chiyao speaker for elderly respondents around Liwonde, and four native Chitumbuka speakers, for Vwaza Marsh respondents.

A resource assessment team comprised of a botanist and two forestry mensuration specialists worked inside each protected area adjacent to the villages selected for intensive study. During the pilot study these researchers were trained in the theoretical background of the livelihood systems approach and all participated in the resource assessment to gain familiarity with the ethnoecological aspects of the study. Both qualitative and quantitative survey instruments were created with feedback from the entire team. Each instrument was tested and modified during the pilot study. Because scientific species names did not always correspond directly with local (and sometimes polysemic) names, a particular effort was made to incorporate local perceptions and classifications into all instrument responses and into how questions were posed (Martin 1995).

A.4.1.1 Rapid appraisal

Research in each protected area began with a rapid appraisal to capture variation among localities and agroclimatic zones (Beebe 1995; Bruce 1989; Freudenberger 1995). Similar to the findings of Brouwer *et al.* (1997) in central Malawi, a "distance of use" survey revealed that villages further than 5km from the rarely used protected area resources. Due to uncertainties regarding topographic survey sheets and census maps, a list of villages within that distance was confirmed through meetings with the District Commissioner and with each Traditional Authority Chiefs (TA) responsible for land adjacent to the protected areas.

A random sample of these villages was selected, and the TA (or a designate) traveled with the authors and introduced them to village chiefs. The village chiefs helped arrange a community meeting and focus group meetings designed to elicit generally shared information on village and household livelihoods, including access to infrastructure, resources, and services, and the role of public lands and resources in local livelihood systems.

Community interviews focused on the history of the village and the use of protected area resources for food, medicine, fuel, and construction materials, and how availability and use of such resources has changed through time. Focus group interviews collected data on village infrastructure, access to resources, and livelihood activities, including the nature of agricultural practices (crops, seasonality, land, labor, conservation strategies), livestock, other income-generating activities (such as wage labor), periods of food insecurity and coping strategies for dealing with them, and patterns of public land resource use. With these qualitative data gathering techniques, 138 villages were sampled during the study. The data collected, including local species names and uses, was subsequently incorporated into participatory and formal survey instruments specific to each protected area.

A.4.1.2 Intensive Study

Patterns identified in the rapid appraisal were compiled and evaluated in conjunction with secondary agroclimatic and ecological data about each protected area. This was followed by a purposive selection of villages for more intensive study, designed to capture biophysical variability and its impact on livelihood systems and protected area resource use. Seventeen villages were selected across the four protected areas under intensive study.

Fieldwork in each village began with a multipurpose meeting with local residents. The three goals of these meetings were: (a) to generate a list frame of household heads for the formal survey, (b) to identify specialized users and other key respondents for interviews, and (c) to map resource utilization zones within the protected area. It was necessary to generate a timely list frame when it became apparent that census and drought-related food aid household lists were out-dated.

A.4.1.3 Key respondent interviews

The rapid appraisal revealed that some essential resource utilization and land tenure information held by a relatively small number of people in each village risked not being captured in a quantitative survey. Therefore, key respondents were targeted for interviews about specialized resource use (i.e. small enterprises involving fuelwood, charcoal, wild foods, hunting, handicrafts, tool making, healing, etc.), land and resource tenure, alternatives to protected area resources, village history and environmental change, prices, and local units of measure. These interviews were semi-structured, often taking place while the respondent was conducting an activity of interest. Where possible, the production process for converting raw resources into products for sale was observed and input/output quantities were measured.

A.4.1.4 Participatory mapping

The participatory mapping exercise was conducted with groups of men and women; each group was composed of individuals of varying ages and experience in resource use (Gupta *et al.* 1989; Momberg, Atok, and Sirait 1996). After delineating infrastructure, soils, and land cover (as part of context and scale training), each group mapped present land use and resource utilization on clear acetate over 1994 aerial photos (1:25,000). The resulting maps were used to evaluate the spatial extent and location of different resource utilization activities, and to determine where physical measurements should be taken.

A.4.1.5 Resource assessment

In order to verify species names, resource utilization patterns, and to assess impact, a resource assessment was conducted. The participatory mapping participants identified one male and one female inhabitant deemed most experienced in the utilization of resources from protected areas. These local experts accompanied the resource assessment team to each protected area vegetation type/resource utilization zone identified in the participatory mapping process. Together, they sampled a total of eight 100 m^2 plots per village and took a variety of ecological measurements in each (Table A.1). In support of the socio-economic analysis, the botanist and local representatives identified woody and herbaceous species in each plot, documenting the local and scientific name for each as well as observed and potential use. This information was then added to the quantitative survey questionnaire.

A.4.1.6 Quantitative survey

The sample for the formal survey was made up of 25 to 30 households drawn randomly from the list frame, with the gender of selected household heads in the same proportion as in the overall population. Recognizing the variable structure and strategies of households (Guyer and Peters 1987; Vaughan 1985; Wilk and Netting 1984), the social and physical unit in this study consisted of members who performed activities that sustained the unit and/or regularly took meals together, irrespective of permanent residence. It is necessary to further note that much of the survey analysis distinguishes between jointly-managed and female-headed households, since this latter group tends to constitute a relatively disadvantaged segment of the rural population. Approximately 28 percent of the sampled households were managed by single women, most of whom were either divorced or widowed. Households where the woman was considered the *de jure* legal and customary head (widowed, divorced, separated, or unmarried women) or the *de facto* head (where the male was absent for more than half the time) were considered female-headed (cf. Kennedy and Peters 1992).

The final data set for the formal survey included 427 households comprised of 2,205 individuals. Designed to capture intralocality variation, this survey instrument collected information in three critical areas: the household asset base (family labor, land,

and animals), access to non-agricultural income, and the detailed use of resources from the protected areas. These data were coded and entered in the SPSS (Statistical Package for the Social Sciences 1998) software system in Malawi, then analyzed at the University of Arizona using this same system.

A.4.2 KEY VARIABLES: INCOME AND NATURAL RESOURCE UTILIZATION

Much of the analysis focused on two variables that define the primary research questions presented above. The first variable was that of household *income*, expressed in terms of both direct and non-direct household income. The second variable was that of household *utilization* of protected area natural resources, broken into seven major categories: food, fuelwood, fiber, tools, medicinal plants, and both wood and thatch construction.

Income estimates from all sources (direct and indirect) were compiled for each individual household and converted into per capita values. *Direct* income was defined as the monetary compensation received by household members for wage labor, sale of agricultural products, remittances, and a variety of off-farm income generating activities, including sales of protected area natural resources. *Indirect* income was the composite of activities that have utility to the household, each being assigned an estimated value derived from local retail market prices. The income from these activities included the value of goods intended for consumption within the household, such as subsistence maize production and protected area resource utilization.

For assessment of both income and utilization, the methodology required annual household totals for categorized items. These were quantities (measured by weight) of agricultural outputs and protected area resources in some instances, and monetary values in others. Requesting annual totals was often contrary to local accounting methods. To calculate reliable annual totals, the modular design of the questionnaire encouraged interviewers to collect data in local units over time periods expressed by the respondent. These locally expressed quantities and time frames were then converted to standard values. All monetary values are reported in Malawian Kwacha (MK), where 1 USD = 15 MK during 1996 and 1997.

A.4.3 VALUATION IN THE MALAWIAN CONTEXT

The objectives of the study warranted assigning economic values based on a "total value of production" approach. This decision was based on the limited alternatives to smallholder agriculture and the essential role the collection of protected area resources plays in the study areas and in Malawi as a whole. This results from a lack of alternative labor markets, lack of arable land, limited technology, and limited access to agricultural inputs that have led many to pursue supplemental income through entrepreneurial activities.

In Malawi, the agriculture sector provides self-employment to 92% of the population. In Africa, only Burundi and Rwanda report a lower proportion of total population in urban areas than Malawi's 14% (World Bank 2000a). There are essentially no local labor alternatives to subsistence agriculture.

The vast majority of agricultural production and natural resource collection is conducted with manual technology on limited land holdings. It is estimated that 40-55% of smallholders in Malawi have land holdings of less than 0.7 ha. The Malawian government has determined that this amount of land is inadequate to produce enough food for subsistence needs (Chilowa 1998). Becker (1990) demonstrated that restricted land availability in Malawi forces rural families to diversify their labor supply to meet off-farm opportunities that might finance subsistence requirements rather than investing in new technologies or replacing farming income all together. Furthermore, subsistence activities that involve protected area resources (i.e. household fuelwood collection) in support of home production are not market replaceable under current land and labor conditions in Malawi (Engberg, Sabry, and Beckerson 1987).

The impact of agricultural inputs on returns to labor in Malawi is also limited. The use of agricultural inputs, free or purchased, is on the decline in Malawi. Following the removal of farm input subsidies in the early 1990's, the smallholder sector decreased its use of fertilizer by almost 75%, purchased only enough hybrid seed to plant 7% of the maize area, and reimbursed creditors for only 20% of the inputs purchased on loan (Carr 1997).

There are few or no opportunities for substitution within existing Malawian land and labor conditions, nor are there alternative technologies or agricultural production methods that might improve agricultural returns. Furthermore, protected area resource utilization is an irreplaceable element of household production. Therefore, the valuation employed in this research was based on total (rather than net) production and protected area resource utilization.

A.4.4 SPECIES IDENTIFICATION

The Forestry Research Institute of Malawi (FRIM) and the National Herbarium provided indispensable assistance with local species names. A field botanist was present at all 136 resource assessment plots, working with local inhabitants to confirm all local names for each species identified. These plots were not spatially nor temporally sufficient to capture all species (and their products) identified on village and household surveys. National experts, and Malawi's rich tradition of gathering ethnographic biological information, proved invaluable where local confirmation was not possible. The extensive plant dictionary of Binns (1972) was used for confirming Latin names. The works of Williamson (1975), Morris and Msonthi (1996), and Morris (1990) were essential for addressing gaps in local plant, fruit, and mushroom descriptions, and provided the foundation for evaluating species use.

Nomenclature for mammals was taken from Ansell and Dowsett (1988), birds from Benson and Benson (1977) and McShane (1985). Nomenclature for insects was taken from Sweeney (1970), and fish from Ribbink *et al.* (1983) and Tweddle and Willoughby (1979). These were all was supported by detailed ethnobiological descriptions of use (CCAM, 1992; Hayes 1978; Kelly 1993; Morris 1998).

A summary of the species by type and lifeform is contained in Table A.2. Of the 694 species encountered during the study, 101 local identifications, accounting for 4.6%

of the total protected area species used by households, could not be verified. The majority of these were annual forbs and insects physically unavailable at the time of data collection.

TABLE A.2. NUMBER OF SPECIES AND HOUSEHOLD OBSERVATIONS OF USE.

Wild Use Lifeform	No. of Species	Domestic Use Lifeform	No. of Species
Mammal	34	Animal	10
Bird	9	Field crop	44
Fish	18	Fruit tree	15
Insect	28	Wood tree	11
Honey	1		
*Mushroom	9		
Tree	235		
Shrub	54		
Climber	39		
*grass	46		
Forb	141		
Total species	614	Total species	80
Household observations of use	12,604	Household observations of use	3,720

*several of households could not provide individual species names for mushrooms and grasses.

Due to cultural and linguistic variation in protected areas and nearby villages, a number of local names were obtained for each species identified, the vast majority of which were available in species dictionary (Binns 1972). We therefore limited reporting here to the most common name cited during the data collection process.

A.4.5 QUANTITY AND WEIGHT ISSUES

Throughout the entire data collection period, local market surveys were carried out for the purpose of converting local units of measure into kilogram weights for a wide range of both domestic commodities and public land resources. Farming families rarely recalled agricultural harvest or forest utilization in standard units of measure. It was therefore necessary to identify common local units of measure, and then determine an average size for each of those units. Some local units of measure had a standard (e.g., "No. 10 Plate"), whereas others (e.g., "basket") were much more variable. During the pilot study measurements of each unit were made in a number of villages and markets to determine a typical unit. Examples of each local unit were then purchased for reference during data collection. Weighing scales were used opportunistically during household interviews and during the market surveys. However, it was not possible to capture all commodities in all possible local units of measure. To compensate, conversion factors among local units were determined by physical comparison tests, using a variety of commodities (Table A.3). "Between-unit" conversion factors are valid only where the volume of an individual item does not overwhelm the volume of the local unit (i.e. "plates of papayas").

These factors were used to calibrate physical weights obtained during the market survey in order to create a standard conversion table of local measures to kilograms. The conversions for agricultural crops are listed in Table A.4. Protected area species were more problematic because of limited samples, or no samples for rare or out-of-season items.

TABLE A.3. VOLUME CONVERSION FACTORS AMONG LOCAL UNITS OF MEASURE.

Local Unit of Measure	Med. Plate	No. 10 Plate	Basin	Lichelo	Basket	50 kg Bag	90 kg Bag	Dengu	Ox Cart
Medium Plate	1.00	1.77	4.33	6.20	15.15	26.62	47.91	75.42	633.57
No. 10 Plate	0.57	1.00	2.45	3.50	8.56	15.04	27.07	42.62	358.01
Basin	0.23	0.41	1.00	1.43	3.50	6.14	11.05	11.05	92.83
Lichelo	0.16	0.29	0.70	1.00	2.44	4.29	7.73	12.17	102.22
Basket	0.07	0.12	0.29	0.41	1.00	1.76	3.16	4.98	41.81
50 kg Bag	0.04	0.07	0.16	0.23	0.57	1.00	1.80	2.83	23.80
90 kg Bag	0.02	0.04	0.09	0.13	0.32	0.56	1.00	1.57	13.22
Dengu	0.01	0.02	0.06	0.08	0.20	0.35	0.64	1.00	8.40
Ox Cart	0.002	0.003	0.01	0.01	0.02	0.04	0.08	0.12	1.00

*"lichelo" is a basket lid, and "dengu" is an extra-large basket.

To compensate, resources extracted for food and medicinal purposes were grouped in size-equivalent classes based on other products identified by respondents as sharing similar size, shape and consistency. Physical descriptions of each protected area product were obtained in the field and then crosschecked with the ethnoecological literature. Average weights of plant parts extracted for medicinal purposes were derived from data collected in 28 key respondent interviews with healers. Table A.5 provides kilogram conversions for such size-equivalent class categories for food and medicinal items, with an example of protected area species that corresponds to each. Table A.6 provides live weights of livestock and wildlife species obtained from the literature (Cockburn 1982; Hayes 1978; Mason and Maule 1960; Owen 1975; Wollny *et al.* 1998).

TABLE A.4. WEIGHT CONVERSIONS AND PRICES FOR AGRICULTURAL CROPS.

Latin Name	Local/English Name	A	B	C	D	E	F	G	H	I	J	Price
		-- weights (kg) per local unit of measure --										MK kg^{-1}
Abelmoschus esculentus (L.) Moench	therere/okra	0.06	1.1	2.0	4.8	6.9	16.9	29.8	54	84	708	21.32
Allium cepa L.	anyezi/onion	0.17	1.2	2.2	5.3	7.5	18.4	32.4	58	92	771	6.50
Ananas comosus (L.) Merr.	nanasi/pineapple	0.81	1.8	3.2	7.8	11.1	27.1	47.6	86	135	1,134	7.90
Arachis hypogaea L.	mtedza/groundnuts	0.05	0.7	1.3	3.1	4.5	11.0	19.3	35	55	460	14.53
Artocarpus integer (Thunb.) Merr.	jakfruit/jackfruit	25.00										0.40
Brassica chinensis L.	tanapozi/Chinese cabbage	0.06	0.9	1.7	4.1	5.8	14.3	25.0	45	71	596	4.83
Brassica napus L. var oleifera DC	swidi/Swedish turnip	0.11	0.8	1.5	3.6	5.1	12.5	22.0	40	62	524	4.30
Brassica napus L. var esculenta DC	mpiru wotuwa/rape	0.05	0.4	0.7	1.8	2.6	6.3	11.1	20	31	265	4.25
Brassica oleracea L. var bullata DC	kabichi/cabbage	1.08	1.7	3.1	7.5	10.8	26.3	46.2	83	131	1,099	4.32
Cajanus cajan Millsp.	nandolo/pigeon pea		1.5	2.6	6.3	9.0	22.1	38.8	70	110	923	9.78
Camellia sinensi (L.) Kuntze	chayi/tea		0.3	0.6	1.5	2.1	5.1	9.0	16	26	215	20.00
Capsicum annuum L.	tsobola/Peppers	0.09	0.9	1.6	4.0	5.7	14.0	24.5	44	69	584	14.75
Carica papaya L.	mpapaya/papaya	0.96	1.7	3.1	7.6	10.8	26.4	46.4	83	131	1,104	1.92
Casimiroa edulis La Llave & Lex.	masuku a chizungu/Mexican apple	0.13	2.1	3.8	9.2	13.2	32.3	56.7	102	161	1,350	2.35
Citrus aurantifolia (Christm.) Swingle	ndimwe/lime	0.07	1.8	3.8	7.8	11.2	27.4	48.0	86	136	1,144	3.32
Citrus limonium (L.) Burm. f.	ndimu/lemon	0.20	1.9	3.4	8.3	11.9	29.1	51.1	92	145	1,217	5.20
Citrus sinensis (L.) Osbeck	malaanji/orange	0.18	2.2	3.8	9.4	13.4	32.7	57.5	103	163	1,368	6.95
Cocos nucifera L.	nkoko/coconut	0.27	0.8	1.4	3.5	5.0	12.2	21.4	38	61	508	7.48
Colocasia esculenta (L.) Schott	koko/coco yam leaves		0.2	0.3	0.7	1.0	2.4	4.3	8	12	102	1.20
Cucumis sativus L.	mankhaka/cucumber	0.20	2.0	3.5	8.6	12.3	30.0	52.6	95	149	1,253	10.11
Cucurbita maxima Duch. ex Lam	thengedza/pumpkin	0.31	1.2	2.1	5.2	7.5	18.3	32.2	58	91	767	2.71
Cucurbita pepo L. (leaves)	mussa/pie pumpkin (leaves)		0.2	0.3	0.7	1.0	2.4	4.3	8	12	102	3.50
Daucus carota L.	carrot/carrot	0.08	1.5	2.6	6.3	9.0	22.0	38.6	70	110	920	6.89
Dioscorea spl.	mpama/yam	0.29	1.9	3.4	8.4	12.0	29.4	51.7	93	146	1,230	1.55
Eleusine coracana (L.) Gaertn.	lipoko/finger millet		1.4	2.5	6.1	8.7	21.2	37.2	67	106	886	11.56
Glycine max (L.) Merr	soya bean/soya bean		1.9	3.4	8.4	12.0	29.3	51.5	93	146	1,227	19.07
Gossypium barbadense / G. hirsutum L.	thonje/cotton		0.1	0.1	0.2	0.3	0.8	1.5	3	4	35	20.00
Helianthus annuus L.	sanifulawa/sunflower		1.9	3.3	8.1	11.6	28.3	49.6	89	141	1,181	2.68
Ipomea batatas (L.) Lam.	mbatata/sweet potato	0.30	2.0	3.5	8.7	12.4	30.3	53.2	96	151	1,266	5.42
Lablab purpureus (L.) Sweet	guza/hyacinth bean		1.5	2.6	6.3	9.0	22.1	38.8	70	110	923	11.58

TABLE A.4 – *Continued.*

Latin Name	Local/English Name	A	B	C	D	E	F	G	H	I	J	MK kg^{-1}
Lactuca sativa L.	saladi/lettuce	0.33	0.8	1.5	3.6	5.2	12.7	22.3	40	63	532	5.10
Lagenaria siceraria (Molina) Standley	mphonda/gourd	0.31	1.2	2.1	5.2	7.5	18.3	32.2	58	91	766	2.71
Lycopersicon esulentum Mill.	mapwetekere/tomato	0.13	2.0	3.5	8.7	12.4	30.3	53.2	96	151	1,267	12.65
Macadamia integrifolia Maiden and Betche	macadamia/macadamia		1.9	3.4	8.3	11.9	29.1	51.1	92	145	1,217	13.01
Malus domestica Borkh.	apulo/apple	0.14	1.7	3.0	7.5	10.7	26.1	45.8	82	130	1,090	4.07
Mangifera indica L.	mango/mango	0.27	1.8	3.2	7.7	11.1	27.0	47.5	85	135	1,131	2.09
Manihot esculanta Crantz.	chinanga/cassava root	0.01	2.1	3.7	9.0	12.9	31.5	55.3	99	157	1,316	3.26
Manihot esculanta Crantz.	chinanga/cassava leaves	0.25	0.2	0.3	0.7	1.0	2.4	4.3	8	12	102	3.55
Morus alba L.	mapulesi/mulberry		1.3	2.3	5.7	8.2	20.0	35.1	63	100	836	7.58
**Musa paradisiaca / M. sapientum* L.	nthochi/banana	0.12	2.3	4.8	10.1	14.5	35.4	62.1	112	176	1,479	8.44
†*Nicotiana tabacum* L.	fodya/tobacco	0.10	0.1	0.2	0.4	0.6	7.6	21.1	38	60	502	21.75
Oryza sativa L. (Gram)	mpunga/rice		2.7	4.8	11.6	16.6	40.7	71.4	129	202	1,701	14.76
Pennisetum americanum (L.) K. Schum.	uchewere/bulrush millet		1.5	2.6	6.4	9.1	22.3	39.2	71	111	933	9.26
Persea americana Mill.	ovocado/avocado	0.85	1.9	3.4	8.3	11.9	29.2	51.2	92	145	1,219	6.67
Phaseolus vulgaris L.	khwanya/haricot or kidney bean		1.4	2.5	6.0	8.7	21.1	37.1	67	105	884	15.09
Physalis peruviana L.	jamu/gooseberry		1.4	2.5	6.2	8.9	21.7	38.1	69	108	906	6.99
Pisum sativum L. var. arvense Gams.	tuware/pea		1.3	2.3	5.8	8.2	20.1	35.3	64	100	841	13.00
Prunus persica (L.) Stokes	pichesi/peach	0.15	1.8	3.1	7.7	11.0	26.8	47.1	85	133	1,121	4.52
Psidium guajava L.	guwava/guava	0.16	1.6	2.9	7.1	10.1	24.7	43.5	78	123	1,034	3.89
‡*Saccharum officinarum* L.	nzimbe/sugar cane	0.50								54	454	1.50
Solanum melongena L.	magringana/egg plant	0.10	1.2	2.1	5.1	7.3	17.9	31.4	57	89	748	16.93
Solanum tuberosum L.	mbatata kachewere/potato	0.11	1.7	3.0	7.5	10.7	26.1	45.8	82	130	1,091	6.42
Sorghum bicolor (L.) Moench	mapila/sorghum		2.1	3.8	9.2	13.2	32.3	56.7	102	161	1,350	11.83
Stizolobium aterrinum Piper and Tracey	chitedze/velvet bean		1.6	2.8	6.8	9.7	23.7	41.6	75	118	989	6.55
Vigna radiata (L.) Wilczek	mphodza/gram bean		1.4	2.5	6.0	8.7	21.1	37.1	67	105	884	9.80
Vigna unguiculata (L.) Walp.	khobwe/cowpea		1.5	2.6	6.5	9.3	22.7	39.8	72	113	948	13.11
Voandzeia subterranea Thou.	nzama/bambarra groundnut		0.6	1.1	2.8	4.0	9.7	17.0	31	48	404	15.63
Zea mays L.	chimanga/maize		1.9	3.3	8.1	11.7	28.5	50.0	90	142	1,191	2.55

Local units of measure: A = individual item; B = medium plate; C = No. 10 Plate; D = basin; E = lichelo; F = basket; G = 50kg bag; H = 90kg bag; I = dengu; J = ox cart * M. paradisiaca and M. sapientum are also locally tabulated in "mkoko" or "bunches" (12.25 kg / mkoko). † N. tabacum is also locally tabulated in "bundles" (100.0 kg / bundle), and "boards" (12.0 kg / board). ‡ S. officinarum is also locally tabulated in "headloads" (9.0 kg / headload).

TABLE A.5. WEIGHT CONVERSIONS AND PRICES FOR PROTECTED AREA FOODS AND MEDICINES, GROUPED INTO CLASSES BY AGRICULTURE PRODUCT SIZE-EQUIVALENTS.

Size Equivalent	Species Example for Each Size Equivalent Latin Species Name	Local/English Name	A	B	C	D	E	F	G	H	I	J	Price MK kg^{-1}
			-- weights (kg) per local unit of measure --										
*food leaves	*Bidens pilosa* L.	chisoso/black-jack	0.01	0.2	0.3	0.7	1.0	2.4	4.3	8	12	102	1.55
grain	*Oryza longistaminata* Chev. and Roehr.	mpungaziwe/red rice		2.7	4.8	11.6	16.6	40.7	71.4	129	202	1,701	0.37
mulberry	*Securinega virosa* (Roxb. ex Willd.) Baill.	mpalapala/snowberry		1.3	2.3	5.7	8.2	20.0	35.1	63	100	836	1.33
gooseberry	*Syzygium cordatum* Hochst. ex Krauss	mchisu/water berry		1.4	2.5	6.2	8.9	21.7	38.1	69	108	906	1.40
masuku	*Uapaca kirkiana* Müll. Arg.	masuku/wild loquat	0.03	1.5	2.7	6.6	9.5	23.2	40.7	73	115	969	1.31
hard bean	*Tamarindus indica* L.	bwemba/tamarind	0.05	0.7	1.3	3.1	4.5	11.0	19.3	35	55	460	1.38
fleshy bean	*Vigna* spp.	chitambe/wild beans	0.05	1.5	2.6	6.3	9.0	22.1	38.8	70	110	923	3.43
peppers	*Hibiscus cannabinus* L.	sonkwe/Deccan hemp	0.09	0.9	1.6	4.0	5.7	14.0	24.5	44	69	584	1.09
guava	*Strychnos spinosa* Lam.	mateme/elephant orange	0.16	1.6	2.9	7.1	10.1	24.7	43.5	78	123	1,034	1.22
mango	*Myrianthus holstii* Engl.	makwakwa	0.27	1.8	3.2	7.7	11.1	27.0	47.5	85	135	1,131	1.12
coconut	*Adansonia digitata* L.	malambe/baobab	0.27	0.8	1.4	3.5	5.0	12.2	21.4	38	61	508	0.93
sweet potato	*Habenaria walleri* Reichb. f.	chikande/wild yam	0.30	2.0	3.5	8.7	12.4	30.3	53.2	96	151	1,266	0.25
papaya	*Telfairia pedata* (Sims) Hook.	matundu/oyster nut	0.96	1.7	3.1	7.6	10.8	26.4	46.4	83	131	1,104	0.29
breadfruit	*Treculia africana* Decne.	njale/African breadfruit	11.0	11.0	11.0	22.0	22.0	33.0	58.0	104	164	1,380	0.09
mushrooms	general mushrooms	bowa/nkhowani/bwawa	0.04	0.3	0.6	1.5	2.1	5.1	9.0	16	26	215	1.47
insects	*Termitidae* spp.	ngumbi/winged termite		0.2	0.4	1.1	1.5	3.8	6.6	12	19	158	8.04
†honey	honey	uchi/ng'oma/honey											13.90
small fish	*Barbus* spp.	matemba/small cypriaid	0.09	2.7	4.8	11.7	16.7	40.9	71.9	129	204	1,711	1.85
medium fish	*Oreochromis* spp.	chambo/chambo	0.90	3.6	7.2	12.6	18.0	44.0	77.3	139	219	1,840	1.11
large fish	*Clarias gariepinus* Burchell	mlamba/sharptooth catfish	3.58	1.8	3.6	10.7	17.9	43.8	76.9	138	218	1,830	1.40
*med. leaves	*Steganotaenia araliacea* Hochst.	mpoloni/carrot tree	0.01	0.2	0.3	0.7	1.0	2.4	4.3	8	12	102	58.44
*med. roots	*Zanha africana* (Radlk.) Exell	changaluche	0.11	0.5	0.9	2.1	3.0	7.3	12.9	23	37	307	20.30
*med. bark	*Cassia abbreviata* Oliv.	mchalamira/heartwood	0.01	0.2	0.3	0.7	1.0	2.4	4.3	8	12	102	58.44
med. fungi	*Coprinus africanus* Pelger	chibowachamuchitsa	0.04	0.3	0.6	1.5	2.1	5.1	9.0	16	26	215	58.44

Local units of measure: A = individual item; B = medium plate; C = No. 10 Plate; D = basin; E = lichelo; F = basket; G = 50kg bag; H = 90kg bag; I = dengu.
*leaves, roots, bark used for medicinal purposes and leaves used for food are also collected and tabulated in small "bunches" or "bundles" (0.25 kg / bundle).
† the local units for honey were litre bottles (1.44 kg / litre)

TABLE A.6. LIVE WEIGHTS AND PRICES OF ANIMAL SPECIES.

Latin Species Name	Local/English Species Name	Live Weight kg	Price MK kg^{-1}
Domesticated Animals			
Anas spp.	bakha/duck	2.7	14.72
Bos indicus Linnaeus	ng'ombe/cattle	195.5	11.46
Capra spp.	mbuzi/goat	19.4	12.45
Cavia porcellus Linnaeus	mbila/guinea pig	0.9	17.76
Gallus domesticus (Linnaeus)	nkhuku/chicken	3.6	10.70
Lepus spp.	kalulu/rabbit	1.8	16.23
Ovis spp.	nkhosa/sheep	40.0	10.00
Suis spp.	nkhumba/pig	125.0	3.01
Treron spp.	nkunda/pigeon	0.5	14.75
Wild Mammals			
Aepyceros melampus Lichtenstein	nswala/impala	59.0	3.80
Atelerix albiventris Wagner	kanungu/four-toed hedgehog	0.5	5.49
Cercopithecus albogularis Sykes	nchima/blue monkey	10.0	4.75
Cercopithecus pygerythrus F. Cuvier	pusi/vervet monkey	8.2	4.75
Cricetomys gambianus Waterhouse	ngwime/giant rat	0.9	5.49
Crocidura hirta Peters	fwilifwili/red musk shrew	0.5	5.49
Heliophobius argentocinereus Peters	mfuko/silvery mole rat	0.9	5.49
Herpestes ichneumon Linnaeus	nyenja/large grey mongoose	3.6	5.49
Hippopotamus amphibius Linnaeus	mvuu/hippopatamus	2268	1.05
Hippotragus equinus Desmarest	chilembwe/roan antelope	272.2	2.90
Hippotragus niger Harris	mphalapala/sable antelope	226.8	2.90
Hystrix africae-australis Peters	nungu/porcupine	20.4	4.75
Kobus ellipsiprymnus Ogilby	chuzu/waterbuck	272.2	2.90
Lepus saxatilis F. Cuvier	kalulu/scrub hare	0.5	5.49
Loxodonta africana Blumenbach	njobvu/African elephant	6000	0.10
Muridae family	mbewa/category of mice	0.5	5.49
Papio cynocephalus Linnaeus	nyani/yellow baboon	40.8	3.80
Paraxerus cepapi A. Smith	benga/bush squirrel	0.2	5.49
Petrodromus tetradactylus Peters	sakhwi/4-toed elephant shrew	0.2	5.49
Phacochoerus aethiopicus Pallus	kaphulika/wart hog	63.5	3.80
Potamochoerus porcus Linnaeus	nguluwe/bush pig	90.7	3.80
Procavia capensis Pallus	mbira/rock hyrax	4.1	5.49
Prondolagus rupestris A. Smith	kafumbwe/red rock hare	0.5	5.49
Raphicerus sharpei Thomas	mtungwa/Sharpe's grysbok	11.3	4.75
Redunga arundinum Boddaert	mphoyo/southern reedbuck	77.1	3.80
Sigmoceros lichtensteinii Peters	nkhozi/Lichtenstein's hartebeest	136.1	2.90
Sylvicapra grimmia Linnaeus	gwape/grey duiker	18.1	4.75
Syncerus caffer Sparrman	njati/African buffalo	680.4	1.67
Taurotragus oryx Pallas	tsefu/eland	680.4	1.67
Thryonomys swinderianus Temminck	nchezi/cane rat	0.9	5.49
Tragelaphus scriptus Pallus	mbawala/bushbuck	68.0	3.80
Birds			
Anthreptes colaris (Vieillot)	songwe/collared sunbird	0.2	5.49
Centopus spp.	nkuta/coucal	0.5	5.49
Francolinus afer (Müller)	nkhwali/red necked francolin	0.9	5.49

TABLE A.6. – *Continued.*

Latin Species Name	Local/English Species Name	Live Weight kg	Price MK kg^{-1}
Nectariniia senegalensis (Linnaeus)	songwe/scarlet-chested sunbird	0.2	5.49
Numida meleagris (Linnaeus)	nkhanga/helmeted guinea fowl	1.4	5.49
Streptopelia deciphens (Hartlaub and Finsch)	njiwa/mourning dove	0.5	5.49
Treron australis (Linnaeus)	nkunda/African green pigion	0.5	5.49
Turtur chalcospilos (Wagler)	katundula/emerald-spotted wood dove	0.5	5.49
Fish (and a freshwater crab)			
Bagrus meridionalis Günther	kampango/kampoyo cat fish	3.6	*0.72
Barbus spp.	matemba/small cypriaids	0.1	*0.72
Barbus brevicauda Keilhack	kadyakolo	1.7	*0.72
Clarias gariepinus Burchell	mlamba/sharptooth cat fish	5.2	*0.72
Engraulicypris sardella Günther	usipa/lake sardine	0.05	*0.72
Hippopotamyrus discorhynchus Peters	ngundamwala/Zambezi parrotfish	0.5	*0.72
Labeo mesops Günther	nchila/African carp	1.4	*0.72
Marcusenius macrolepidotus Peters	mphuta/bulldog	0.5	*0.72
Marcusenius nyasensis Worthington	samwamowa	0.5	*0.72
Opsaridium microlepis Günther	mpasa/lake salmon	2.3	*0.72
Oreochromis spp.	chambo/tilipia	0.8	*0.72
Rhamphochromis spp.	ncheni/tigerfish	0.8	*0.72
Serranochromis robustus Günther	nkakafodya/yellow-bellied bream	2.0	*0.72
Synodontis njassae Keilhack	chikolokolo/Malawi squeaker	0.5	*0.72
Potomonautes montivagus Chace F.	nkhanu/freshwater crab	0.05	1.85

*The 0.72 MK kg^{-1} fish price was used for all but Liwonde National Park, where market surveys showed a significantly higher price of 4.47 MK kg^{-1} due high demand from and easy access to nearby urban customers.

Assessing the quantity of biomass extracted for wood (fuel, construction, and tools) fiber, thatch, and handicrafts required a number of conversion factors. Wood volume to mass conversions were obtained from an urban biomass fuel study (Openshaw 1997), while all other local unit measurements were derived from the average of recorded measurements across all four protected areas in this study (Table A.7). Direct physical measurements were adequate to estimate quantity where a one-to-one relationship existed between biomass extracted and biomass sold or consumed (food, thatch, and fuelwood). Estimating the quantity of biomass extracted for medicinal purposes, fiber, tools, and handicrafts required additional information about the quantities extracted (often by plant part) used to create a final product. Though the random sample of the formal survey captured some of these specialized uses, it was necessary to conduct key respondent interviews to obtain more detailed estimates. This included interviews with 18 healers, 10 timber cutters, and 27 artisans making utilitarian handicrafts (baskets, mats, hand tools, etc.).

TABLE A.7. CONVERSION UNITS FOR WOOD, THATCH AND FIBER.

Local Unit of Measure	kg	Local Units of Measure Conversion Factors
*Solid cubic meter	667	9.7 headloads per ox cart
*Stacked cubic meter	367	25 wood poles per ox cart
Headload of fuelwood	32.6	3.6 wood poles per headload
Headload of thatch	23.6	12 bamboo poles per headload
Headload of bamboo	21.3	5 thatch bundles per headload
Wood pole	9.1	5 fiber bundles per wood headload
Bamboo pole	1.4	48.5 bundles per ox cart
Palm frond	1.3	
†Herbaceous fiber bundle	4.7	
†Palm fiber bundle	4.0	
†Agave fiber bundle	3.9	
†Woody fiber bundle	6.5	

* based on air dry wood (15% moisture content) from Openshaw (1997)
† this is the weight of the biomass extracted in order to make a bundle of fiber.

Though wood utilization was generally reported in "headloads" or "poles," a number of observations were reported as "whole mature trees" either on farmland or within a protected area. To estimate the biomass of a standardized individual tree, the average height (H) and diameter at breast height (DBH) for these species was calculated from resource assessment data, and then used in single tree volume equations obtained from the literature (Table A.8). Recent empirical research by Abbot, Lowore and Werren (1997) in Malawi provided single tree volume equations for Miombo woodland settings, addressing the majority of species identified in the study that were extracted whole. *Eucalyptus* and *Pinus* spp. and *Colophospermum mopane* were also reported as being extracted whole.

TABLE A.8. SINGLE TREE VOLUME EQUATIONS.

Type	Single Tree Volume Estimation Volume (and data source)	DBH cm	H m
Miombo (Canopy Species)	$\log_{10} V = -3.98 + 2.6 \log_{10} D$ (Abbot, Lowore, and Werren 1997)	19.1	11.6
Miombo (Understory Species)	$\log_{10} V = -3.87 + 2.43 \log_{10} D$ (Abbot, Lowore, and Werren 1997)	18.7	10.8
Eucalyptus spp.	$V = 0.000032141\ D^{1.87089668} * H^{1.12102097}$ (Shiver and Brister 1992)	14.8	21.2
Pinus spp.	$\log_{10} V = -4.674 + 1.8644 \log_{10} D + 1.3246 \log_{10} H$ (Malimbwi and Philip 1989)	21.2	20.1
Colophospermum mopane	Dried biomass (kg) = 0.85 * (-326 + 31.3 (D)) (Mushove *et al.* 1995)	21.5	12.2

V = total overbark volume (m3); D = diameter at breast height (cm), H = height (m)

A.4.6 PRICE

Items sold by households were valued directly by the retail price obtained from their sale in the market. Households valued subsistence production and protected area resource utilization on the price they would have paid if the items had been purchased (Chibnik 1978; Mellor 1966). These items were therefore assigned value based on retail prices reported by households or obtained during the local market surveys. Prices were captured when products were at market and averaged over the year.

The average retail prices for food and medicinal plants are reported in the final column of Tables 4 and 5. The average retail prices for meat (Table A.6) were based on live animal weights of species which were sold whole, or for the saleable meat weights for larger species butchered prior to sale (Fa and Purvis 1997; Martin 1984). Prices for all major wood, fiber, and handicraft categories are listed in Table A.9.

Local market retail prices for protected area food, fuel, thatch, and fiber products tended to be based more on the measurement unit of sale, regardless of the species sold (i.e. 5 MK per plate, 4 MK per headload, etc.). It was therefore possible to use the local market retail price of the closest substitute for those protected area resources for which a local price was unavailable (Godoy, Lubowski and Markandya 1993).

Key respondent interviews with healers revealed some variability in price among species used for medicinal purposes. However these data were not sufficient to assign differential prices by species. A price estimate generalized across species was possible by relating the revenue generated from the practice of healing to the weight of the plant part used to generate that revenue. A similar strategy was used for major utilitarian handicrafts (brooms, mats, baskets, wooden and bamboo hand tools), curios made for tourists, and timber. The pricing differential among species was captured through a cost structure assigned by the Malawian Forestry Department based on a royalty or volumetric assessment (Table A.9).

TABLE A.9. PRICES FOR BIOMASS USED TO CREATE WOOD AND HANDICRAFT PRODUCTS.

Vegetation Type	‡Royalty	Species Example for Each Vegetation Type	Local/English Name	Whole Tree	Tools/ Timber	Pole	Head-load	Fiber	Handi-craft
	--MK--	Latin name		-- price (MK kg^{-1}) --					
Miombo canopy	15.00	*Pericopsis angolensis* (Bak.) van Meeuwen	mwanga/afrormosia wood	0.10	0.63	0.21	0.13	0.31	0.63
Miombo canopy	50.00	*Vitex doniana* Sweet	ntonogoli/black plum	0.33	2.09	0.70	0.13	0.31	2.09
Miombo canopy	85.00	*Terminalia sericea* Burch. ex DC.	naphini/silver terminala	0.57	3.55	1.18	0.13	0.31	3.55
Miombo canopy	100.00	*Pterocarpus angolensis* DC.	mlombwa/African teak	0.67	4.17	1.39	0.13	0.31	4.17
Miombo canopy	170.00	*Khaya nyasica* Stapf	mbawa/red mahogany	1.01	6.30	2.02	0.13	0.31	6.30
Miombo understory	15.00	*Piliostigma thonningii* (Schumach.) Milne-Redh.	chitimbe/camelfoot	0.13	0.84	0.28	0.13	0.31	0.84
Miombo understory	100.00	*Apodytes dimidiata* E. Mey. ex. Arn.	muzaza/white pear	0.90	5.62	1.87	0.13	0.31	5.62
Miombo shrubs	15.00	*Byrsocarpus orientalis* (Baill.) Bak.	kamenenambuzi	0.06	0.06	0.06	0.13	0.31	0.55
Mopane	50.00	*C. mopane*	tsanya/butterfly-tree	0.17	1.06	0.35	0.13	0.31	1.06
*Mulanje cedar	155.72	*W. nodiflora*	mkungudza/Mulanje cedar	0.71	4.45	1.48	0.13	0.31	4.45
**Eucalyptus* spp.	10.59	*Eucalyptus grandis* W. Hill ex Maiden	bulugamu/flooded gum	0.10	0.66	0.22	0.13	0.31	0.66
**Pinus* spp.	48.35	*P. kesiya*	paini/kesiya pine	0.22	1.35	0.45	0.13	0.31	1.35
Palm	40.00	*Borassus aethiopum* Mart.	mlaza/Deleb fan palm			0.45	0.11	0.50	1.25
†Bamboo	1.00	*Oxytenanthera abyssinica* (A. Rich.) Munro	msungwi/common bamboo	0.70	0.70	0.70	0.70		1.25
Agave	n/a	*Agave sisalana* (Engl.) Perrine	khonje/sisal					0.51	1.25
Reeds	n/a	*Phragmites mauritianus* Kunth.	mbango/matete/reed grass				0.11		1.25
Thatch	n/a	*Hyparrhenia nyassae* (Rendle) Stapf	kamphe/bush thatch grass				0.11		1.25
Herbacious crafts	n/a	*Sida acuta* Burm. f.	masache/broom plant				0.11	0.43	0.55

*The Forestry Department prices species commonly used to make timber by the cubic meter, here converted to a "standard tree" as defined in Table 7.

†Bamboo royalties are charged by individual poles rather than whole plants.

‡The royalty for individual wood and bamboo species is assigned annually be the Malawian Forestry Department for sales to timber and carpentry companies.

A.5 DATA SUMMARY

By integrating data collection methods for the assessment of livelihood security and protected area resource utilization, aggregated species-level results can be presented from the perspective of the household. In order to normalize for variance in household size, most results are reported "per capita," and averaged to reflect each overall protected area.

A.5.1 DOMESTIC PRODUCTION

Domestic production included field crop and fruit trees cultivation, wood lots for fuelwood and timber, and livestock production. The mean per capita value of total domestic production in Dzalanyama (3,975 MK) and Vwaza (4,587 MK) was between 100 and 150% greater than that of Mulanje (1735 MK) and Liwonde (1705 MK). The major difference between the communities surrounding these reserves is access to land, primarily a function of population density. High population density around Mulanje and Liwonde limits farmers to half the land area for cultivation available to farmers around Dzalanyama and Vwaza (Table A.10).

TABLE A.10. POPULATION, LAND, AND AGRICULTURAL PRODUCTION.

Protected Area	Population Density persons km^2	Mean Land Holding ha $capita^{-1}$	Mean Crop Production kg $capita^{-1}$ yr^{-1}	Mean Crop Production MK $capita^{-1}$ yr^{-1}
Mulanje	211	.146	308.0	1658.36
Liwonde	166	.194	365.1	1553.23
Dzalanyama	119	.316	819.8	3238.98
Vwaza	95	.329	581.8	2424.46

A.5.2 PROTECTED AREA NATURAL RESOURCE UTILIZATION

Though many factors influence the level of natural resource utilization, inhabitants around all four protected areas raised the issue of barriers to access as most important. These included government agency efforts at protection (i.e. policing with forest guards, wildlife reserve and national park scouts, and fencing), and physical barriers (primarily distance from household, elevation and slope, and flooding). Table A.11 provides a relative assessment of barriers to access along with mean per capita figures for overall protected area resource utilization for each protected area.

TABLE A.11. BARRIERS TO PROTECTED AREA ACCESS AND OVERALL UTILIZATION.

Protected Area	Relative Level of Protection	Relative Ease of Physical Access	Mean Total Utilization	Mean Total Utilization
			kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}
Mulanje	Low	Very Difficult	873	388.51
Liwonde	Very High	Difficult	484	379.35
Dzalanyama	Low	Easy	1135	520.94
Vwaza	Medium	Easy	1449	681.90

Residents around Liwonde National Park reported the lowest natural resource utilization, due to protection, and at least in part, to fears of government detection of their activities. The fear may have inhibited some respondents, resulting in an underestimate of Liwonde utilization. However it should be noted that the most common request during the Liwonde rapid appraisal was for a tour of the Park in order to see, *for the first time*, the large wildlife species inside. While scouts are not constant fixtures on the boundaries, Liwonde is the base of training for wildlife scouts throughout Malawi, and is fenced on its more populated western boundary. One kilometer east of that boundary is the Shire River and its flood plain, encouraging a high fishing trade, but serving as an effective barrier to most other uses.

The exceptionally steep slopes of Mulanje Mountain and local beliefs about the plateau itself limited access to the lower slopes. Dzalanyama had the fewest physical barriers, and like Mulanje, is a forest reserve with fewer use restrictions and limited agency personnel available for protection. Inhabitants around Vwaza Marsh reported high levels of policing near a small government base camp at Lake Kuzuni, but much lower levels away from that camp. Flooding limited, but did not prohibit, access to parts of the reserve during the rainy season.

A.6 RESULTS AND DISCUSSION

Species-level data on the quantity and consumptive use value of protected area resources can be aggregated to assess the importance of protected area resource utilization for household livelihood strategies. In each category of use are essential elements of household production (i.e. fuelwood consumption), strategies to vary the diet or extend food stocks during vulnerable times (i.e. food), and the actions taken to diversify income risk (i.e. handicrafts). Taken in aggregate and compared with all other income, these data provide a sense of local community *reliance* on protected area resources. At the protected area-level, reliance on specific categories of resources can help the natural resource manager qualify the importance of demand in terms of alternatives. Comparing reliance across households can provide insight on how protected area resources influence both the struggle against poverty and the distribution of income.

A.6.1 RELIANCE

The most direct measure of the importance of protected area resources to the livelihoods of those living in adjacent communities is income. By capturing all elements of household production, including subsistence production and natural resource utilization, it is possible to calculate the proportion of total income that is protected area based. The relationship between these key variables – total income and income derived from protected areas – can be termed *reliance*. It describes the relationship of all income to that portion of income derived from protected areas, including protected area employment, direct petty commerce (i.e. sale of wild foods), indirect petty commerce (i.e. those proceeds from healing or brewing related to protected area resources), and home use of protected area natural resource products. Figure A.1 portrays mean per capita elements of income, including that, which is protected area based. It also displays the relative proportions provided by each element of income in percentage terms. Households adjacent to Mulanje and Liwonde generate less than half the income of those surrounding Dzalanyama and Vwaza. Yet the proportion of total income that was protected area derived is much higher (20.3 and 15.8% for Mulanje and Liwonde compared to 10.4 and 13.3% for Dzalanyama and Vwaza, respectively).

Some insight is gained by calculating reliance for major resource categories (Table A.12). Though protected area food prices tended to be lower than those for domestic agricultural food products, the percentage of plant and animal food that was derived from the protected area was high. Enforcement of government restrictions on resource use limited the plant food utilization around Liwonde, whereas adjacent to Vwaza, much higher per capita income resulted in few households requiring food supplements during the rainy season. Low levels of domestic livestock production were compensated by high levels of hunting in protected areas in all but Dzalanyama, where domestic livestock production was much higher than the other reserves. The importance of protected area wood and medicinal resources was high in all four protected areas.

TABLE A.12. PERCENTAGE OF TOTAL FOOD, WOOD, AND MEDICINES THAT WAS DERIVED FROM PROTECTED AREA NATURAL RESOURCS.

	Plant Food Biomass	Plant Food Value	Animal Food Biomass	Animal Food Value	Wood Biomass	Wood Value	Medicinal Value
				-- % --			
Mulanje	31	10	82	63	83	91	68
Liwonde	8	1	93	85	74	82	91
Dzalanyama	23	9	27	17	69	77	76
Vwaza	10	4	93	72	88	94	87

A.6.2 RELIANCE AND TOTAL INCOME

More insight into overall reliance by local populations on the protected areas is gained by investigating variation between households. McGregor (1995), using a wealth ranking exercise (poor vs. rich) and a diet study, found that poorer households were more dependent on miombo woodland resources than wealthy households in a communal area in Zimbabwe. Her research suggests that further differentiation of wealth might reveal patterns beyond the scope of a binary assessment. On that basis, we ranked and plotted estimates of per capita income for all 427 households, stacking the portion of income associated with protected areas on top of all non-protected area income (Figure A.2).

Household protected area resource utilization strategies vary considerably across the data set, however the pattern displayed suggests a greater portion of total income is protected area based for poorer households. We used the statistical technique of simple regression model with an exponential curve fit to confirm our visual interpretation. The regression model, $Y = ce^{bX}$, where Y = dependent variable, reliance (the percentage of income that is protected area based), X = independent variable, per capita income, b and c are constants, and e = equals the base of the natural logarithm. This was run on 30 equal groups of households (Table A.13). The values for each group were based on the mean per capita income and the mean portion of that income that was protected area-based to calculate the reliance percentage. The regression was run at the 95% confidence level.

TABLE A.13. SUMMARY OF REGRESSION RESULTS.

Model Summary

Exponential Curve Fit	R	R^2	Adjusted R^2	Standard Error of the estimate
	0.919(*)	0.844	0.834	0.182

* predictors: (constant), per capita income

ANOVA(†)

	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.036	1	5.036	151.899	.000(*)
Residual	0.928	28	.0332		
Total	5.964	29			

* predictors: (constant), per capita income
† dependent variable: reliance

Coefficients*

	Coefficients	Std. Error	t-stat	Sig.
(Constant)	0.295	0.013	22.302	0.000
per capita income	-8.79E-05	7.13E-06	-12.325	0.000

* predictors: (constant), per capita income

The overall model, tested with the F-statistic, was significant at the 0.001 level. The significance of the independent variable (per capita income) was tested with the t-statistic, and proved to be significant at a probability level of 0.001. While these two statistics provide evidence in favor of the model, the role of the R^2 statistic is limited to providing some indication of goodness of fit of the sample in a body of data (Gujarati 1995). In this analysis, the R^2 statistic of 0.84 suggests a reasonable fit of the exponential curve fit model (Figure A.3).

On the basis of the high probability of significance of the t-statistic, the null hypothesis that per capita income has no impact on reliance can be rejected. The shape and direction of the exponential curve fit suggests an inverse income–reliance relationship. On average, for every 100 MK increase in per capita income, the portion of income that is protected area-based can be expected to decline by 0.1%.

A.6.3 DISTRIBUTION OF INCOME AND POVERTY

The results of the reliance model suggest inhabitants of nearby communities rely on protected areas for a substantial portion of their income, and that reliance is greater for poorer households. These results, however, do not fully explain the influence of reliance on protected areas as a strategy against poverty. Does the fact the poorer households show greater reliance actually impact the distribution of income, and does it play a role in poverty alleviation?

One method (proposed by Loomis 1993) of addressing these questions is to conduct a “without and with” analysis. In this case, we assessed the distribution of income *without* protected area proceeds first, and then compared the results to an assessment *with* those proceeds. The specific tools used were standard quantitative methods for measuring inequality and poverty. These included a Lorenz curve, a Gini coefficient and polarization index derived from the Lorenz curve, and three poverty indices. The mathematical methods selected to parameterize the Lorenz curve and determine the underlying indices are listed in Table A.14. The actual calculations were conducted in POVCAL software, developed specifically for this purpose by the World Bank (Chen, Datt, and Ravallion 1992).

TABLE A.14. POVERTY MEASURES AND ONE POLARIZATION MEASURE FOR THE GENERAL QUADRATIC PARAMETERIZATION OF THE LORENZ CURVE.*

Equation of the general quadratic Lorenz curve (L(p))	$L(1-L) = a(p^2 - L) + bL(p-1) + c(p-L)$ or, $L(p) = -[bp = e + (mp^2 + np + e^2)^{1/2}]/2$	Villaseñor and Arnold (1989)
Headcount index (H)	$H = [n + r(b + 2z/\mu)\ \{(b + 2z/\mu)^2 - m\}^{-1/2}]/(2m)$	Dutt and Ravallion (1992)
Poverty gap index (PG)	$PG = H - (\mu/z)L(H)$	Dutt and Ravallion (1992)
Foster-Greer-Thorbecke poverty index (P_2)	$P_2 = 2PG - H - (\mu^2/z^2)[aH + bL(H) - (r/16)\ln\{(1 - H/s_1)/(1 - H/s_2)/\}]$	Foster, Greer, and Thorbecke (1984)
Wolfson polarization index (W)	$W = 2(\mu^{COR} - \mu^L)/med$	Wolfson (1994)

*Adapted from Dutt and Ravallion (1992).
z = the poverty line; μ = mean income; L = the Lorenz curve; $L(p)$ = parameterized Lorenz curve; a, b, c, are constants in the general quadratic form; $e = -(a + b + c + 1)$; $m = \mu^2 - 4a$; $n = 2be - 4c$; $r = (n^2 - 4me^2)^{1/2}$; $s_1 = (r-n)/(2m)$; $s_2 = -(r+n)/(2m)$; G = Gini coefficient; μ^{COR} = distribution-corrected mean income = $\mu(1-G)$; μ^L = the mean income of the poorest half of the population; med = median income.

A.6.3.1 Measures of inequality

The Lorenz curve was first proposed by statistician Max Lorenz in 1905 as a method to compare wealth through a cumulative income curve. Coined the "gold standard" for the concept of inequality (Wolfson 1994), it is the most commonly used distributional tool for assessing cumulative income in a population. The curve plots the proportion of total income (vertical axis) received by the bottom 1%, 5%, 50%, etc. income earners against the corresponding population proportion (horizontal axis) so that mean income equals unity (Figure A-4). The curve must pass through the two corners and be convex, and the state of perfect equality would lie exactly across the diagonal at 45° (Amiel and Cowell 1999). For complete inequality, in which only one person has all the income, the Lorenz curve would coincide with a right angle made by the lower and right boundaries of the curve. In Figure A-4, we compare the distribution of income that is a) inclusive of protected area proceeds and b) exclusive. Regardless of the difference in total value, if these two measures of income are distributed in the same proportions across all households, the two curves would coincide. Instead, we find that income inclusive of protected area proceeds is more equitably distributed (that is, closer to the 45° egalitarian line).

The most common measure of dispersion within group values represented by the Lorenz curve is the Gini index (*G*), developed by Corrado Gini in 1912. It is defined as the arithmetic average of the absolute values of differences between all pairs of incomes (Sen 1973, p. 31),

$$G = (1/2n^2\mu)\ \Sigma^n_{i=1}\ \Sigma^n_{j=1}\ | y_i - y_j |$$

Where n = number of persons, $i = 1, \ldots n$, y_i = the income of person i, y_j = the income of person j, and μ = the average level of income.

It is therefore the area of the lens-shaped piece formed by the diagonal line of absolute equality and the Lorenz curve itself, divided by the area of the entire triangular region underneath the diagonal. The larger the coefficient, the greater the degree of dispersion, implying greater inequality. It can be generally stated that more highly developed countries tend to have lower differentiation of income (expressed as percentages, a Gini index of 25 to 40%) while developing nations tend to have higher differentiation (45 to 60%).

The income distribution in this study results in a Gini index of 56.3% when proceeds from protected areas are excluded (Table A.15). The ratio declines to 50.9% (more equity) when the protected area proceeds are included in the income totals.

TABLE A.15. DESCRIPTIVE STATISTICS AND INEQUALITY INDICES FOR INCOME WITHOUT AND WITH PROTECTED AREA PROCEEDS.

	Descriptive Statistics Per Capita Annual Income (MK)			Inequality Indices	
				Dispersion	Polarization
	Mean (μ)	Standard Deviation	Median	Gini (G) %	Wolfson (W) %
Without protected area proceeds	3646.65	4783.31	2074.02	56.3	57.1
With protected area proceeds	4320.25	4937.69	2706.02	50.9	50.2

The Gini index may not capture changes in income by the middle strata, a phenomenon Wolfson (1994) calls the "disappearing middle class." To assess this possibility, a polarization index was also calculated. When there is complete equality there is no polarization. Polarization increases as the index increases, until a hypothetical maximum is reached where half the population has zero income and the other half has twice the mean. Here, the magnitude and direction of change in the polarization index were very similar to the Gini index results (57.1 and 50.2%, respectively). This suggests a more equitable distribution of income associated with the addition of protected area livelihood strategies was accompanied by a decline in polarization.

Although popular, the Gini index gives little insight into the location and concentration of income inequality among high- versus low-income groups (Foster 1992, p. 146). This problem can be addressed in part by calculating relative income shares (Figure A.5), as the World Bank does in its World Development Reports (e.g. World Bank 2000b). The inequitable distribution of income common in developing countries is evident, and corresponds with the results of the Lorenz and Gini analyses. Note that the addition of protected area-based income results in a more equitable overall distribution, with a decline in the share held by the richest group and increases in the other four groups. The percentage changes in relative income share are more evident illustrated in Figure A.6.

A.6.3.2 Measures of poverty

Change in relative income share suggests that protected area livelihood strategies play a central role in poverty alleviation for communities adjacent to the four protected areas. However, to understand poverty, the assessment of the distribution of income must be augmented by its relationship to a pre-determined poverty threshold. Two poverty thresholds were considered, one based on basic human needs and the other based on an arbitrary reference based on the national survey data that indicate 32% of Malawi households are below the poverty threshold.

The "basic needs" poverty threshold relates minimum nutritional requirements to the energy provided by a primary diet staple, which in turn can be converted into a value based on the market price of that staple. In the case of Malawi, the Government of Malawi, the Food and Agriculture Organization, the World Health Organization combined forces to determine the dietary and energy requirements needed to meet the nutritional needs of healthy persons (Johnson 1996). The values assessed for all classes of people (i.e. men, women, children, pregnant women, etc.) were multiplied against population estimates for each category for all of Malawi to create a single per capita energy requirement figure. The annual maize requirement necessary to supply that energy is 170.3 kg per capita of Malawian maize. Multiplied by the average price of maize over the study period (2.55 MK), and increased to reflect that food represents about 65% of total expenditures of poor households (World Bank 1996), we calculated the "basic needs poverty threshold" in Malawi to be 668.10 MK in annual income in 1996/97.

Theoretically, the poorest third of households in Malawi should fall below this threshold if the income data in our study were based on the same factors considered in the national studies. However, our research included all aspects of subsistence production and protected area resource utilization, the majority of which are not captured in the national studies. Thus, we calculated a second "poverty reference threshold" (1700.00 MK) to include the poorest 32% of all households to reference the national prevalence of absolute poverty reported by the World Bank (1996).

Next we selected three poverty measures from among the many available in the literature, basing our decision on the practices of major development organizations such as the World Bank. Assessing poverty by a single measure, such as the percentage of the population below the poverty threshold relative to the population as a whole may ignore one or more facets of poverty. For example, though a poverty head count quantifies the number of poor, but ignores the depth of poverty (i.e. all poor are not equally poor). It also does not relate poverty to economic inequality. For these reasons we added two other measures that consider poverty as being proportional to the poverty gap and relate it to the inequality captured in the Lorenz curve (Table A.16).

TABLE A.16. POVERTY INDICES.*

Headcount index (*H*)	The proportion of population who are poor.
Poverty gap index (*PG*)	The aggregate income shortfall of the poor as a proportion of the poverty threshold and normalized by population size.
Foster-Greer-Thorbecke (P_2)	Like *PG*, but based on the sum of squared poverty deficits so that any increase in subgroup poverty must increase total poverty.

*Adapted from Dutt and Ravallion (1992); equations are in Table A-14.

Using the maize equivalent "basic needs" poverty threshold (668.10 MK), a head count provides a direct indication of the number of people who are able to meet minimum needs in part due to protected area-based income. Across all four protected areas, an estimated 353,438 people were living within 5 km of the reserve boundaries (Malawi Government 1998; Orr *et al.* 1998). Applying the results of our sample to this population, 17.5%, or 61,820 of those people would fall below the basic needs poverty threshold without access to protected area-based income (Table A.17). When protected area proceeds are included in the calculation of total income, only 8.8% of the total population, or 31,064 people remain below the basic needs poverty threshold. In other words, fully half the population who would fall below the basic needs poverty threshold without protected area-based income is rise above the poverty threshold due to income generated from protected areas.

TABLE A.17. POVERTY ANALYSIS.

	Poverty Threshold (MK)	Poverty Indices (%)		
	(z) *Basic Needs*	Head Count (H)	Poverty Gap (PG)	FGT (P_2)
Without protected area proceeds	668.10	17.5	6.9	3.6
With protected area proceeds	668.10	8.8	2.3	0.8
	Reference			
Without protected area proceeds	1700.00	43.6	21.8	13.9
With protected area proceeds	1700.00	31.9	13.5	7.5

*FGT = Foster-Greer-Thorbecke poverty gap index.

The proportion of the total population that falls below the "poverty reference threshold" (1700.00 MK) is obviously much higher (43.6 and 31.9%, respectively). This translates into 154,146 people who would fall below the poverty reference threshold without benefit of protected area proceeds. What is striking is that a much smaller percentage (27%, as opposed to the 50% noted with the "basic needs" threshold) of those people rise out of poverty with the benefit of protected area-based income. This suggests that protected area resources and other associated protected area income impacts far more of the poorest of the poor than those above them on the income ladder.

Though the initial percentages are lower, the results for the poverty gap index and the Foster-Greer-Thorbecke poverty gap index show the same direction of change as the head count. The magnitude of the difference "without" and "with" the benefit of protected area proceeds (on the basic need poverty threshold, 66% for *PG*, and 77% for P_2) is even larger than the headcount (50%). Like the head count index, the proportion of people who rise out of poverty when measured on the basic needs poverty threshold is almost double that of the higher, reference poverty threshold. These findings strongly suggest that

a) protected area-based income provides a livelihood strategy that can lift a great number of the poor above the poverty threshold, and that
b) that benefit is more pronounced for the poorest of the poor.

A.7 CONCLUSIONS

This research introduces a multidimensional field methodology that can provide both baseline socio-economic information concerning household production and detailed, species level protected area resource utilization. Using the example of four protected areas in Malawi, we have demonstrated how the annual harvests of agricultural and protected area natural resource products were: (a) identified; (b) measured (by volume in local units of measure); (c) converted to weight units, (d) verified against on-site physical measurements and key respondent interviews; and (e) valued in monetary units.

When collected data collected are aggregated to the household level, the importance of protected area-based income becomes quite evident. Poor households are generally more reliant on protected area resources than other households. In turn, that reliance has a major influence on the distribution of income between poor and rich households. Exploitation of protected area resources is a livelihood strategy that halved the number of households that otherwise would have remained beneath the basic needs poverty threshold. These findings have major policy ramification, not only for environmental management and conservation, but also for poverty alleviation.

In a society that is almost entirely dependent on agriculture households, and in particular poor households, have created income-generating alternatives to maintain livelihood security. That these alternatives are based on protected area proceeds represents a challenge and an opportunity to those attempting to balance sustainable use and sustainable development simultaneously. The methodology represents a unique blend of tools used to gather livelihood security information and ethnoecological data in conjunction with larger initiatives that traditionally have not captured the role of protected area resources. This provides the opportunity to address and monitor the influence of those resources on local communities and gauge the ecological impact of resource demand.

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A.9 FIGURE LEGENDS

FIGURE A.1. THE RELATIVE IMPORTANCE OF ALL INCOME ELEMENTS.

FIGURE A.2. PROTECTED AREA AND NON-PROTECTED AREA COMPONENTS OF PER CAPITA INCOME FOR ALL SAMPLED HOUSEHOLDS.

FIGURE A.3. SIMPLE LINEAR REGRESSION FOR PER CAPITA INCOME AS A PREDICTOR FOR RELIANCE ON PROTECTED AREA RESOURCES.

FIGURE A.4. LORENZ CURVES FOR INCOME INCLUSIVE AND EXCLUSIVE OF PROTECTED AREA PROCEEDS.

FIGURE A.5. DIFFERENCES IN RELATIVE INCOME BETWEEN INCOME GROUPS.

FIGURE A.6. CHANGE IN RELATIVE INCOME SHARE RESULTING FROM THE ADDITION OF PROTECTED AREA-BASED PROCEEDS TO HOUSEHOLD INCOME.

A.10 FIGURES

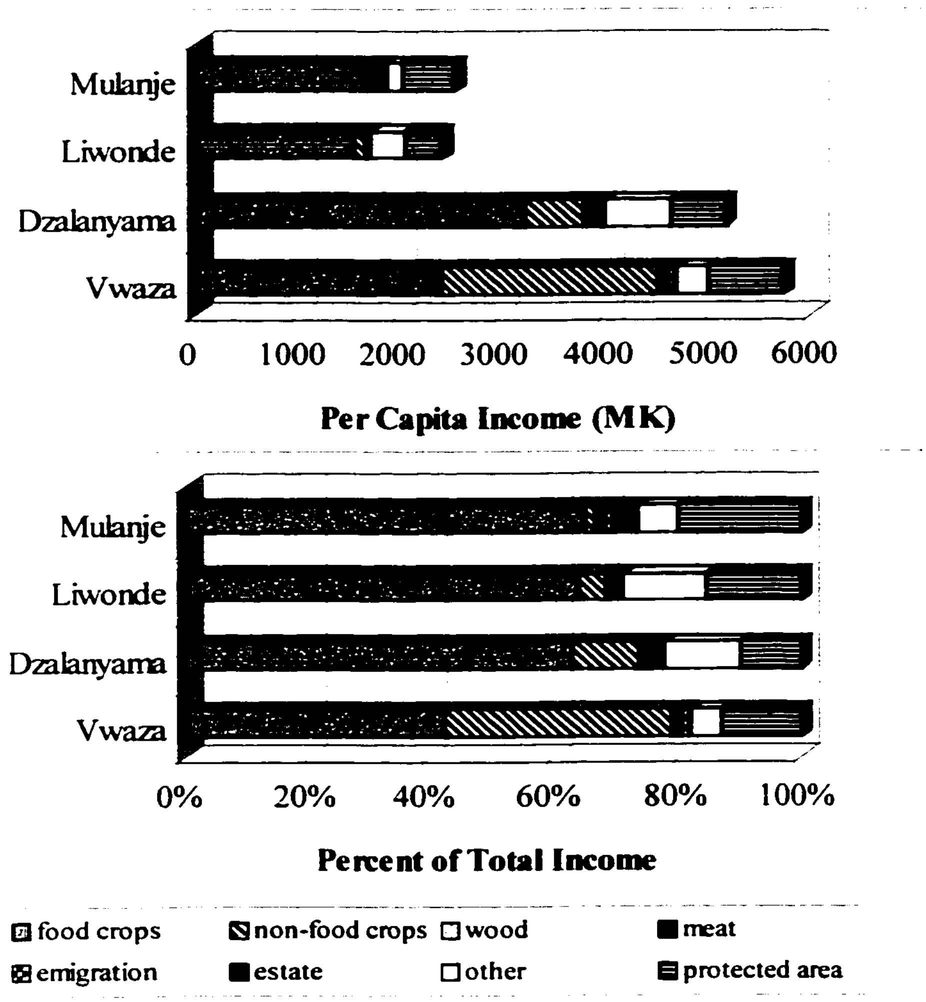

FIGURE A.1. THE RELATIVE IMPORTANCE OF ALL INCOME ELEMENTS.

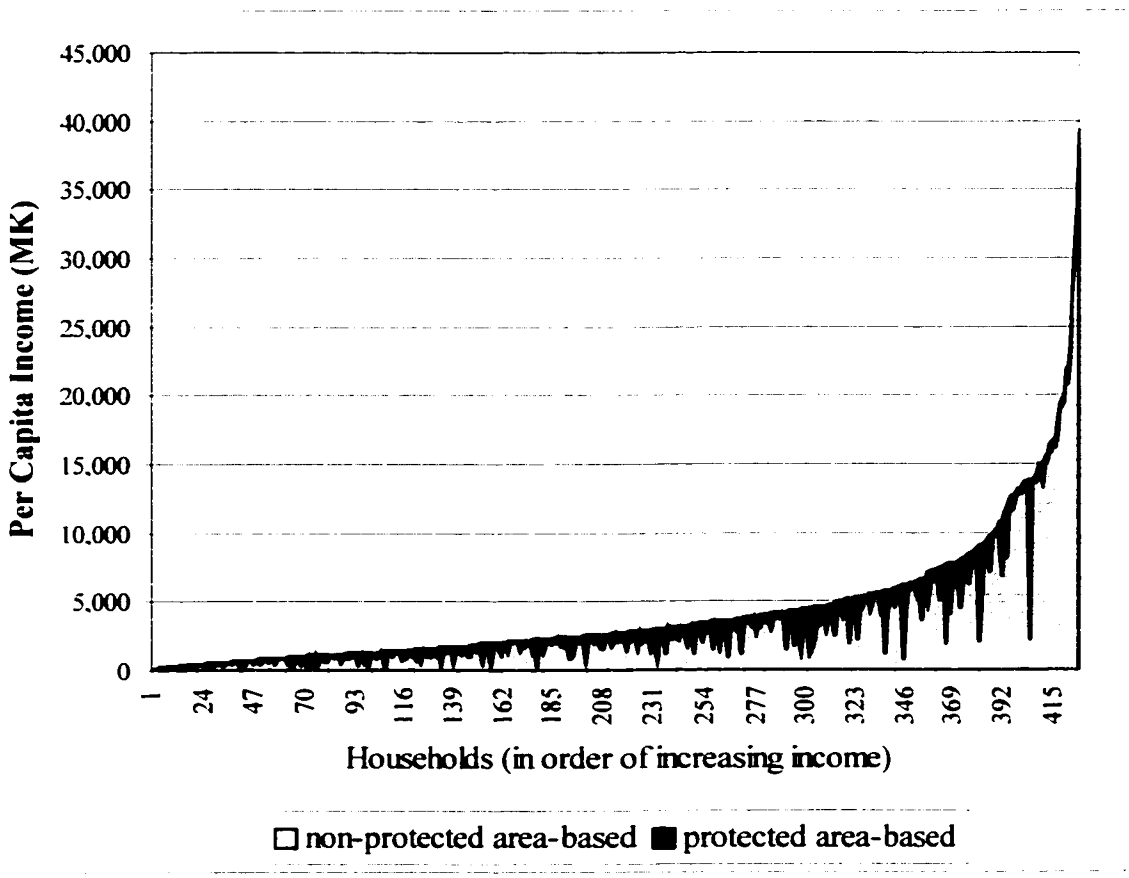

FIGURE A.2. PROTECTED AREA AND NON-PROTECTED AREA COMPONENTS OF PER CAPITA INCOME FOR ALL SAMPLED HOUSEHOLDS.

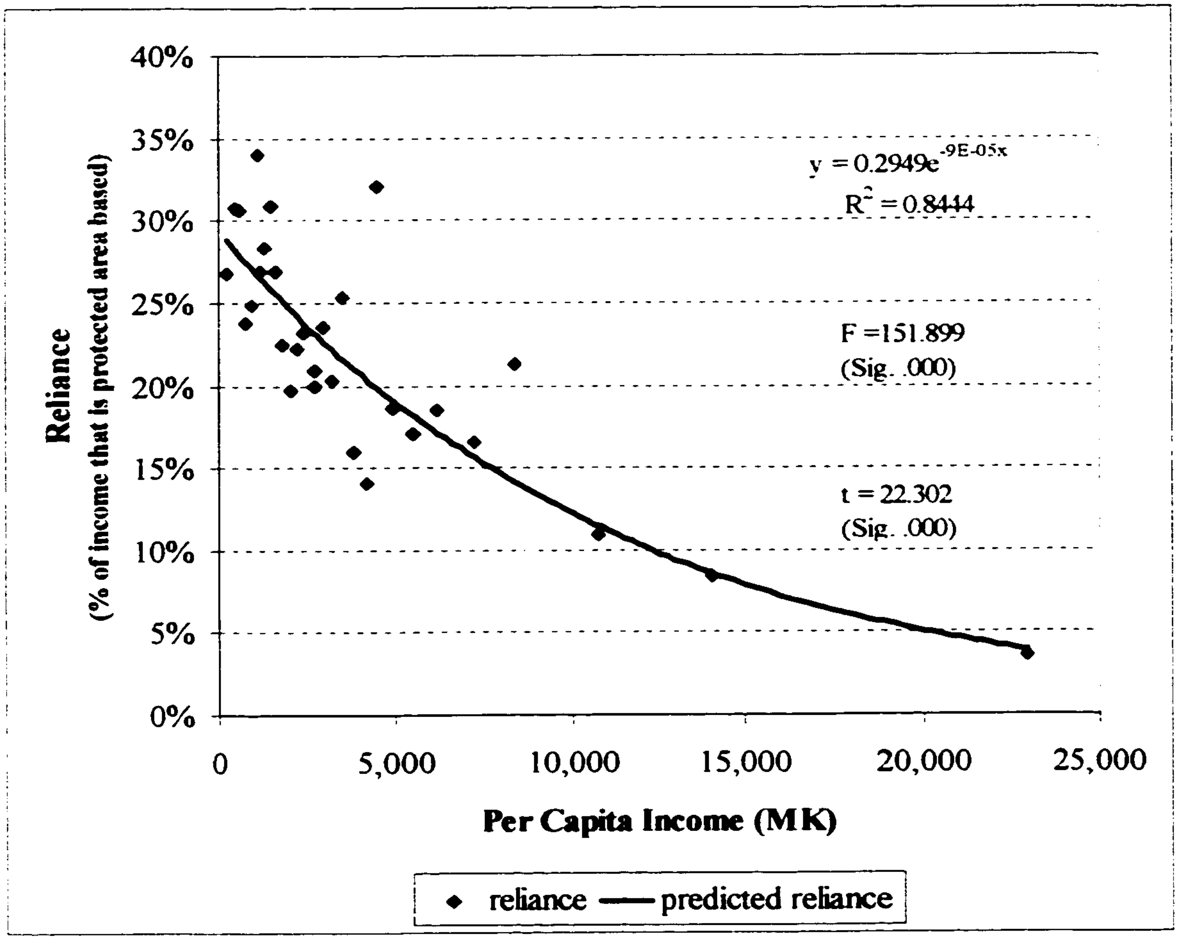

FIGURE A.3. REGRESSION FOR PER CAPITA INCOME AS A PREDICTOR FOR RELIANCE ON PROTECTED AREA RESOURCES.

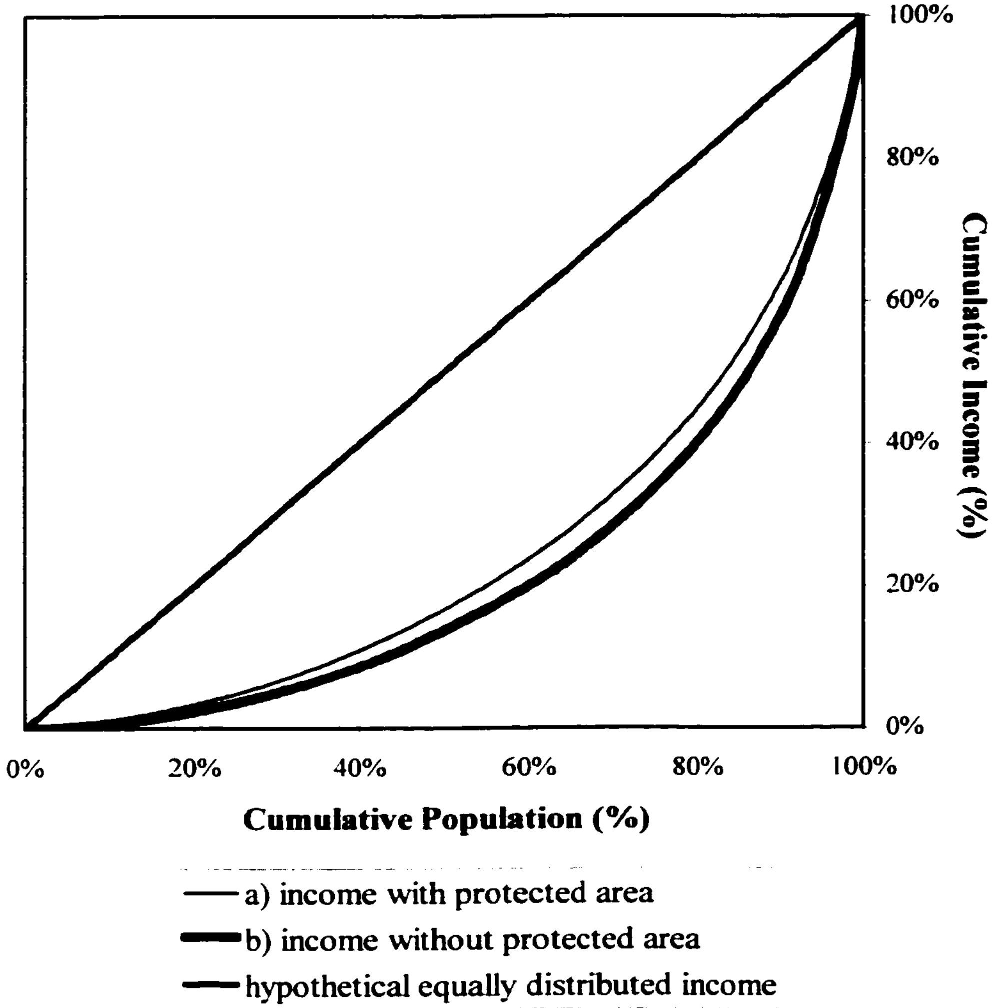

FIGURE A.4. LORENZ CURVES FOR INCOME INCLUSIVE AND EXCLUSIVE OF PROTECTED AREA PROCEEDS.

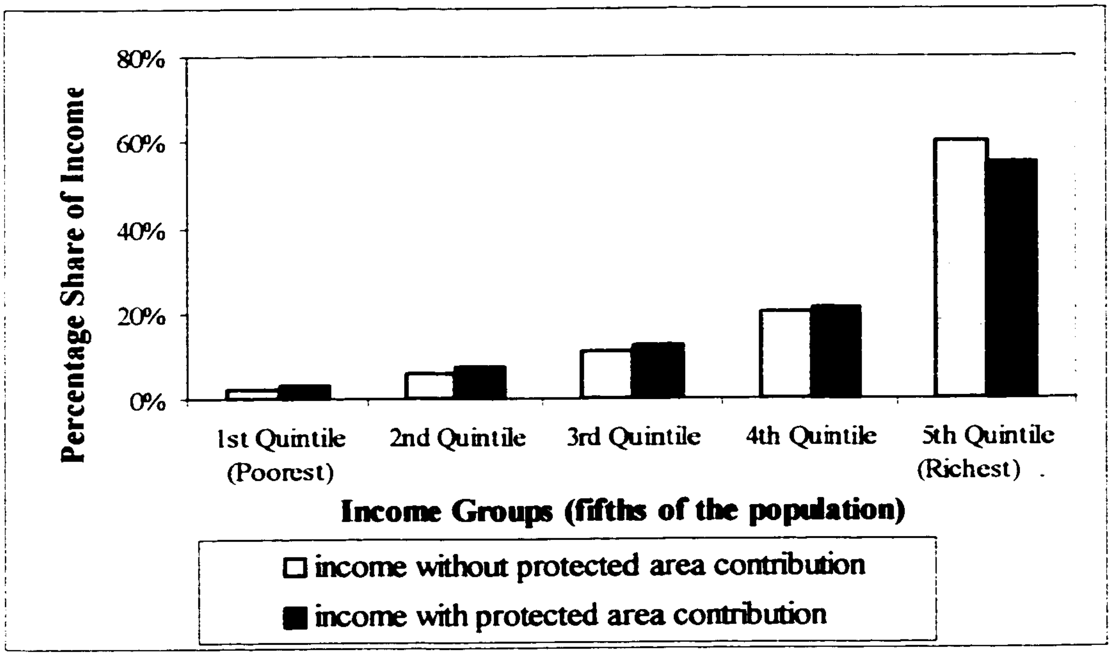

FIGURE A.5. DIFFERENCES IN RELATIVE INCOME BETWEEN INCOME GROUPS.

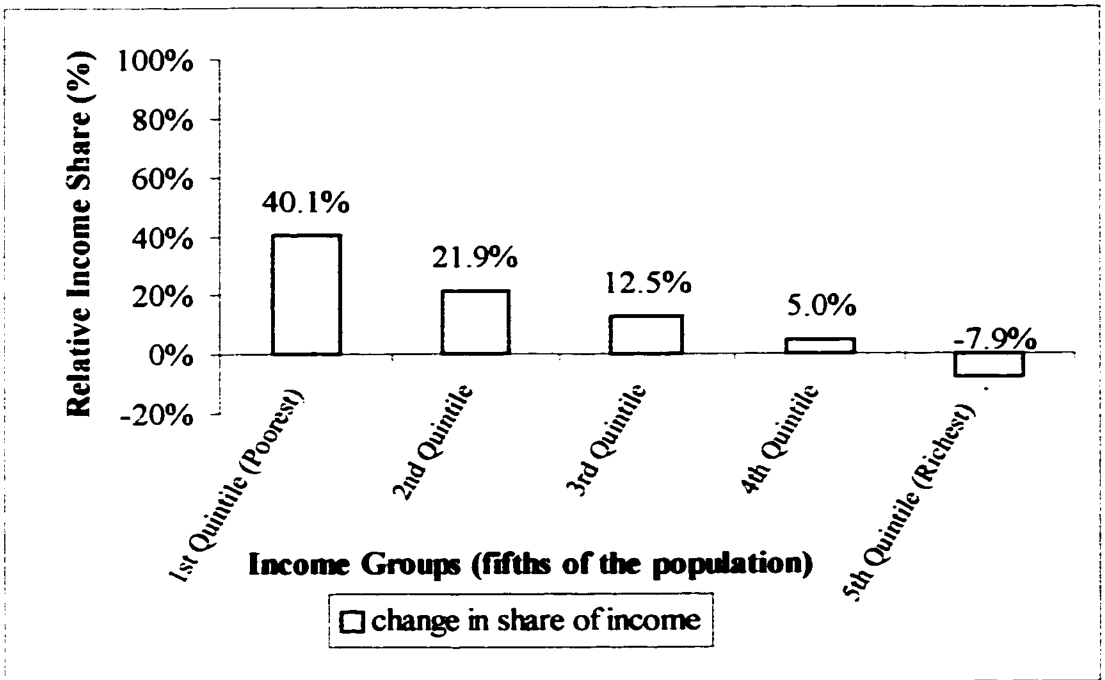

FIGURE A.6. CHANGE IN RELATIVE INCOME SHARE RESULTING FROM THE ADDITION OF PROTECTED AREA-BASED PROCEEDS TO HOUSEHOLD INCOME.

B. APPENDIX B. QUANTIFYING PROTECTED AREA RESOURCE DEMAND AT THE SPECIES LEVEL: ANOTHER CONSIDERATION FOR INTEGRATED CONSERVATION AND DEVELOPMENT PROJECTS

B.1 ABSTRACT

Orr, Barron J. *(Office of Arid Land Studies, University of Arizona, 1955 E. 6th Street, Tucson, AZ 85719, USA, barron@ag.arizona.edu)*, **H.T. Chapama, and Luke N. Malembo** *(Forestry Research Institute of Malawi, P.O. Box 270, Zomba, Malawi, frim@malawi.net).* QUANTIFYING PROTECTED AREA RESOURCE DEMAND AT THE SPECIES LEVEL: AN ESSENTIAL ELEMENT OF INTEGRATED CONSERVATION AND DEVELOPMENT PROJECTS. *This study quantified resource utilization at the species level and overall resource demand in order to evaluated sustainable use in four protected areas in Malawi. The annual harvests of agricultural and protected area natural resource products from 427 households were identified, measured (by volume in local units of measure), converted to weight units, verified against on-site physical measurements and key respondent interviews, and valued in monetary units. Results for the major species used for each category of use are documented. Overall woody resource demand is compared to sustainable supply through spatial analysis of mean annual increment and population pressure over time. If resource use is confined to the population with a 5 km zone of influence, the sustainable supply of total protected area ecological resources has the potential to meet demand for 50 years in three of the reserves, and 100 years in the fourth. The analysis of both species-level and aggregate resource demand provides a set of monitoring tools for community management and conservation.*

Key Words: protected area resources; valuation; resource demand; sustainable use; sustainable development; participatory rural appraisal; ethnoecology; Malawi.

B.2 INTRODUCTION

In the past, the goals of conservation biology and economic development were rarely integrated in projects despite their common human dimension. While researchers from both groups studied natural resources, one group tended to focus on human impact while the other assessed human need. With the emergence of the ecological and economic reality that human natural resource demand may outstrip environmental capacity (Vitousek *et al.* 1986), the call for sustainable development (where environmental, social and economic conditions can be maintained or improved for future generations) became a more common theme (World Commission on Environment and Development 1987).

Evolving societal concerns have increased pressure to meld the goals of conservation and sustainable development. The desire to improve upon conventional "fences and fines" approach to conservation (Barrett and Arcese 1995) coincided with a more general trend towards including local communities in research, planning, and management of development initiatives (Brandon and Wells 1992). Protected area natural resources are increasingly viewed as the fundamental link between conservation and sustainable development (Wild and Mutebi 1997). This has fostered interdisciplinary research that integrates socio-economic and ecological perspectives where concerns for protection of natural areas and economic development of local communities converge (Munasinghe 1992).

Although the potential of community-based conservation of natural resources has come under increased scrutiny (Wainwright and Wehrmeyer 1998), the long-term financial benefits of conservation to local people have the potential to outweigh those of agriculture or logging (e.g. Kremen *et al.* 2000). In spite of potential benefits, local populations in developing countries tend to receive a small share of the use and non-use values assessed by outsiders (Godoy *et al.* 2000). To rectify this inequality, community-based natural resource management and integrated conservation and development projects (IDCPs) have become widespread. Their goal is to exploit the role that human consumption of protected natural resources can play in both conservation and development by directing the returns derived from conservation back into the community (Brandon and Wells 1992).

Though IDCPs are viewed as having greater appeal than the exclusionary, "fences and fines" conservation strategies that preceded them (Barrett and Arcese 1995), they require far more ecological, economic, social, and institutional monitoring. Much of the criticism of early IDCPs focused on: (1) project implementation with poor ecological data relative to socioeconomic data describing changes over time: (2) limited ecological understanding of the potential impacts of various harvest rates; and (3) poor assessment of the economic, political, and social benefits of existing utilization (Barrett and Arcese 1995; Gibson and Marks 1995).

The consumptive use-value of protected area natural resources is the portion of forest resource value that has direct local benefit. The quantity and value of resource demand tend to be roughly estimated or overlooked entirely when IDCPs are designed

(Barrett and Arcese 1995). As the number of uses and resource users increases, the complexity and costs of managing sustainable use conspicuously increases (Cunningham 1994). This suggests a need for data on the quantity and value of resources consumed from the protected area targeted by the ICDP as well as a consideration of the alternatives derived from household production and expenditure. If such information were regularly collected at the species level, resource demand could be monitored, making sustainable use a more practical goal.

This research demonstrates how an integration of regularly collected social and economic data can be augmented with ethnobiological information in order to capture protected area resource demand. We used a multi-dimensional approach in communities around four protected areas in Malawi to address three fundamental questions at the species level:

(9) Which species are used for household livelihood?

(10) What are the per capita quantities of each species used for various uses, whether agriculturally produced or collected from the protected area?

(11) What are the per capita consumptive use-values of agricultural production and protected area resource utilization?

In aggregate form, these data were then integrated with information on population trends and compared to assessments of sustainable resource supply, to address two questions:

(1) Does the current supply of protected area resources meet current demand?

(2) Based on current patterns of use and population growth, how long before sustainable supply is outstripped by demand?

B.3 STUDY AREAS

In 1997, 19% of Malawi's 94,000 km^2 of land was under protection in the form of four wildlife reserves, five national parks, and seventy-seven forest reserves (Orr *et al.* 1998). This percentage is not exceptional in Africa or elsewhere. However, in the same year, 86% of the country's 9.65 million people lived in rural areas (Malawi Government 1998). Malawi's average population density of 103 persons/km^2 of land was three times that of its neighbors (United Nations Population Division 2000). This translates into a density that twice as high on both protected and non-protected wooded areas. The demand for agricultural land is substantial because mean farm size is at or below 1.0 ha for a family of five in rural Malawi (BDPA/AHT 1998; House and Zimalirana 1992) and traditional agriculture is the dominant livelihood systems. Furthermore, 98% of rural and 94% of urban energy demand is satisfied through fuelwood and charcoal (Arpaillange 1996), a level of dependence exceeded internationally only by Nepal (Pearce and Turner 1990).

As a result of demand for wood and agricultural land, the forested area in Malawi was reduced by half between 1946 and 1996 (FAO 1981; FAO 1999; Millington et al. 1989; Openshaw 1996, Willan 1947). This has increased the importance of remaining protected area resources as both common resource base and potential agricultural land.

In response to pressure to convert protected areas to agriculture, the Government of Malawi commissioned a Public Lands Utilization Study (PLUS) in 1996 to study the environmental risks of conversion and the importance of the reserves to adjacent communities (Orr *et al.* 1998). The study was guided by a national Steering Committee on Land, which was made up of 60 government and non-government stakeholder agencies. The Committee selected four protected areas for intensive study, including Mulanje Forest Reserve, Liwonde National Park, Dzalanyama Forest Reserve and Ranch, and Vwaza Wildlife Reserve.

B.3.1 MULANJE FOREST RESERVE

Mulanje Forest Reserve is located in southeastern Malawi, centered on 15°57'S, 35°39'E, covering 56,314 ha of mostly mountainous terrain. It has vegetation ranging from montane woodland and grassland on the plateau to miombo woodland (mesic-dystrophic savanna, dominated by *Julbernardia* and *Brachystegia* species) on the lower slopes. Geologically, the massif consists of a large syenitic intrusion, rising from the surrounding plain from 600m to 3,000m above sea level. Steep slopes and shallow dystric-fersialic soils limit the agricultural suitability of the forest to some lowlands on the southern and eastern edge of the reserve (Paris 1991a; Pike and Rimmington 1965).

The reserve protects a number of watersheds from erosion. It also shelters considerable biological diversity that includes a variety of wildlife greater than any other forest reserve in Malawi and more than thirty endemic flora species (Chapman 1962; Edwards 1985). The reserve also serves as a tourist attraction and a source of high quality timber. A large Eucalyptus plantation in the southeastern portion of Mulanje was intended to supply fuelwood and charcoal locally, though the cost of transport has limited its success. The average population density around the reserve in 1996 was 211 persons km^{-2}, with the greatest concentration on the southern side of the reserve near Malawi's most productive tea estates.

B.3.2 LIWONDE NATIONAL PARK

Liwonde National Park is located in south central Malawi centered on 14°50'S, 35°21'E, encompassing 54,633 ha in the Upper Shire River valley. It occupies a flat, riverine-lacustrine plain covered in mostly mopanic and gleyic soils ill suited for agriculture (Venema 1991). Liwonde was intended to protect wildlife in the Upper Shire and is a Malawian example of mopane woodland, broad-leafed, lowland, drought deciduous woodland and savanna dominated by mopane (*Colophospermum mopane* (Kirk ex Benth.) Kirk ex Léonard). Along the Shire, Liwonde has extensive marsh and floodplain areas that include both palm (*Borasus aethiopum* Mart.) and reed (*Phragmites mauritianus* Kunth.) communities.

Three years after being declared extinct in Malawi, the first black rhinoceros (*Diceros bicornis* L. *minor*) were introduced to a sanctuary within the Park in 1993 (Bhima and Dudley 1997). The population in 2000 is five. Once in decline, the Park is home to the only elephant (*Loxodonta africana* Blumenbach) population in the country that has grown significantly in the past 25 years (Bhima and Bothma 1997). Tourism is the primary use of the park, with the objective of attracting high revenue tourists to Malawi.

A wire fence on the densely populated western edge of the Park and security measures combine to enforce stricter protection in Liwonde than in all other protected areas in Malawi. The Park also serves a critical watershed catchment protection role for the Shire River, the primary source of the country's electricity. The average population density around the Park in 1996 was 166 persons km^{-2}, with heavier concentrations along the northeastern corridor.

B.3.3 DZALANYAMA FOREST RESERVE AND RANCH

Dzalanyama Forest Reserve is located in the central, western part of Malawi, centered on 14°20'S, 33°22'E. It is Malawi's largest forest reserve, encompassing 98,827 ha. The western third of this area is closed-canopy, upland miombo (Ngalande 1995). The rest is shared with a government agricultural scheme, Dzalanyama Ranch, located in a low-lying area of open miombo and dambo (grasslands in seasonally inundated drainage lines). The lowlands are dominated by eutric-fersialic soils that are suitable for agriculture (Lorkeers and Venema 1991).

The natural woodland and almost 5,000 ha of plantations in *Pinus kesiya* Royle ex Gordon, *Eucalyptus camaldulensis* Dehnh., and *E. tereticornis* Sm. supply fuelwood locally and to the Lilongwe metropolitan area. Two dams fed from Dzalanyama streams account for 30% of all water needs for Lilongwe. The western edge of the reserve runs along a forested area in Mozambique that has seen limited use over the past 25 years. The rest of the reserve is bounded by a population averaging 119 persons km^{-2}, with heavier concentrations near tertiary roads that lead to the main national highway.

B.3.4 VWAZA MARSH WILDLIFE RESERVE

Vwaza Marsh Wildlife Reserve (11°00'S, 33°28'E) is composed of a Brachystegia-Julbernardia Miombo woodland, interspersed with montane woodland, dambo grassland, mopane woodland, and thicket associated with perched water tables. The majority of Vwaza Marsh is situated on eutric-ferralic soils that are suitable for agriculture (Paris 1991b).

Vwaza is rich in both flora and fauna, with 1,200 plant, 427 bird, 85 mammal, 34 reptile, and 22 amphibian species. It serves to protect biodiversity and wildlife, and to promote ecotourism (McShane 1985). Dating from the 18th century, Vwaza was created as a game reserve but also to contain the tsetse fly. The elephant population, estimated at 250 in 1985, has declined to the point that sighting assessments are no longer considered valid. The eastern Zambian side of the reserve is sparsely populated. However, the land surrounding the Malawian boundary averaged 95 persons km^{-2} in 1996, a density due in part to the creation of numerous tobacco estates over the past 20 years.

B.4 METHODS

B.4.1 APPROACH

To capture the quantity and value of protected area resource demand, it was necessary to develop a multidimensional approach that captured baseline socioeconomic information and resource utilization in a quantitative, integrated manner. This approach involved the integration of qualitative and quantitative ethnobiological and socioeconomic information concerning household agricultural production and the use of plant and animal species from protected areas, as well as spatial analysis of biophysical data (see Table B.1, and Appendix A for detailed summary). Central to this effort was a quantitative survey of 427 households comprised of 2,205 individuals across the four protected areas. The survey was based on respondent recall of production and resource utilization activities, particularly at the species level. A coincident market survey was done to permit conversion of local volumetric measures to kilograms, and to establish retail prices for each species.

TABLE B.1. SUMMARY OF DATA COLLECTION METHODS.

Data Gathering Activity	Primary Objectives
Rapid Appraisal (138 villages)	
Interviews with traditional officials	• Village list, locations, resource patterns
Community meetings	• Patterns of livelihood strategies • Patterns of protected area use • Crop, livestock, wild resource species list
Focus group interviews (men and women separately)	• Qualitative specialized use • Land and resource tenure • Attitudes towards protection • Changes in resource availability/access
Intensive study (17 villages)	
Participatory mapping	• Present and past resource utilization
Key respondent interviews	• Quantitative specialized use *(223 respondents)* • Local unit volume and weight conversions • Local market retail prices
Resource assessment *(136 plots)*	• Vegetation measurements • Local name / Latin name verification
Formal survey *(427 households)*	• Income (agriculture production, livestock, remittances, off-farm activities, etc.) • Protected area resource utilization

With the exception of the single formal survey, data were gathered through participatory methods: local inhabitants carried out the investigation, presentation, and preliminary analysis under the guidance and training of the research team (Campbell, Luckert, and Scoones 1997; Chambers 1990, 1994). The field research team was made up of four Malawian male and female enumerators conversant in the key local languages (primarily Chichewa, Chiyao, and Chitumbuka).

Overlapping key respondent interviews captured specialized resource use (i.e., small enterprises involving fuelwood, charcoal, wild foods, hunting, handicrafts, tool making, healing, etc.). Data were collected through interviews conducted in the villages and in the protected areas during resource extraction. These surveys were essential in linking the size and price of final products back to the physical quantity of species used. This was particularly important for uses where the relationship was not one to one (i.e., handicrafts, healing services). All monetary values are reported in Malawian Kwacha (MK), where 1 USD = 15 MK during 1996 and 1997.

The aggregate results provided an estimate of protected area resource demand for 1996. A geographic information system was employed to assess the sustainability of use over time. Rural population estimates based on population totals and growth trends derived from the 1998 census were mapped according to Environmental Planning Areas (EPA), the smallest administrative unit available for population data. It was necessary to assume that the rural population was evenly distributed across each EPA and then limit the analysis to the portion of each EPA adjacent to the protected areas of interest with a resource utilization "zone of influence." The extent of influence was on average 5 kilometers, determined by surveys during the rapid appraisal and verified in independent research (Brouwer *et al.* 1997). Finally, the population for urban centers located within the zone of influence as added to the rural total. Total protected area resource demand equaled the total population in the zone of influence times the mean per capita resource utilization estimates (kg) for 1996.

The threshold for sustainable protected area resource extraction was defined as the volumetric (m^3 ha^{-1} yr^{-1}) mean annual increment (MAI) of all woody biomass in the protected area, based on a roundwood equivalent (wood in its natural state as felled, or otherwise harvested). The threshold was tied to woody resource extraction because the combination of forest clearing for agriculture and fuelwood consumption overwhelm all other biomass use, and generally represent the destruction of habitat. Vegetation classifications created from 1994 Landsat Thematic Mapper satellite imagery during PLUS (Orr *et al.* 1998) were converted into biomass maps using MAI estimates for each vegetation type developed by FRIM (Masamba and Ngalande 1997). The threshold for sustainable extraction was the total of the MAI estimates for each vegetation class multiplied by the total hectares for each class across the protected area.

Per capita estimates for total protected area resource demand in 1996 were held constant and applied to population estimates based on 1987 through 1998 growth rates (Malawi Government 1998). The total demand for protected area resources was compared to the estimated sustainable supply through time to determine when that sustainable supply would be exhausted.

B.4.2 SPECIES IDENTIFICATION

The Forestry Research Institute of Malawi (FRIM) and the National Herbarium provided indispensable assistance with local species names. A field botanist was present at all 136 resource assessment plots, working with local inhabitants to confirm all local names for each species identified. Because scientific species names did not always correspond directly with local (and sometimes polysemic) names, a particular effort was made to incorporate local perceptions and classifications into all instrument responses and into how survey questions were posed (Martin 1995).

These plots were not spatially nor temporally sufficient to capture all species (and their products) identified on village and household surveys. National experts, and Malawi's rich tradition of gathering ethnographic biological information, proved invaluable where local confirmation was not possible. The extensive plant dictionary of Binns (1972) was used for confirming Latin names. The works of Williamson (1975), Morris and Msonthi (1996), and Morris (1990) were essential for addressing gaps in local plant, fruit, and mushroom descriptions, and provided the foundation for evaluating species use.

Nomenclature for mammals was taken from Ansell and Dowsett (1988), birds from Benson and Benson (1977) and McShane (1985). Nomenclature for invertebrates was taken from (Sweeney 1970), and fish from and fish from Ribbink *et al.* (1983), and Tweddle and Willoughby (1979). These were all was supported by detailed ethnobiological descriptions of use (CCAM, 1992; Hayes 1978; Kelly 1993; Morris 1998).

A summary of the species by type and lifeform is contained in Table B.2. Of the 694 species encountered during the study, 101 local identifications, accounting for 4.6% of the total protected area species used by households, could not be verified. The majority of these were annual forbs and insects physically unavailable at the time of data collection.

TABLE B.2. NUMBER OF SPECIES AND HOUSEHOLD OBSERVATIONS OF USE.

Wild Use Lifeform	No. of Species	Domestic Use Lifeform	No. of Species
Mammal	34	Animal	10
Bird	9	Field crop	44
Fish	18	Fruit tree	15
Insect	28	Wood tree	11
Honey	1		
*Mushroom	9		
Tree	235		
Shrub	54		
Climber	39		
*grass	46		
Forb	141		
Total species	614	Total species	80
Household observations of use	12,604	Household observations of use	3,720

*several of households could not provide individual species names for mushrooms and grasses.

Due to cultural and linguistic variation in protected areas and nearby villages, a number of local names were obtained for each species identified, the vast majority of which were available in species dictionary (Binns 1972). We therefore limited reporting here to the most common name cited during the data collection process.

B.5 RESULTS: SPECIES USE

By integrating data collection methods for the assessment household production and protected area resource utilization, results can be presented from the perspective of the species (by use) as well as the household. In order to normalize for variance in household size, most results are reported "per capita," and averaged to reflect each overall protected area.

B.5.1 DOMESTIC PRODUCTION

Domestic production included field crop and fruit trees cultivation, wood lots for fuelwood and timber, and livestock production. The mean per capita value of total domestic production in Dzalanyama (3,975 MK) and Vwaza (4,587 MK) was between 100 and 150% greater than that of Mulanje (1735 MK) and Liwonde (1705 MK). The major difference between the communities surrounding these reserves is access to land, primarily a function of population density. High population density around Mulanje and Liwonde limits farmers to half the land area for cultivation available to farmers around Dzalanyama and Vwaza (Table B.3).

TABLE B.3. POPULATION, LAND, AND AGRICULTURAL PRODUCTION.

Protected Area	Population Density	Mean Land Holding	Mean Crop Production	Mean Crop Production
	persons km^2	ha $capita^{-1}$	kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}
Mulanje	211	.146	308.0	1658.36
Liwonde	166	.194	365.1	1553.23
Dzalanyama	119	.316	819.8	3238.98
Vwaza	95	.329	581.8	2424.46

Crops represented over 70% of the mass and 90% of the value of domestic production in all four protected areas. The variation in agroclimatic conditions around the four reserves permit cultivation of cash, non-food crops (primarily tobacco) in some areas and not in others. The proceeds from non-food crops made a major difference in Vwaza (primarily tobacco, *Nicotiana tabacum* L.) representing 45% of the total value of domestic production, compared to 14, 6, and 2% in Dzalanyama, Liwonde, and Mulanje.

Though farmers interviewed in this study tend to cultivate a wide variety of crops (6.36 different species per household), maize (*Zea mays* L.*)* was the dominant food crop in all but Mulanje, where fruit species were equally important (Figure B.1). Tobacco was the dominant cash crop. Agroclimatic conditions in Vwaza are particularly suited for the Burley variety, which explains the much higher value of agricultural production around that reserve. Households around all four protected areas cultivated smaller amounts of a variety of other crops to supplement the maize production (Figure B.2). In Mulanje, the combination of banana (*Musa paradisiaca* L. and *M. sapientum* L.) and *Ananas comosus* (L.) Merr.) accounts for 35% of agricultural crop income. Groundnuts (*Arachis hypogaea* L.) provide 16% of Dzalanyama's and 20% of Vwaza's crop income, while rice (*Oryza sativa* L. (Gram)) provides 14% in Liwonde. Tomatoes (*Lycopersicon esulentum* Mill.) grown in communities Dzalanyama and Liwonde are regularly sold, providing 14% and 18% of agricultural proceeds, respectively.

Only 9% of Malawi's food protein is met by livestock production, compared to 20% for other developing countries (Banda and Kamwanja 1993). In this research, livestock contributed only 2% of household income in Mulanje, Liwonde, and Vwaza, and

4% on Dzalanyama (Table B.4). Household livestock production is higher near Dzalanyama in part because the protected area also serves as the largest cattle ranch in the country. The same individuals hired to tend small herds of the Ranch's cattle also own their own animals. In the other three reserves, chickens, goats, and pigs are the most important livestock species (Figure B.3).

TABLE B.4. LIVESTOCK AND WOOD PRODUCTION ON AGRICULTURAL LAND.

Protected Area	Mean Livestock Production	Mean Livestock Production	Mean Wood Production	Mean Wood Production
	kg capita^{-1} yr^{-1}	MK capita^{-1} yr^{-1}	kg capita^{-1} yr^{-1}	MK capita^{-1} yr^{-1}
Mulanje	2.9	31.23	129.1	13.36
Liwonde	3.5	38.63	114.1	12.16
Dzalanyama	19.1	155.71	326.5	32.67
Vwaza	14.2	80.95	124.5	12.57

The well-documented importance of trees on farms in Malawi (e.g. Dewees 1995) is evident in our findings. Adjacent to Mulanje, trees provide the majority of agricultural income, while around Dzalanyama households plant and maintain over four times the number of trees per capita for wood production than the other three protected areas. In villages adjacent to Dzalanyama, 46 of the 47 trees capita^{-1} found on agricultural land are not for food. They contribute 327 kg capita^{-1} yr^{-1} of wood, most of which is sold (Table B.4). By contrast, only 10 trees capita^{-1} are found on agricultural land in the other three protected areas, and between 20% (Liwonde and Vwaza) and 50% (Mulanje) of these are maintained primarily for their fruit.

Eucalyptus spp. dominate wood produced on agricultural land, most of which is consumed as fuel wood or poles in house construction in Mulanje, Liwonde, and Vwaza

(Figure B.4). The exception is Dzalanyama where relatively large agricultural tracts are dedicated to as many as 1000 fast-growing, fuelwood trees. A portion of these are regularly harvested, cut into short sticks in preparation for the 60 kilometer bicycle journey to Lilongwe where they are sold to meet urban demand.

B.5.2 PROTECTED AREA NATURAL RESOURCE UTILIZATION

Of the 610 protected area species encountered during the study, 580 were described as collected and used by at least one household. The quantities collected of the most important species for each major category of use are reported below. Due to space limitations, most use category values are reported in aggregate only.

B.5.2.1 Overall utilization

Though many factors influence the level of natural resource utilization, inhabitants around all four protected areas raised the issue of barriers to access as most important. These included government agency efforts at protection (i.e. policing with forest guards, wildlife reserve and national park scouts, and fencing), and physical barriers (primarily distance from household, elevation and slope, and flooding). Table B.5 provides a relative assessment of barriers to access along with mean per capita figures for overall protected area resource utilization for each protected area.

TABLE B.5. BARRIERS TO PROTECTED AREA ACCESS AND OVERALL UTILIZATION.

Protected Area	Relative Level of Protection	Relative Ease of Physical Access	Mean Total Utilization	Mean Total Utilization
			kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}
Mulanje	Low	Very Difficult	873	388.51
Liwonde	Very High	Difficult	484	379.35
Dzalanyama	Low	Easy	1135	520.94
Vwaza	Medium	Easy	1449	681.90

Residents around Liwonde National Park reported the lowest natural resource utilization, due to protection, and at least in part, to fears of government detection of their activities. The fear may have inhibited some respondents, resulting in an underestimate of Liwonde utilization. However it should be noted that the most common request during the Liwonde rapid appraisal was for a tour of the Park in order to see, *for the first time*, the large wildlife species inside. While scouts are not constant fixtures on the boundaries, Liwonde is the base of training for wildlife scouts throughout Malawi, and is fenced on its more populated western boundary. One kilometer east of that boundary is the Shire River and its flood plain, encouraging a high fishing trade, but serving as an effective barrier to most other uses.

The exceptionally steep slopes of Mulanje Mountain and local beliefs about the plateau itself limited access to the lower slopes. Dzalanyama had the fewest physical barriers, and like Mulanje, is a forest reserve with fewer use restrictions and limited agency personnel available for protection. Inhabitants around Vwaza Marsh reported high levels of policing near a small government base camp at Lake Kuzuni, but much lower levels away from that camp. Flooding limited, but did not prohibit, access to parts of the reserve during the rainy season.

Comparing total utilization across uses is problematic due to variation in life form (plants vs. animals), or even parts within similar life forms (leaves for medicine vs. wood for fuel). Therefore, the species-level results are presented by type of use. However, one species stands out from all others in the data set.

In terms of the quantity of biomass extracted, fuelwood was the most important natural resource product extracted from all four reserves (Figure B.5). Despite the differences in total utilization between the reserves (Table B.5), the relative importance of fuelwood to other uses was consistent. Fuelwood accounted for 48% of all biomass utilization in Vwaza, 60% in Liwonde and Dzalanyama, and 64% in Mulanje.

Food resources provided the largest share of protected area resource value among all use categories (Figure B.6). The combination of plants (including mushrooms) and animals/animal products (including honey) represented 43% of utilization value in Vwaza, 57% in Mulanje, 63% in Liwonde, and 66% in Dzalanyama.

When totals are aggregated across all uses, the most important individual species collected was the semi-deciduous fruit tree known locally as masuku. At 82.6 kg capita^{-1} yr^{-1}, the amount of *Uapaca kirkiana* biomass extracted was nearly double that of its nearest competitor, *Pericopsis angolensis*. On value, *Uapaca kirkiana* was 2.7 times more important than the next greatest protected area species, mushrooms. By providing 83.11 MK per capita, masuku would rank as the tenth most important agricultural crop in the data set, ahead of all domesticated fruits but mango and banana. These exceptional utilization levels and the multipurpose nature of this tree (food, fuel, tools, medicine, etc.) are why Ngulube (1995) has suggested this is a "Cinderella" tree, known well to those who use it extensively, but generally overlooked by horticulturists and agroforestry researchers.

B.5.2.2 Food utilization

Over 81% households surveyed reported collecting food products from the protected areas. Of these households, 86% used at least part of that food to supplement inadequate food stocks and 72% sold protected area food products for cash. Protected area plant food utilization was highest in Dzalanyama and Mulanje, while meat utilization was highest in Vwaza and Liwonde, home to much larger wildlife and fish populations (Table B.6).

TABLE B.6. PER CAPITA PROTECTED AREA FOOD UTILIZATION.

Protected Area	Mean Plant Food Utilization	Mean Plant Food Utilization	Mean Meat* Utilization	Mean Meat* Utilization
	kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}	kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}
Mulanje	135.6	175.33	12.8	52.90
Liwonde	31.8	17.10	49.4	221.59
Dzalanyama	241.6	306.25	7.8	41.25
Vwaza	65.5	88.08	203.3 †	229.42 †

*wild animal meat utilization, including honey and insects used for food.
†Vwaza's meat utilization is high in part due to one household that reported hunting 10 elephants, selling most of the meat for much less than other reported wildlife meat sales.

Though very rare in Liwonde National Park, and relatively uncommon in Vwaza, the fruit of *Uapaca kirkiana* was still the most important food, collected by half of all households surveyed, and representing over half the plant food biomass extracted from both Mulanje and Dzalanyama (Figure B.7). It, and the second most commonly collected fruit, *Parinari curatellifolia,* were ranked as the top two priority fruits identified by Malawian farmers to be included in a domestication program proposed by researchers from the International Centre for Research in Agroforestry (Malembo, Chilanga, and Maliwichi 1998).

Over 65% of the households surveyed reported collecting mushrooms, and 35% of those sold at least some for cash. Though individual species were rarely reported, the wide variety included *Amanita hemibapha* (Berk. and Br.) Sacc., *Coprinus africanus* Pelger, *Russula schizoderma* Pat., *Strobilomyces costatipora* (Beeli) Gilb, and *Termitomyces clypeatus* Heim.. In Liwonde, flood plain areas produce a wild rice (*Oryza longistaminata*) close to neighboring villages, and is the important plant food collected from within Park boundaries. Tubers of ground orchids were important in all four reserves, particularly *Habenaria walleri* in Dzalanyama.

A large number of other tuber, fruit, and green leafy vegetable species were collected from each protected area, the most important of which are reported in Figure B.8. Four different wild yams (*Dioscorea* spp.) were reported in Mulanje and another in Liwonde as necessary for meeting food needs when stores of maize run out during the rainy season. Species of the genus *Dioscorea* have been found to have adequate nutritional value to permit populations living in the African tropical rainforest to live independently of agriculture (Hladik and Dounias 1993).

The total quantities of green leafy vegetables collected are lower than fruits and tubers on the basis of weight. This underestimates their importance to Malawian diet as they are regularly served with the maize-based staple food called nsima. Across all four protected areas, 72 different vegetable species were observed as used by at least one household, and of these 40 were described as species used specifically to help bridge the "hungry season" from the onset of rains to dry season harvest. The most important of these included *Bidens pilosa* L., *Amaranthus thunbergii* Moq., and *Solanum nigrum* L.. The elevation in Mulanje provides habitat for *Momordica foetida* Schumach. and Thonn., and *Thunbergia lancifolia* T. Anders., which explains their importance for communities near the mountain and their absence in the other three protected areas.

Proximity to Lake Malombe and the Shire River contributed to high overall meat utilization in communities around Liwonde National Park (Table B.6; Figure B.9). In both Liwonde and Vwaza the most important fish species utilized was sharptooth catfish (*Clarias gariepinus* Burchell). Despite similarly high quantities collected in Vwaza, the value of fish was much higher adjacent to Liwonde due to the proximity of major urban markets in Blantyre and Zomba. Utilization of large mammals was higher in Vwaza and Liwonde because these species are simply not prevalent in either forest reserve (Figure B.10).

The largest single contributor to overall wild animal utilization was actually 109.5 kg $capita^{-1}$ of *Loxodonta africana*, due to a single household in Vwaza that reported hunting 10 elephants in 1996. The vast majority of the 27% of households that fished inside the protected areas sold some portion of their catch. Hunters were present in 48% of households, and those hunting large mammals also sold some of their quarry. However, almost 40% of the households that collected meat from the protected areas concentrated on smaller mammals like the edible rodents (classified locally as mbewa, mostly of the Muridae family).

The most common insects collected from the protected areas for food were caterpillars of the Lepidoptera order, winged termites (*Macrotermes* spp.) and grasshoppers (*Acanthacris ruficornis* (Audinet-Serville)) and *Cyrtacanthacris aeruginosa* (Stoll). Other species included the sand cricket (*Brachytrypes membranaceus*), the black flying ant (*Carebara vidua* F. Smith), the red locust (*Nomadacris septemfasciata* (Serville)), cicadas (*Cicada* spp.) and a shield bug (*Sphaerocoris* sp.). Though 36% of all households surveyed reported collecting insects, only 11% of these reported any sales. In addition, 11% of households (mostly in Vwaza and Dzalanyama) collected honey from the protected area, half of which some sold for cash. The miombo woodland bee species responsible for this honey are *Meliponula bocandei* Spin, *Trigona* spp., and the domesticated *Apis mellifica adansonii* (Latr.) (Parent, Malaisse, and Verstraeten 1978). Though the reported sales of insects and honey were lower than other secondary food products, when queried, local inhabitants did not dismiss their economic potential. This supports the suggestion by Munthali and Mughogho (1992) that caterpillar utilization and bee keeping in Malawi could provide almost 60% more income per hectare than traditional agriculture in ecologically appropriate locations, if the economic incentives to develop such enterprises were made available.

B.5.2.3 Fuelwood and construction utilization

During the rapid appraisal, inhabitants of villages adjacent to Mulanje, Dzalanyama, and Vwaza reported obtaining the majority of their fuelwood far from the protected area, whereas Liwonde residents suggested that less than half their needs were met by the National Park. The quantitative assessment of total fuelwood collected in the villages studied intensively corroborated with the rapid appraisal (Table B.7.), with Liwonde residents collecting only half that of the other three reserves, primarily because prohibition on protected resource use is well enforced. The Mulanje fuelwood quantity of 560.8 kg $capita^{-1}$ yr^{-1} is similar to results obtained by Abbot and Homewood (1999) for Lake Malawi National Park (*c.* 10.1 kg $capita^{-1}$ yr^{-1} or 525.2 kg $capita^{-1}$ yr^{-1}). The amounts for Dzalanyama (677.2 kg $capita^{-1}$ yr^{-1}) and Vwaza (696.5 kg $capita^{-1}$ yr^{-1}) correspond well with18 estimates for southern Africa reviewed in 1993 by Shackleton (687 kg $capita^{-1}$ yr^{-1} $\pm$ 48.8 kg $capita^{-1}$ yr^{-1}).

TABLE B.7. PER CAPITA PROTECTED AREA FUELWOOD AND CONSTRUCTION UTILIZATION.

Protected Area	Mean Fuelwood Utilization	Mean Fuelwood Utilization	Mean Construction Utilization	Mean Construction Utilization
	kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}	kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}
Mulanje	560.8	72.91	7.2	3.24
Liwonde	288.3	37.48	26.9	10.00
Dzalanyama	677.2	88.03	35.7	11.50
Vwaza	696.5	90.54	208.8	66.99

The species extracted from the protected areas for fuelwood varied from village to village due to biophysical conditions or the location of government plantations. In all, 181 different species were observed as being used for fuel. While no individual species overwhelmingly dominated, the top 10 species collected accounted for 40% of all fuelwood used, and the top 30 species accounted for 73% (Figure B.11).

Fuelwood species preferences corresponded to those found by Abbot *et al.* (1997), working in central Malawi's Chimaliro Forest Reserve. In a community ranking procedure they found *Julbernardia paniculata* and *Pericopsis angolensis*, to be the most preferred of sixteen miombo woodland species studied. Using a fuelwood index, they found *Pericopsis angolensis* to be the highest quality fuelwood. In the current study, *Pericopsis angolensis* was the most popular fuelwood species, accounting for 38.1 kg capita^{-1} yr^{-1}, or 6.8 % of all fuelwood collected from the four protected areas, while *Julbernardia paniculata* ranked third at 24.4 kg capita^{-1} yr^{-1}, or 4.3%.

Though all species of the genus *Brachystegia* evaluated by Abbot *et al.* (1997) ranked among the less fuel-efficient and of lower community preference, their widespread availability in Mulanje, Dzalanyama and Vwaza made these species important for meeting fuel needs. The combined utilization of the ten *Brachystegia* species encountered in this study (including Liwonde National Park, where the genus is uncommon) was 86.6 kg capita^{-1} yr^{-1}, or 15.4% of all fuelwood collected. In Liwonde, *Colophospermum mopane* was the most important protected area fuelwood species, followed by *Combretum* spp. (which were also selected frequently for fuel in Vwaza).

Exotic plantations of *Eucalyptus* spp. and *Pinus* spp. within protected area boundaries met 24% of the reported protected area fuelwood demand in Mulanje. The only other reserve-based plantations encountered in the sample were of *E. camaldulensis* and *E. tereticornis* in Dzalanyama, accounting for 5% of the reported fuelwood utilization there.

Demand for protected area wood for construction purposes (poles, timber, carpentry, etc.) ranged from only 7.2 kg capita^{-1} yr^{-1} around Mulanje to 208.8 kg capita^{-1} yr^{-1} around Vwaza (Table B.7). Inhabitants adjacent to Mulanje indicated that mountain's steep slopes discouraged all but construction specialists from sourcing poles or timber from the reserve. In Vwaza, limited physical barriers and exceptional demand led to very high utilization rates. The demand resulted from the liberalization of tobacco legislation in the early 1990's, permitting smallholders to grow a Burley variety that requires drying sheds for air curing, commonly constructed as a latticework of poles. Smallholders surrounding Vwaza have shifted rapidly into Burley cultivation, precipitating a heavy demand for poles to construct sheds.

The greatest construction demand placed on an individual species in one protected area occurred in Liwonde (Figure B.12). *Colophospermum mopane*, used at a rate of 20.4 kg capita^{-1} yr^{-1}, accounted for 77% of the poles and timber extracted from the Park by neighboring villages. In the other three protected areas, no individual species dominated.

Limited alternatives and the light weight of bamboo species *Arundinaria alpina* placed it in higher demand than any wood species extracted for construction in Mulanje. The most common protected area bamboo species used for construction in Liwonde and Dzalanyama was *Oxytenanthera abyssinica*.

B.5.2.4 Fiber, tool, and handicraft utilization

During the rapid appraisal it became clear that fiber, primarily for making rope, was an important natural resource product that was often secured from protected areas. The quality varied from "high" when used to bind poles during house construction to "low" when used to secure headloads of fuelwood. Fiber was most commonly obtained by stripping the bark of a sapling (1.5 – 10 cm diameter) of a preferred woody species and, separating the fiber layer from the cortex. Key respondent interviews with house construction specialists indicated that 30 to 50 saplings yielded the fiber necessary for construction of a typical earthen, thatched roof home (9 m^2). This is comparable to the 35 saplings found to be necessary by Peham (1996) in research on Liwonde National Forest, just south of Liwonde National Park.

Protected area fiber utilization ranged from 4.8 kg $capita^{-1}$ yr^{-1} in Liwonde to 21.1 kg $capita^{-1}$ yr^{-1} in Vwaza (Table B.8). The lower figures reported in Liwonde are in part due to a long tradition of extracting the nylon linings from discarded tires. The strips (called linja) are used for construction in general and by fishermen to make seine nets.

TABLE B.8. PER CAPITA PROTECTED AREA FIBER, TOOL AND HANDICRAFT UTILIZATION.

Protected Area	Mean Fiber Utilization	Mean Fiber Utilization	Mean Tools/Crafts Utilization	Mean Tools/Crafts Utilization
	kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}	kg $capita^{-1}$ yr^{-1}	MK $capita^{-1}$ yr^{-1}
Mulanje	6.9	2.19	61.9	58.02
Liwonde	4.8	1.50	29.5	34.18
Dzalanyama	9.9	3.17	12.9	12.21
Vwaza	21.1	6.62	43.0	43.19

In Dzalanyama, higher fiber usage was attributed to the construction of animal pens for livestock, while in Vwaza, fiber is used to bind the pole-based drying sheds for air curing of Burley tobacco.

Species selection depended on availability and use, with preference being given to woody species (i.e. *Brachystegia* spp.) of known strength and durability (Figure B.13). Fiber derived from sisal leaves (*Agave sisalana*) was used to make a high-quality string, and an herbaceous species such as *Cissampelos mucronata* was used for binding in basket making.

The manufacture of some utilitarian products also required fiber (e.g. hand brooms), however, the portion of biomass utilized was accounted for under the category "handicrafts" listed in the right-most columns of Table B.8. Over 61% of Mulanje's 61.9 kg $capita^{-1}$ yr^{-1} utilization in this category came from a carpentry enterprise, and another 36% was spread across several highly specialized hand-broom enterprises on the southern side of the mountain that supply markets throughout Malawi. The majority of Liwonde's utilization was associated with basket-making enterprises servicing nearby Mangochi. In contrast to this, Vwaza's totals were spread across the majority of households surveyed: 66% made mats, baskets and/or utilitarian wicker tools, and 81% made wooden hand tools. Dzalanyama's utilization in this category was the lowest (12.9 kg $capita^{-1}$ yr^{-1}), with a limited handicraft industry. Almost three-quarters of the utilization reported there was associated with the manufacture of wooden hand tools.

The quantity of biomass extracted from major species used for making crafts and tools is documented in Figure B.14. The key carpentry species extracted in Mulanje included *Brachestegia* spp., *Burkea africana*, *Pericopsis angolensis*, and *Uapaca kirkiana*. The hand brooms involved a combination of *Xerophyta splendens* and *Sida acuta*, generally supplemented with *Psychotria zombamontana*, *Hypoxis nyasica* Bak, or *Triumfetta rhomboidea*. The baskets in Liwonde and Vwaza were predominantly made from the fronds of *Borassus aethiopum*. Mats in all protected areas were made with *P. mauritianus* if available. Where not available, they were made with *Pennisetum purpurium* or *Hyparrhenia rufa*. Tool handles were most commonly made from the durable, non-splitting suffrutices of *Acacia polyacantha* , *Annona senegalensis*, *Brachestegia spiciformis*, *Julbernardia paniculata*, and *Xeroderris stuhlmannii*.

B.5.2.5 Thatch and medicinal plant utilization

Utilization of protected area grasses for thatch roofs ranged from Liwonde's 52.0 kg capita^{-1} yr^{-1} to almost four times that amount in Vwaza (Table B.9). Most of the residents who did not use protected area thatch could obtain the necessary grasses from customary land. Others had lower overall demand because they did not have thatch roofs: over 18% of the households surveyed in Mulanje had installed corrugated iron roofs versus only 1% in Vwaza.

TABLE B.9. PER CAPITA PROTECTED AREA THATCH AND MEDICINAL PLANT UTILIZATION.

Protected Area	Mean Thatch Utilization	Mean Thatch Utilization	Mean Medicinal Utilization	Mean Medicinal Utilization
	kg capita^{-1} yr^{-1}	MK capita^{-1} yr^{-1}	kg capita^{-1} yr^{-1}	MK capita^{-1} yr^{-1}
Mulanje	86.8	9.55	0.4	14.38
Liwonde	52.0	5.72	1.4	51.77
Dzalanyama	148.4	16.32	1.7	42.20
Vwaza	205.0	22.55	5.5	134.52

The protected area utilization quantities of the most important major and minor thatch species are displayed in Figure B.15. The genus *Hyparrhenia* accounted for 57% of the thatch grass extracted from the protected areas. Only in Mulanje did a non-*Hyparrhenia* species (*Heteropogon contortus*) predominate. A number of households were unable to report thatch usage on the basis of individual species. In those cases, thatch was reported in aggregate as "udzu," or general grass.

A special effort was made to elicit information about the use of protected area species for their medicinal properties. During the pilot study and throughout the rapid appraisal a view was expressed by local inhabitants that researchers (in general) might exploit local knowledge about medicinal plants. The research team therefore agreed to focus on aggregated quantities and value rather than the specifics of medicinal use, particularly since exceptional detail about these products and their uses in Malawi has already been documented by Morris and Msonthi (1996) and Williamson (1974). Despite the agreement to limit disclosure, the research team felt that particularly in Mulanje and Liwonde, protected area medicinal plant usage was largely under-reported. Only in Vwaza did the majority of households feel comfortable in disclosing this information.

The aggregated quantities and value of reported protected area medicinal natural resource product utilization is reported in the right-most columns of Table B.10. Across the four protected areas, 272 different species were reported as used for medicinal purposes. For most species, far more biomass was extracted in order to create root or stem-based medicines than for leaf, bark, or fruit based medicines. To account for this, species importance was determined by the number of households using the species, rather than the total biomass extracted to create those medicines. The top fifteen protected area species utilized for medicinal purposes fc: each protected area is reported in Table B.10. In order to respect our agreement with local inhabitants, species are ranked only.

TABLE B.10. THE FIFTEEN MOST FREQUENTLY REPORTED SPECIES USED FOR MEDICINAL PURPOSES IN EACH PROTECTED AREA.

Medicinal Plant Species	M	L	D	V
	--rank--			
Albizia zimmermanii Harms	--	--	--	13
Allophylus africanus Beauv	--	15	--	--
Annona senegalensis Pers.	*	--	--	10
Antidesma venosum E. Mey. ex Tul.	--	8	--	*
Asparagus africanus Lam.	*	--	*	15
Borassus aethiopum Mart.	--	9	--	*
Bridelia carthatica Bertol. f.	--	--	5	--
Burkea africana Hook.	*	--	--	8
Byrsocarpus orientalis (Baill.) Bak.	--	--	--	9
Cassia abbreviata Oliv.	--	3	*	3
Cassia sp.	--	*	2	--
Catunarecam spinosa (Thunb)	--	11	*	*
Cyphostemma junceum (Webb) Descoings	12	--	*	--
Cyphostemma nieriense	2	14	--	--
Dalbergia nitudula Welw. ex Bak.	--	--	*	5
Desmodium velutinum (Willd.) DC.	8	*	--	--
Dicoma anomala Sond.	--	5	1	*
Dicoma sessiliflora Harv. Sub sp. *sessiliflora*	--	--	6	6
Euphorbia hirta L.	9	*	--	--
Fagara macrophylla (Oliv.) Engl.	--	--	14	4
Ficus capensis Thunb.	--	--	*	12
Flacourtia indica (Burm. f.) Merr.	--	--	11	*
Heteromorpha trifoliata (Wendl.) Eckl. and Zeyh.	4	--	--	--
Iboza riparia (Hochst.) N. E. Br.	13	--	--	--
Leptactina benguelensis (Welw. ex Benth. & Hook.f.) Good	--	--	--	7
Melia azedarach L.	--	13	--	--
Mondia whytei (Hook. F.) Skeels	5	--	*	--
Olax obtusfolia De Wild.	10	--	--	--
Olinia usambarensis Gilg	1	--	--	--
Ozoroa reticulata (Bak. f.) R. and A. Fernandez	--	--	3	*
Pterocarpus angolensis DC	*	4	*	--

Medicinal Plant Species	M	L	D	V
		--rank--		
Piliostigma thonningii (Schumach.) Milne-Redh.	3	2	13	1
Pseudolachnostylis maprouneifolia Pax	--	--	15	*
Psorospermum febrifugum Spach.	--	1	*	*
Rhus longipes Engl.	6	*	*	*
Steganotaenia araliacea Hochst.	7	12	7	11
Schrebera alata (Hochst.) Welw.	--	7	*	--
Sclerocarya caffra Sond.	--	10	*	*
Securidaca longepedunculata Fresen.	14	--	9	*
Strombosia scheffleri Engl.	15	--	--	*
Terminalia sericea Burch. ex DC.	*	*	*	14
Terminalia stenostachya Engl. and Diels	11	--	--	--
Vernonia amygdalina Delile	--	--	8	--
Vigna fischeri Harms	--	--	10	--
Zanha africana (Radlk.) Exell	--	6	4	2
Zizyphus mucronata Willd.	*	*	12	--

M = Mulanje; L = Liwonde; D = Dzalanyama; V = Vwaza
* = reported as used, but not among top 15; -- = not reported as used for medicine

B.6 RESULTS: SUSTAINABILITY ANALYSIS

Protected area resource utilization data collected at the species level can be aggregated in order to evaluate sustainable use for the entire protected area over time. In the case of Malawian protected areas, the two predominant pressures are felling trees in preparation for farming, and extracting wood for fuel, construction, etc. While poaching and the over-utilization of fruits and medicinal plants are equally important, the loss of habitat as a consequence of woody species extraction threatens both wildlife and rare plants. Our research therefore focused on sustainable supply of wood as a measure of overall sustainable use.

Sustainability analysis at the protected area level shows that in 50 years, the local demand for protected area wood will exceed sustainable supply in all but Dzalanyama, where supplies will last another 50 years (Table B.11 and Figure B.16). Resource demand was based on the average wood utilization per capita multiplied by the population in the zone of influence for each protected area. Each protected area has very different projected rates of population growth and wood consumption, resulting in varied rates of resource decline. For example, the sustainable supply of woody biomass in highly protected Liwonde is projected to last a few years longer than Vwaza, despite the much larger resource base available inside Vwaza Wildlife Reserve.

TABLE B.11. SUSTAINABILITY OF WOODY PROTECTED AREA RESOURCES.

	--1996 Estimates--				--Forecast After 1996--		
	Sustainable Wood Supply	Total Wood Demand	Per Capita Wood Demand	Zone of Influence Population	Estimated Population Growth Rate	How Many More People Could Be Supported?	When Would Sustainable Supply Be Exhausted?
	--m^3--			people	%	people	year
M	163,233	127,686	628	135,648	0.5	37,765	2046
L	125,122	48,844	327	99,604	1.8	155,547	2049
D	395,413	81,995	730	74,868	1.6	286,177	2096
V	233,937	61,763	951	43,316	2.7	120,751	2046

M = Mulanje, L = Liwonde, D = Dzalanyama, V = Vwaza

B.7 CONCLUSIONS

The quantity and consumptive use value of protected area species can be used to inform natural resource management in each protected area. Knowledge of the level of demand for an individual species can be compared with field survey analysis of its ecological status. Where rates of demand are deemed excessive, alternative species in the protected area can be promoted. Moreover, the role each individual species plays in overall household income can be assessed. Substitutes among agricultural crops or livestock can be identified, and where necessary, alternative income generating activities can be promoted to reduce the pressure on specific species.

Variation was high among four Malawian protected areas in products extracted from them and the species that were used. In some cases this was due to biophysical conditions that favored specific species, or protection policies that target selected species, such as large mammals. In other cases, local preferences or the availability of alternatives explained the variation. For example, freshwater crabs are relatively common throughout Malawi, but are generally favored for consumption in two areas Mulanje National Forest, and Zomba National Forest, where the crab species *Potomonautes montivagus* Chace F. is found. A similar example is the bush pig (*Potamochoerus porcus* L.), which is also relatively widespread, but not reported as consumed in villages adjacent to Liwonde. That region is predominantly of Yao ethnicity, mostly practitioners of Islam, which does not permit the consumption of this species.

Despite this variation, for each use category, a few species dominated, none more than the multipurpose fruit tree, masuku (*Uapaca kirkiana* Müll. Arg.). This species was the most important protected area source of food, was very important for fuelwood, and was used for construction, fiber, and medicinal purposes. Our findings support the conclusion of both Ngulube (1995) and Malembo, Chilanga, and Maliwichi. (1998) who both found the pervasive use of masuku in the wild as in important factor supporting its candidacy for domestication as an agroforestry tree.

Aggregation of woody species utilization data provides an estimate of overall protected area resource demand. In three of the protected areas studied, demand will exceed the sustainable supply of woody biomass in 50 years, and in 100 years in the fourth. This suggests that, barring any additional demand pressure, there is time to enhance community-based natural resource initiatives that are promoted for all four protected areas. In addition to their institutional and management complexities, community conservation efforts must take these time constraints into account.

This analysis of protected area resource demand and sustainable supply has caveats. The analysis does not account for the spatial impact of encroachment. Though theoretically barred, encroachment of agriculture into protected areas would effectively reduce the overall biomass base, thereby accelerating the decline in sustainable supply. Equally, this analysis does not account for spatial variation in use that might result from differential access, or the distribution of favored resources. Pressure points that might receive higher than sustainable utilization can result in habitat fragmentation, a significant threat to sustainability.

An analysis of aggregate sustainable use provides a context for natural resource decision making. The analysis, particularly when combined with species-level demand assessments and physical resource inventories, provides a set of monitoring tools for community management and conservation. Without regularly updated estimates of protected area resource demand, threats to individual species can only be assessed by impact on the resource, a metric applied only after the damage is done. Providing resource demand information enhances the management options and offers an understanding of the problem from the perspective of the user. Working without this information where managed use is encouraged limits the tools available to resource managers to find alternatives for threatened resources.

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B.9 FIGURES LEGENDS

FIGURE B.1. PER CAPITA PRODUCTION FOR MAJOR CROPS.

A = *N. Tabacum tabacum* L., B = *Zea mays* L.

FIGURE B.2. PER CAPITA PRODUCTION FOR IMPORTANT MINOR CROPS.

A = *Ananas comosus* (L.) Merr. (pineapple), B = *Arachis hypogaea* L. (groundnut), C = *Brassica chinensis* L. (Chinese cabbage), D = *Cucurbita maxima* Duch. ex Lam (pumpkin), E = *Ipomea batatas* (L.) Lam. (sweet potato), F = *Lycopersicon esulentum* Mill. (tomato), G = *Mangifera indica* L. (mango), H *Manihot esculanta* Crantz (cassava), I = *Musa paradisiaca* L. *M. sapientum* L. (banana), J = *Oryza sativa* L. (Gram) (rice), K = *Persea americana* Mill. (avocado), L = *Pennisetum americanum* (L) K. Schum. (millet), M = *Saccharum officinarum* L. (sugar cane).

FIGURE B.3. PER CAPITA LIVESTOCK PRODUCTION.

A = *Anas* spp. (duck), B = *Bos indicus* Linnaeus var. Malawi Zebu (cattle), C = *Capra* spp. (goat), D = *Cavia porcellus* Linnaeus (guinea pig), E = *Gallus domesticus* (chicken), F = *Lepus spp.* (rabbit), G = *Ovis* spp. (sheep), H = *Suis* spp. (pig), I = *Terron* spp. (pigeon).

FIGURE B.4. PER CAPITA WOOD PRODUCTION ON AGRICULTURAL LAND.

A = *Acacia* spp., B = *Colophospermum mopane* (Kirk ex Benth.) Kirk ex Léonard, C = *Eucalyptus* spp., D = *Gmelina arborea* Roxb., E = *Melia azedarach* L., F = *Piliostigma thonningii* (Schumach.) Milne-Redh., G = *Pinus* spp., H = *Toona ciliata* M. Roem..

FIGURE B.5. OVERALL PROTECTED AREA UTILIZATION BY CATEGORY OF USE (PER CAPITA QUANTIES AND RELATIVE PERCENTAGES).

FIGURE B.6. OVERALL PROTECTED AREA UTILIZATION BY CATEGORY OF USE (PER CAPITA VALUE AND RELATIVE PERCENTAGES).

FIGURE B.7. PER CAPITA UTILIZATION OF MAJOR PLANT AND MUSHROOM SPECIES FOR FOOD.

A = *Habenaria walleri* Reichb. f., B = mushrooms, C = *Oryza longistaminata* Chev. and Roehr., D = *Parinari curatellifolia* Planch. ex Benth., E = *Uapaca kirkiana* Müll. Arg.

FIGURE B.8. PER CAPITA UTILIZATION OF A SELECTION OF THE MOST IMPORTANT MINOR PLANT FOOD SPECIES.

A = *Adansonia digitata* L., B = *Amaranthus thunbergii* Moq., C = *Annona senegalensis* Pers., D = *Bidens pilosa* L., E = *Canthium crassum* (Schweinf.), F = *Dioscorea* spp., G = *Momordica foetida* Schumach. and Thonn., H = *Solanum nigrum* L., I = *Strychnos spinosa* Lam., J = *Syzygium cordatum* Hochst. ex Krauss, K = *Tamarindus indica* L., L = *Thunbergia lancifolia* T. Anders. , M = *Treculia africana* Decne., N = *Uapaca robynsii* De Wild., O = *Vangueria infausta* Burch.

FIGURE B.9. PER CAPITA UTILIZATION OF MAJOR FISH SPECIES.

A = *Barbus* spp. (small cypriaids), B = *Clarias gariepinus* Burchell (sharptooth cat fish), C = *Rhamphochromis* sp., D = *Labeo mesops* Günther, E = *Opsaridium microlepis* Günther (lake salmon), F = *Oreochromis* spp. (chambo), G = *Marcusenius macrolepidotus* Peters (bulldog fish).

FIGURE B.10. PER CAPITA FOOD UTILIZATION OF WILD ANIMALS, INCLUDING INSECTS AND HONEY.

A = *Aepyceros melampus* Lichtenstein (impala), B = *Hippotragus niger* Harris (sable antelope), C = honey, D = insects (all species), E = *Kobus ellipsiprymnus* Ogilby (waterbuck), F = *Muridae family* (edible rodents known locally as mbewa), G = *Numidea meleagris (Linnaeus)* (helmeted guinea fowl), H = *Potamochoerus porcus* Linnaeus (bush pig), I = *Potomonautes montivagus* Chace F. (freshwater crab), J = *Procavia capensis* Pallus (rock hyrax), K = *Raphicerus sharpei* Thomas (Sharpe's grysbok), L = *Redunga arundinum* Boddaert (reedbuck), M = *Sigmoceros lichtensteinii* Peters (Lichtenstein's hartebeest), N = *Sylvicapra grimmia* (grey duiker), O = *Syncerus caffer* Sparrman (African buffalo), P = *Taurotragus oryx* Pallas (eland), Q = *Tragelaphus scriptus* Pallus (bushbuck). NB: due to scale, does not include 109.5 kg capita^{-1} of *Loxodonta africana* Blumenbach in Vwaza.

FIGURE B.11. PER CAPITA PROTECTED AREA FUELWOOD UTILIZATION. A = *Acacia nigrescens* Oliv., B = *Aguaria salicifolia* (Lam.) Oliv., C = *Brachystegia boehmii* Taub., D = *Brachystegia floribunda* Benth., E = *Brachystegia longifolia* Benth., F = *Brachystegia spiciformis* Benth., G = *Brachystegia utilis* Burtt Davy and Hutch, H = *Burkea africana* Hook., I = *Colophospermum mopane*, J = *Combretum apiculatum* Sond., K = *Combretum fragrans* F. Hoffm., L = *Combretum imberbe* Wawra, M = *Combretum molle* R. Br. ex Don, N = *Dalbergia melanoxylon* Guill. and Perr., O = *Dichrostachys cinerea* (L.) Wight and Arn., P = *Diospyros mespiliformis* Hochst. ex A. DC., Q = *Eucalyptus* spp., R = *Faurea saligna* Harv., S = *Faurea speciosa* Welw., T = *Julbernardia globiflora* (Benth.) Troupin, U = *Julbernardia paniculata* (Benth.) Troupin, V = *Lonchocarpus capassa* Rolfe, W = *Newtonia buchananii* (Bak.) Gilbert and Boutique, X = *Parinari curatellifolia*, Y = *Pericopsis angolensis* (Bak.) van Meeuwen, Z

= *Piliostigma thonningii*, α = *Pinus* spp., β = *Syzygium cordatum*, γ = *Terminalia sericea* Burch. ex DC., δ = *Uapaca kirkiana*.

FIGURE B.12. PER CAPITA PROTECTED AREA CONSTRUCTION UTILIZATION. A = *Acacia nigrescens* B = *Aguaria salicifolia*, C = *Arundinaria alpina* K. Schum, D = *Brachystegia longifolia*, E = *Brachystegia spiciformis*, F = *Burkea africana*, G = *Byrsocarpus orientalis* (Baill.) Bak., H = *Cassipourea mollis* (R.E. Fr.) Alston, I = *Colophospermum mopane*, J = *Combretum apiculatum*, K = *Combretum fragrans*, L = *Combretum molle*, M = *Dalbergia nitudula* Welw. ex Bak., N = *Dichrostachys cinerea*, O = *Diplorhynchus condylocarpon* (Muell. Arg.) Pich., P = *Eucalyptus* spp., Q = *Friesodielsia obovata* (Benth.) Verdc., R = *Hymenocardia mollis* Pax, S = *Hymenodictyon parvifolium* Oliv., T = *Jatropha curcas* L., U = *Julbernardia paniculata*, V = *Oxytenanthera abyssinica*, W = *Pericopsis angolensis*, X = *Syzygium cordatum*, Y = *Terminalia sericea*.

FIGURE B.13. PER CAPITA PROTECTED AREA FIBER UTILIZATION. A = *Adenia gummifera* (Harv.) Harms, B = *Agave sisalana* (Engl.) Perrine, C = *Brachystegia boehmii*, D = *B. bussei*, E = *B. floribunda*, F = *B. longifolia*, G = *B. spiciformis*, H = *B. utilis*, I = *Cissampelos mucronata* A. Rich., J = *Colophospermum mopane*, K = *Combretum fragrans*, L = *Dombeya dawei* Sprague, M = *Julbernardia paniculata*, N = *Lannea schimperi* (Hochst. ex A. Rich.), O = *Piliostigma thonningii*, P = *Sterculia africana* (Lour.) Fiori .

FIGURE B.14 PER CAPITA PROTECTED AREA TOOL AND HANDICRAFT SPECIES UTILIZATION.

A = *Acacia polyacantha* Willd., B = *Annona senegalensis* Pers. C = *Arundinaria alpina*, D = *Bauhinia petersiana* Bolle, E = *Borassus aethiopum* Mart., F = *Brachystegia* spp., G = *Burkea africana*, H = *Cassia singueana* Del., I = *Cissampelos mucronata*, J = *Diospyros squarrosa* Klotzsch., K = *Diplorhynchus condylocarpon* (Muell. Arg.) Pich., L = *Ficus natalensis* Hochst., M = *Hyparrhenia rufa* (Nees) Stapf, N = *Hyparrhenia nyasica* (Rendle) Stapf, O = *Julbernardia paniculata*, P = *Lonchocarpus capassa* Rolfe, Q = *Maytenus senegalensis* (Lam.) Exell, R = *Oxytenanthera abyssinica*, S = *Pennisetum purpurium* Schumach., T = *Pericopsis angolensis*, U = *Phragmites mauritianus* Kunth., V = *Psychotria zombamontana* (Kuntze) Petit, W = *Pteridium aquilinum* (L.) Kuhn, X = *Pterocarpus angolensis* DC., Y = *Sida acuta* Burm. f., Z = *Triumfetta rhomboidea* Jacq.., α = *Uapaca kirkiana*, β = *Widdringtonia whytei* Rendle, γ = *Xeroderris stuhlmannii* (Taub.) Mendonca and E.P. Sousa, δ = *Xerophyta splendens* Menezes.

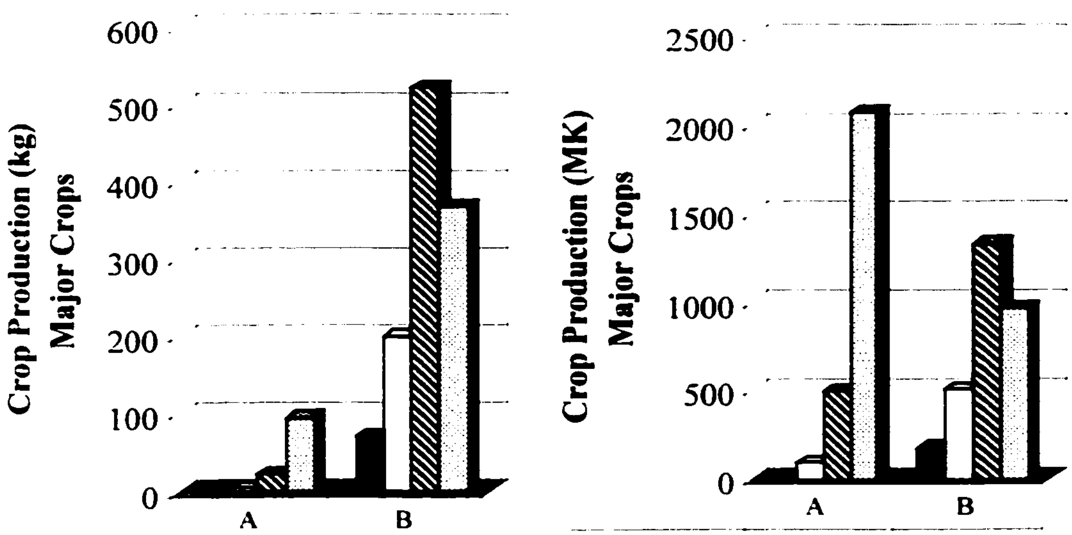
FIGURE B.15. PER CAPITA PROTECTED AREA THATCH UTILIZATION.

A = *Dactyloctenium aegytium* (L.) Willd., B = general thatch grass, C = *Helictotrichon elongatum* (Hochst. ex A. Rich.), D = *Heteropogon contortus* (L.) Beauv. ex Roem. and Schult., E = *Hyparrhenia filipendula* (Hochst.) Stapf, F = *Hyparrhenia gazensis* (Rendle) Stapf, G = *H. nyassae*, H = *H. rufa*, I = *Themeda triandra* Forsk., J = chambundu grass, K = *Beckeropsis uniseta* (Nees) Stapf, L = *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf, M = *Chloris gayana* Kunth., N = *Digitaria diagonalis* (Nees) Stapf, O =

Echinochloa colona (L.) Link, P = *Hyperthelia dissoluta* (Nees ex Steud.) W. D. Clayton, Q = *Imperata cylindrica* (L.) Beauv., R = *Panicum maximum* Jacq., S = *Pennisetum purpurium*, T = *Setaria palustris* Stapf, U = *Setaria sphacelata* (Schumach.) Stapf and C.E. Hubbard ex M.B. Moss, V = chilambulire grass, W = chisungumbe grass.

FIGURE B.16. PROJECTED DECLINE IN THE SUSTAINABLE SUPPLY OF WOOD (MAI ROUNDWOOD EQUIVALENT) AS POPULATION GROWS.

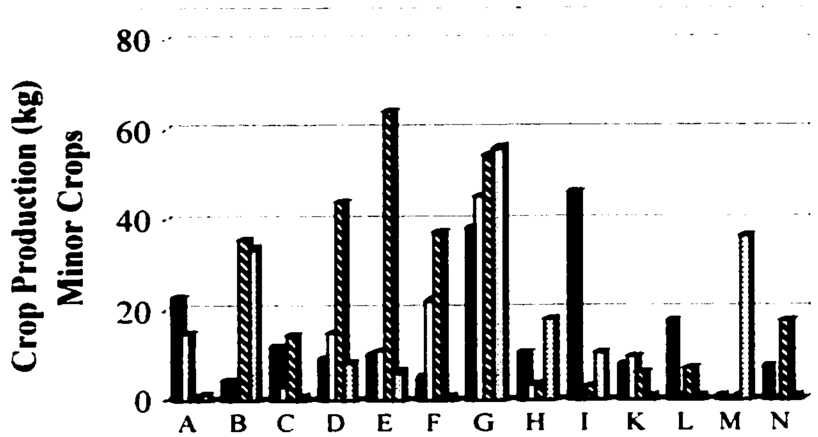
B.10 FIGURES



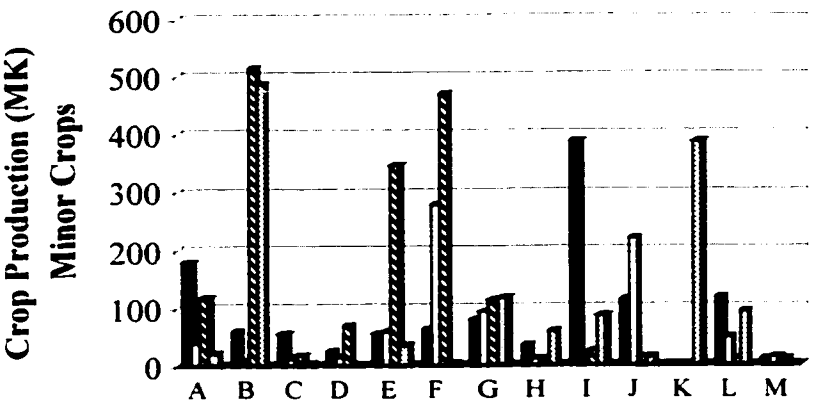
	A	B
Mulanje	1	71
Liwonde	4	200
Dzalanyama	23	521
Vwaza	95	369

	A	B
Mulanje	7	180
Liwonde	96	511
Dzalanyama	496	1329
Vwaza	2069	966

FIGURE B.1. PER CAPITA PRODUCTION FOR MAJOR CROPS.
A = *N. Tabacum tabacum* L., B = *Zea mays* L.

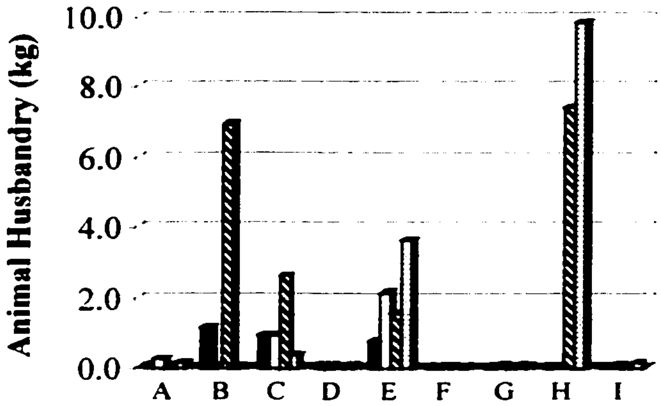


	A	B	C	D	E	F	G	H	I	K	L	M	N
■ Mulanje	23	4	12	9	10	5	38	11	46	8	17	1	7
□ Liwonde	15	1	3	15	11	22	45	3	1	10	1	0	0
▨ Dzalanyama	1	35	15	44	64	37	54	3	3	6	7	1	17
□ Vwaza	1	33	1	8	6	1	56	18	10	1	1	36	1

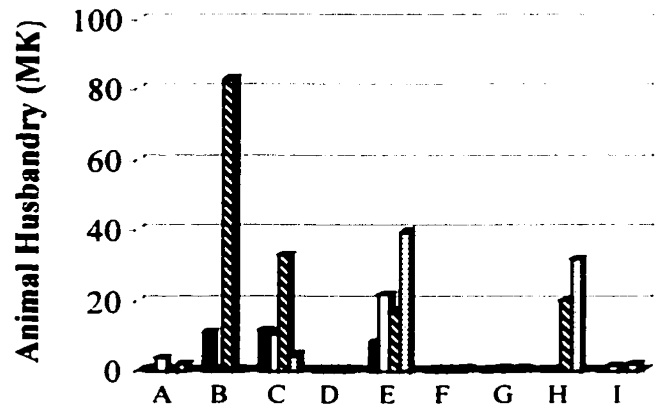


	A	B	C	D	E	F	G	H	I	J	K	L	M
■ Mulanje	180	60	56	25	54	62	79	34	388	113	1	116	11
□ Liwonde	40	7	10	15	60	278	94	10	8	219	1	50	15
▨ Dzalanyama	118	513	19	70	346	468	114	11	24	13	1	11	9
□ Vwaza	22	486	4	2	34	5	117	58	87	15	388	93	1

FIGURE B.2. PER CAPITA PRODUCTION FOR IMPORTANT MINOR CROPS. A = *Ananas comosus* (L.) Merr. (pineapple), B = *Arachis hypogaea* L. (groundnut), C = *Brassica chinensis* L. (Chinese cabbage), D = *Cucurbita maxima* Duch. ex Lam (pumpkin), E = *Ipomea batatas* (L.) Lam. (sweet potato), F = *Lycopersicon esulentum* Mill. (tomato), G = *Mangifera indica* L. (mango), H *Manihot esculanta* Crantz (cassava), I = *Musa paradisiaca* L. / *M. sapientum* L. (banana), J = *Oryza sativa* L. (Gram) (rice), K = *Persea americana* Mill. (avocado), L = *Pennisetum americanum* (L) K. Schum. (millet), M = *Saccharum officinarum* L. (sugar cane).

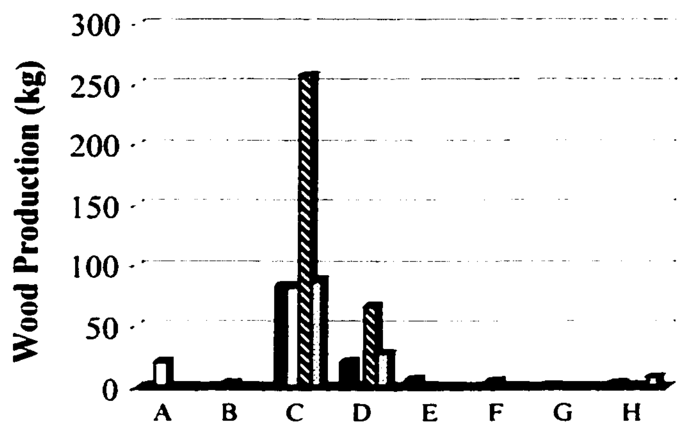


	A	B	C	D	E	F	G	H	I
■ Mulanje	0.1	1.2	0.9	0.1	0.8	0	0	0	0
□ Liwonde	0.3	0	0.9	0.1	2.1	0	0.1	0	0.1
▧ Dzalanyama	0.1	6.9	2.6	0	1.5	0	0	7.4	0
□ Vwaza	0.1	0	0.4	0.1	3.6	0	0.1	9.8	0.1

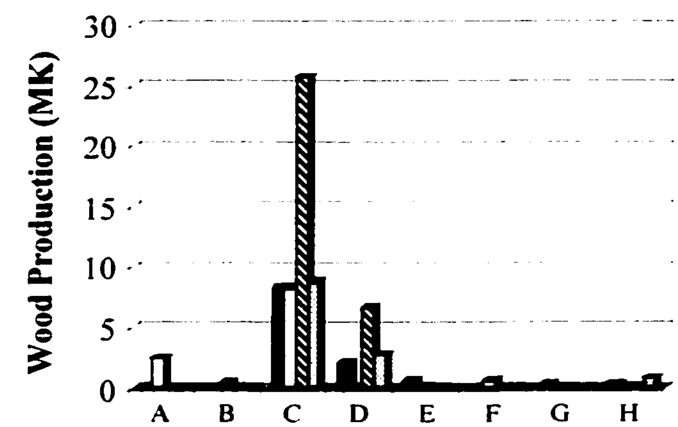


	A	B	C	D	E	F	G	H	I
■ Mulanje	0.68	10.7	11.3	0.21	8.26	0	0	0	0
□ Liwonde	3.83	0	10.7	0.33	21.6	0.05	0.85	0	1.27
▧ Dzalanyama	0.08	82.6	32.9	0	16.8	0	0	20	0.42
□ Vwaza	1.79	0	4.49	0.30	39.3	0.71	0.73	31.6	2.12

FIGURE B.3. PER CAPITA LIVESTOCK PRODUCTION.
A = *Anas* spp. (duck), B = *Bos indicus* Linnaeus var. Malawi Zebu (cattle), C = *Capra* spp. (goat), D = *Cavia porcellus* Linnaeus (guinea pig), E = *Gallus domesticus* (chicken), F = *Lepus spp.* (rabbit), G = *Ovis* spp. (sheep), H = *Suis* spp. (pig), I = *Terron* spp. (pigeon).



	A	B	C	D	E	F	G	H
■ Mulanje	1	0	83	20	6	0	1	4
□ Liwonde	20	3	83	0	1	5	0	1
▧ Dzalanyama	0	0	258	67	0	0	0	2
□ Vwaza	0	0	88	28	0	0	0	8



	A	B	C	D	E	F	G	H
■ Mulanje	0.07	0	8.32	2.04	0.6	0	0.29	0.39
□ Liwonde	2.48	0.41	8.31	0.03	0.1	0.62	0	0.13
▧ Dzalanyama	0	0	25.76	6.68	0	0	0	0.21
□ Vwaza	0	0	8.8	2.81	0	0	0	0.82

FIGURE B.4. PER CAPITA WOOD PRODUCTION ON AGRICULTURAL LAND.
A = *Acacia* spp., B = *Colophospermum mopane* (Kirk ex Benth.) Kirk ex Léonard, C = *Eucalyptus* spp., D = *Gmelina arborea* Roxb., E = *Melia azedarach* L., F = *Piliostigma thonningii* (Schumach.) Milne-Redh., G = *Pinus* spp., H = *Toona ciliata* M. Roem.

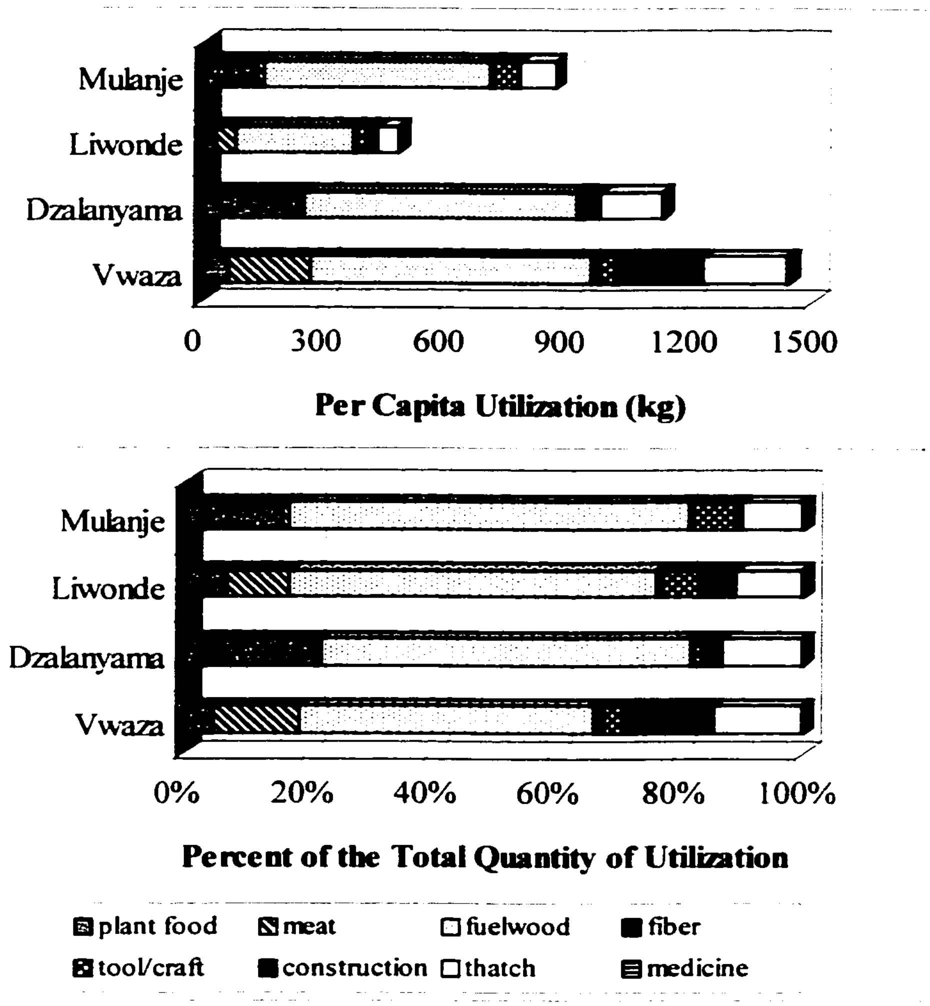


FIGURE B.5. OVERALL PROTECTED AREA UTILIZATION BY CATEGORY OF USE (PER CAPITA QUANTIES AND RELATIVE PERCENTAGES).

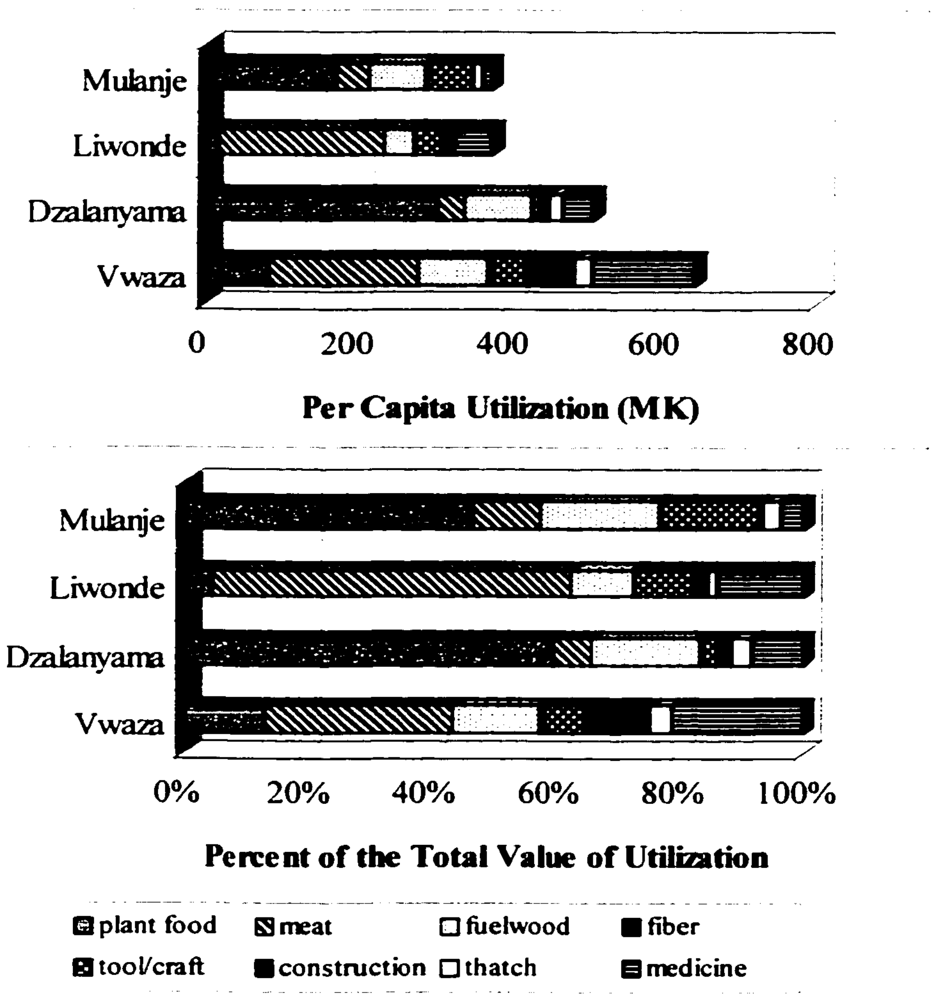
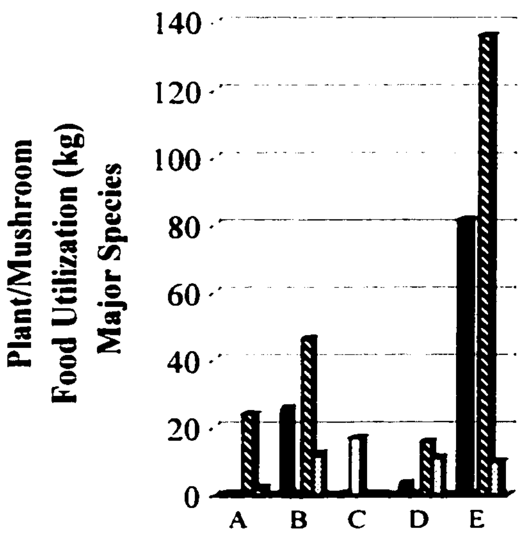
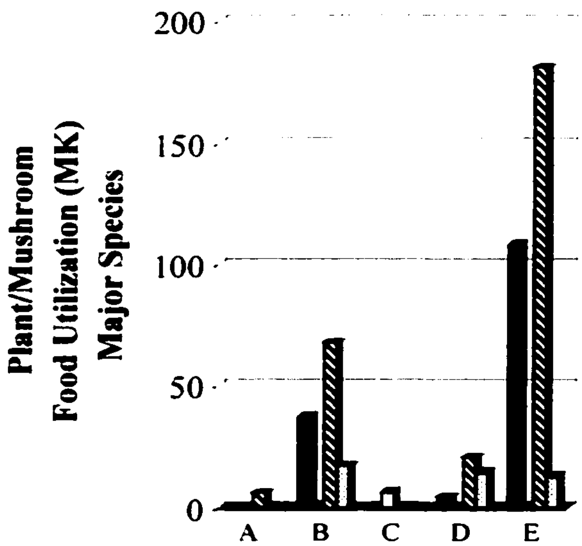


FIGURE B.6. OVERALL PROTECTED AREA UTILIZATION BY CATEGORY OF USE (PER CAPITA VALUE AND RELATIVE PERCENTAGES).

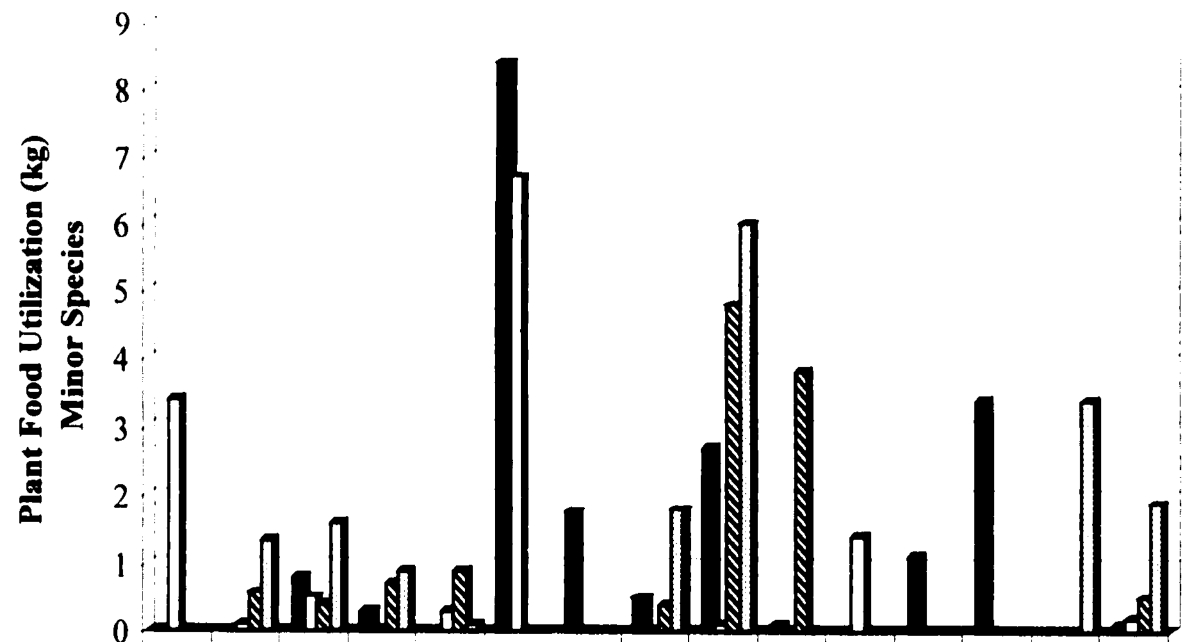


	A	B	C	D	E
Mulanje	0	25.4	0	3.1	81.5
Liwonde	0	0.5	17	0	0
Dzalanyama	23.8	46.2	0	15.5	136
Vwaza	1.8	11.8	0	11	9.7



	A	B	C	D	E
Mulanje	0	37.28	0	4.17	108.3
Liwonde	0	0.5	6.29	0	0
Dzalanyama	5.95	67.90	0	20.58	181
Vwaza	0.45	17.34	0	14.67	12.89

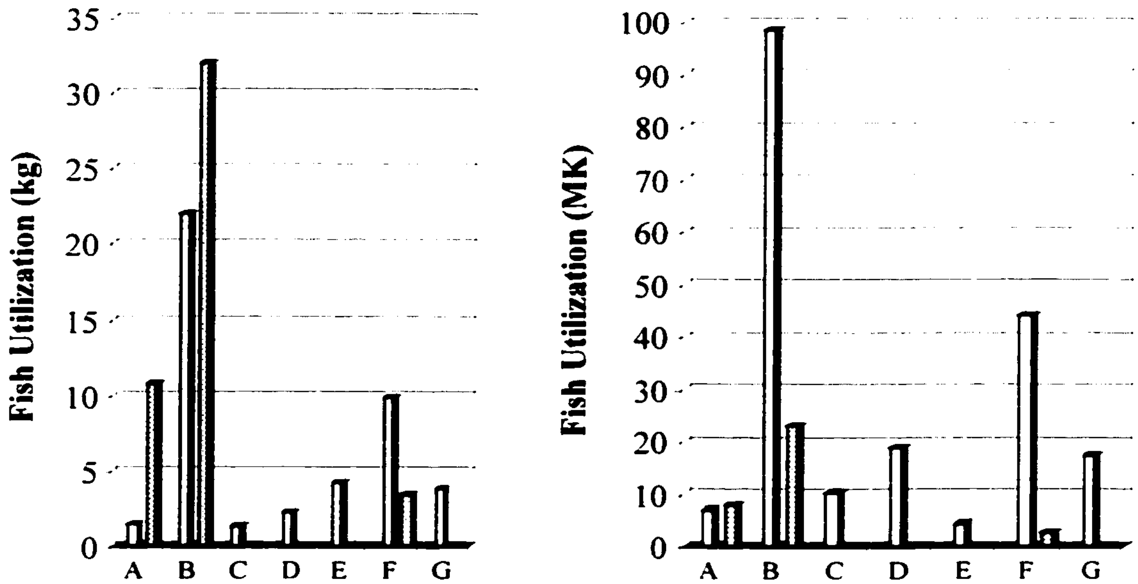
FIGURE B.7. PER CAPITA UTILIZATION OF MAJOR PLANT AND MUSHROOM SPECIES FOR FOOD.
A = *Habenaria walleri* Reichb. f., B = mushrooms, C = *Oryza longistaminata* Chev. and Roehr., D = *Parinari curatellifolia* Planch. ex Benth., E = *Uapaca kirkiana Müll.* Arg.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
■ Mulanje	0	0	0.8	0.3	0	8.4	1.8	0.5	2.7	0.1	0	1.1	3.4	0	0.1
□ Liwonde	3.4	0.1	0.5	0	0.3	6.7	0	0	0.1	0	1.4	0	0	0	0.2
▧ Dzalanyama	0	0.6	0.4	0.7	0.9	0	0	0.4	4.8	3.8	0	0.0	0	0	0.5
□ Vwaza	0	1.3	1.6	0.9	0.1	0	0	1.8	6	0	0	0	0	3.4	1.9

FIGURE B.8. PER CAPITA UTILIZATION OF A SELECTION OF THE MOST IMPORTANT MINOR PLANT FOOD SPECIES.

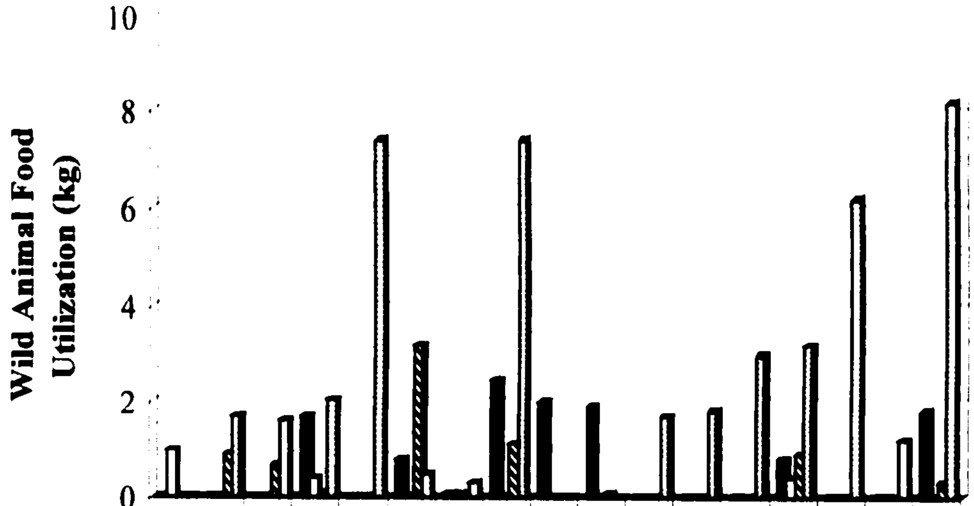
A = *Adansonia digitata* L., B = *Amaranthus thunbergii* Moq., C = *Annona senegalensis* Pers., D = *Bidens pilosa* L., E = *Canthium crassum* (Schweinf.), F = *Dioscorea* spp., G = *Momordica foetida* Schumach. and Thonn., H = *Solanum nigrum* L., I = *Strychnos spinosa* Lam., J = *Syzygium cordatum* Hochst. ex Krauss, K = *Tamarindus indica* L., L = *Thunbergia lancifolia* T. Anders. , M = *Treculia africana* Decne., N = *Uapaca robynsii* De Wild., O = *Vangueria infausta* Burch.



	A	B	C	D	E	F	G
■ Mulanje	0	0	0	0	0	0	0
□ Liwonde	1.5	22.0	1.3	2.3	4.2	9.9	3.8
▧ Dzalanyama	0.2	0.2	0	0	0	0	0
□ Vwaza	10.8	31.9	0	0	0	3.4	0

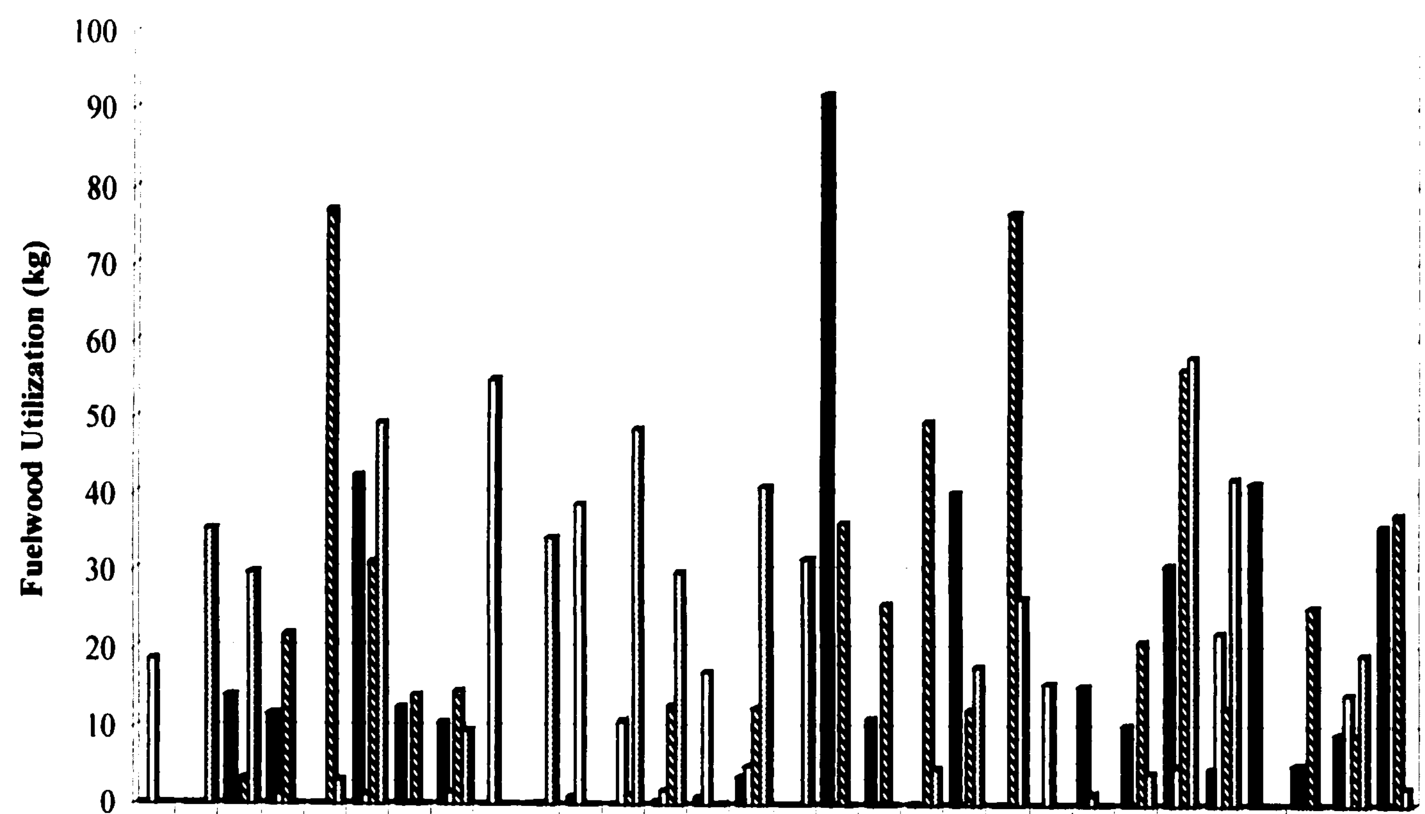
	A	B	C	D	E	F	G
■ Mulanje	0	0	0	0	0	0	0
□ Liwonde	6.91	98.54	10.15	18.90	4.20	44.13	17.21
▧ Dzalanyama	0.11	0.15	0	0	0	0	0
□ Vwaza	7.78	22.95	0	0	0	2.45	0

FIGURE B.9. PER CAPITA UTILIZATION OF MAJOR FISH SPECIES.
A = *Barbus* spp. (small cypriaids), B = *Clarias gariepinus* Burchell (sharptooth cat fish). C = *Rhamphochromis* sp., D = *Labeo mesops* Günther, E = *Opsaridium microlepis* Günther (lake salmon), F = *Oreochromis* spp. (chambo), G = *Marcusenius macrolepidotus* Peters (bulldog fish).



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Mulanje	0	0	0	1.7	0	0.8	0.1	2.5	2.0	1.9	0	0	0	0.8	0	0	1.8
Liwonde	1.0	0	0	0.4	0	0	0.1	0	0	0	0	0	0	0.4	0	0	0
Dzalanyama	0	0.9	0.7	0.1	0	3.2	0.1	1.1	0	0.1	0	0	0	0.9	0	0	0.3
Vwaza	0	1.7	1.6	2.1	7.4	0.5	0.3	7.4	0	0	1.7	1.8	3.0	3.2	6.2	1.2	8.2

FIGURE B.10. PER CAPITA FOOD UTILIZATION OF WILD ANIMALS, INCLUDING INSECTS AND HONEY. A = *Aepyceros melampus* Lichtenstein (impala), B = *Hippotragus niger* Harris (sable antelope), C = honey, D = insects (all species), E = *Kobus ellipsiprymnus* Ogilby (waterbuck), F = *Muridae family* (edible rodents known locally as mbewa), G = *Numidea meleagris* (Linnaeus) (helmeted guinea fowl), H = *Potamochoerus porcus* Linnaeus (bush pig), I = *Potomonautes montivagus* Chace F. (freshwater crab), J = *Procavia capensis* Pallus (rock hyrax), K = *Raphicerus sharpei* Thomas (Sharpe's grysbok), L = *Redunga arundinum* Boddaert (reedbuck), M = *Sigmoceros lichtensteinii* Peters (Lichtenstein's hartebeest), N = *Sylvicapra grimmia* Linnaeus (grey duiker), O = *Syncerus caffer* Sparrman (African buffalo), P = *Taurotragus oryx* Pallas (eland), Q = *Tragelaphus scriptus* Pallus (bushbuck). NB: due to scale, does not include 109.5 kg capita^{-1} of *Loxodonta africana* Blumenbach (elephant) in Vwaza.

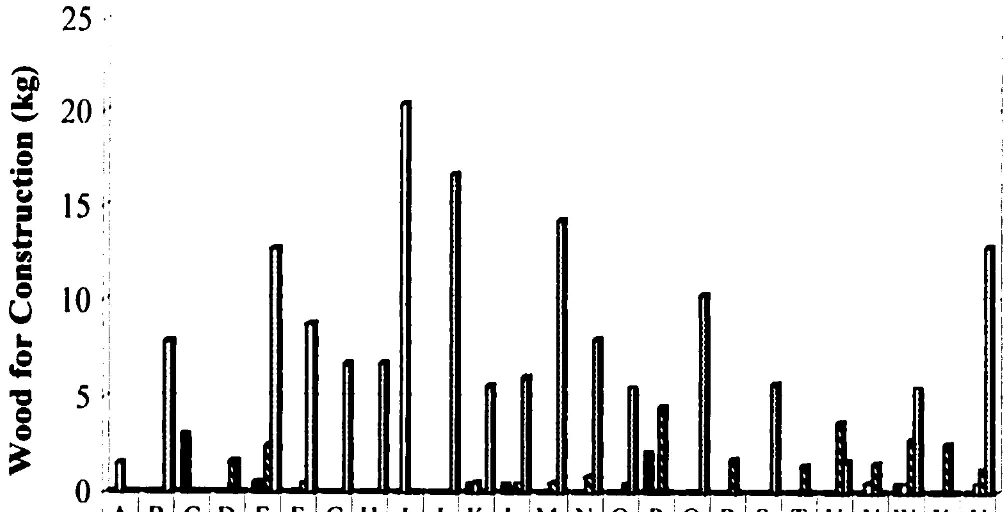


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	α	β	γ	δ
Mulanje	0	0	14	12	0	42	13	11	0	0	1	0	0	1	4	0	92	11	0	40	0	0	16	10	31	5	42	5	9	36
Liwonde	19	0	0	1	0	1	0	2	55	0	39	11	2	17	5	0	0	0	0	0	0	16	1	0	5	22	0	0	15	0
Dzalanyama	0	0	4	22	77	31	14	15	0	0	0	1	13	0	13	0	36	26	50	12	77	0	0	21	57	13	0	25	9	38
Vwaza	0	35	30	0	3	49	0	10	0	34	0	49	30	0	41	32	0	0	5	18	27	0	0	4	58	42	0	0	20	2

FIGURE B.11. PER CAPITA PROTECTED AREA FUELWOOD UTILIZATION.

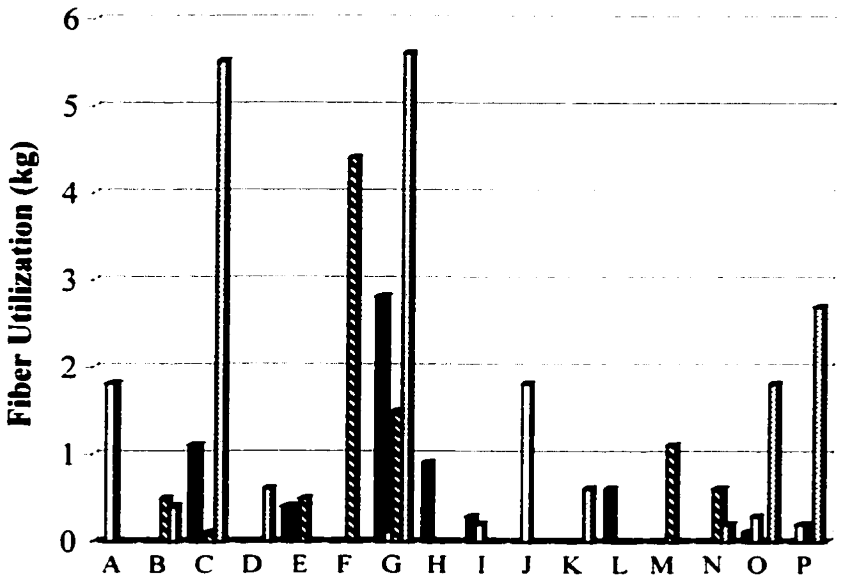
FIGURE B.11 – *Continued.*

A = *Acacia nigrescens* Oliv., B = *Aguaria salicifolia* (Lam.) Oliv., C = *Brachystegia boehmii* Taub., D = *Brachystegia floribunda* Benth., E = *Brachystegia longifolia* Benth., F = *Brachystegia spiciformis* Benth., G = *Brachystegia utilis* Burtt Davy and Hutch, H = *Burkea africana* Hook., I = *Colophospermum mopane*, J = *Combretum apiculatum* Sond., K = *Combretum fragrans* F. Hoffm., L = *Combretum imberbe* Wawra, M = *Combretum molle* R. Br. ex Don, N = *Dalbergia melanoxylon* Guill. and Perr., O = *Dichrostachys cinerea* (L.) Wight and Arn., P = *Diospyros mespiliformis* Hochst. ex A. DC., Q = *Eucalyptus* spp., R = *Faurea saligna* Harv., S = *Faurea speciosa* Welw., T = *Julbernardia globiflora* (Benth.) Troupin, U = *Julbernardia paniculata* (Benth.) Troupin, V = *Lonchocarpus capassa* Rolfe, W = *Newtonia buchananii* (Bak.) Gilbert and Boutique, X = *Parinari curatellifolia*, Y = *Pericopsis angolensis* (Bak.) van Meeuwen, Z = *Piliostigma thonningii*, α = *Pinus* spp., β = *Syzygium cordatum*, γ = *Terminalia sericea* Burch. ex DC., δ = *Uapaca kirkiana*..



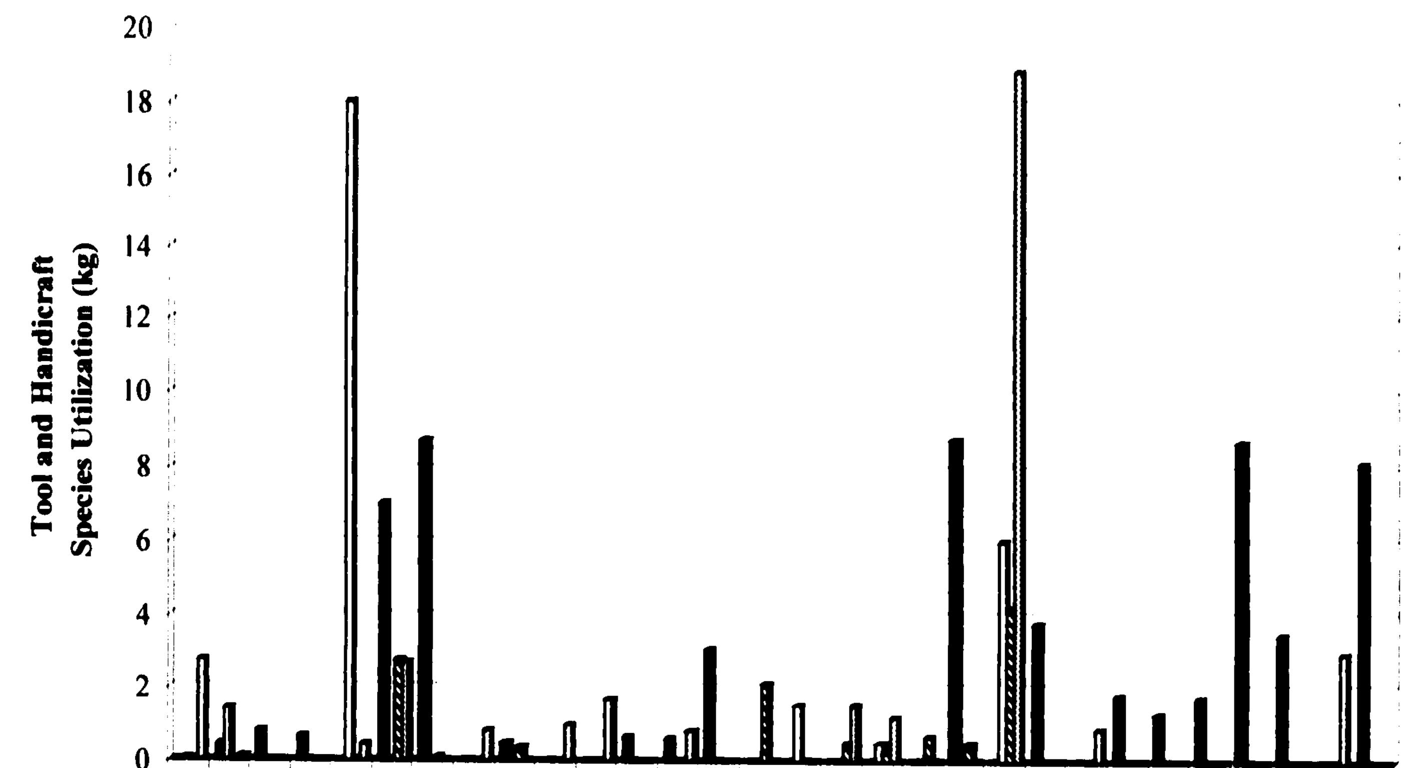
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
■ Mulanje	0	0	3	0	1	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0	0	0	1	0	0
□ Liwonde	2	0	0	0	0	0	0	0	20	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1
▧ Dzalanyama	0	0	0	2	3	1	0	0	0	0	0	1	1	1	1	5	0	2	0	2	4	2	3	3	1
□ Vwaza	0	8	0	0	13	9	7	7	0	17	6	6	14	8	6	0	10	0	6	0	2	0	6	0	13

FIGURE B.12. PER CAPITA PROTECTED AREA CONSTRUCTION UTILIZATION.
A = *Acacia nigrescens* B = *Aguaria salicifolia*, C = *Arundinaria alpina* K. Schum, D = *Brachystegia longifolia*, E = *Brachystegia spiciformis*, F = *Burkea africana*, G = *Byrsocarpus orientalis* (Baill.) Bak., H = *Cassipourea mollis* (R.E. Fr.) Alston, I = *Colophospermum mopane*, J = *Combretum apiculatum*, K = *Combretum fragrans*, L = *Combretum molle*, M = *Dalbergia nitudula* Welw. ex Bak., N = *Dichrostachys cinerea*, O = *Diplorhynchus condylocarpon* (Muell. Arg.) Pich., P = *Eucalyptus* spp., Q = *Friesodielsia obovata* (Benth.) Verdc., R = *Hymenocardia mollis* Pax, S = *Hymenodictyon parvifolium* Oliv., T = *Jatropha curcas* L., U = *Julbernardia paniculata*, V = *Oxytenanthera abyssinica*, W = *Pericopsis angolensis*, X = *Syzygium cordatum*, Y = *Terminalia sericea*.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
■ Mulanje	0	0	1.1	0	0.4	0	2.8	0.9	0.3	0	0	0.6	0	0	0.1	0
□ Liwonde	1.8	0	0	0	0	0	0.1	0	0.2	1.8	0	0	0	0	0.3	0.2
▨ Dzalanyama	0	0.5	0.1	0	0.5	4.4	1.5	0	0	0	0	0	1.1	0.6	0	0
□ Vwaza	0	0.4	5.5	0.6	0	0	5.6	0	0	0	0.6	0	0	0.2	1.8	2.7

FIGURE B.13. PER CAPITA PROTECTED AREA FIBER UTILIZATION.
A = *Adenia gummifera* (Harv.) Harms, B = *Agave sisalana* (Engl.) Perrine, C = *Brachystegia boehmii*, D = *B. bussei*, E = *B. floribunda*, F = *B. longifolia*, G = *B. spiciformis*, H = *B. utilis*, I = *Cissampelos mucronata* A. Rich., J = *Colophospermum mopane*, K = *Combretum fragrans*, L = *Dombeya dawei* Sprague, M = *Julbernardia paniculata*, N = *Lannea schimperi* (Hochst. ex A. Rich.), O = *Piliostigma thonningii*, P = *Sterculia africana* (Lour.) Fiori .

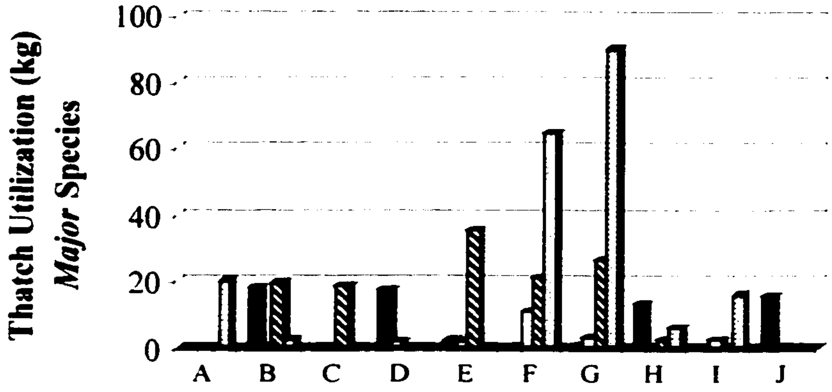


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	α	β	γ	δ
■ Mulanje	0	0.4	0.8	0.7	0	7.1	8.7	0	0.5	0	0	0.6	0.6	3.1	0	0	0	0	0	8.8	0	3.8	0	1.8	1.3	1.7	8.7	3.5	0	8.2
□ Liwonde	0.1	1.4	0	0	18	0	0	0	0.1	0	0	0	0	0	0	1.5	0	0.5	0	0	6.0	0	0	0	0	0	0	0	0	0
▧ Dzalanyama	0	0	0	0	0	2.7	0.1	0	0.4	0	0	0	0	0	2.1	0	0.5	0.2	0.6	0.5	4.2	0	0	0	0	0	0	0	0	0
□ Vwaza	2.7	0.1	0	0	0.4	2.7	0	0.8	0	1.0	1.7	0	0.8	0	0	0	1.5	1.2	0	0	19	0	0.8	0	0	0	0	0	3.0	0

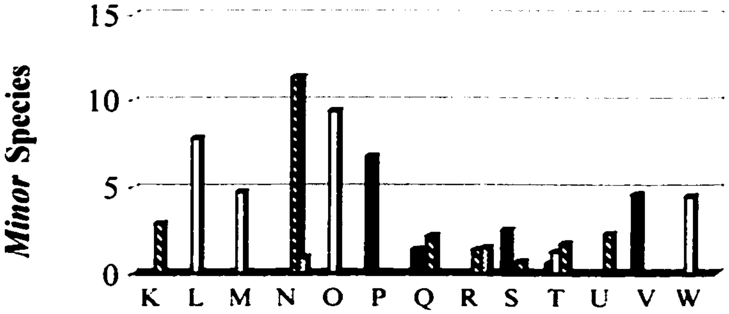
FIGURE B.14. PER CAPITA PROTECTED AREA TOOL AND HANDICRAFT SPECIES UTILIZATION.

FIGURE B.1 – *Continued.*

A = *Acacia polyacantha* Willd., B = *Annona senegalensis* Pers. C = *Arundinaria alpina*, D = *Bauhinia petersiana* Bolle, E = *Borassus aethiopum* Mart., F = *Brachystegia* spp., G = *Burkea africana*, H = *Cassia singueana* Del., I = *Cissampelos mucronata*, J = *Diospyros squarrosa* Klotzsch., K = *Diplorhynchus condylocarpon* (Muell. Arg.) Pich., L = *Ficus natalensis* Hochst., M = *Hyparrhenia rufa* (Nees) Stapf, N = *Hyparrhenia nyasica* (Rendle) Stapf, O = *Julbernardia paniculata*, P = *Lonchocarpus capassa* Rolfe, Q = *Maytenus senegalensis* (Lam.) Exell, R = *Oxytenanthera abyssinica*, S = *Pennisetum purpurium* Schumach., T = *Pericopsis angolensis*, U = *Phragmites mauritianus* Kunth., V = *Psychotria zombamontana* (Kuntze) Petit, W = *Pteridium aquilinum* (L.) Kuhn, X = *Pterocarpus angolensis* DC., Y = *Sida acuta* Burm. f., Z Triumfetta rhomboidea Jacq.., α = *Uapaca kirkiana*, β = *Widdringtonia whytei* Rendle, γ = *Xeroderris stuhlmannii (Taub.)* Mendonca and E.P. Sousa, δ = *Xerophyta splendens* Menezes.



	A	B	C	D	E	F	G	H	I	J
■ Mulanje	0	17.9	0	17.3	2.3	0	0.8	13.2	0	15.5
□ Liwonde	0	0	0	2.1	2.0	11.0	3.1	0	2.5	0
▧ Dzalanyama	0	19.6	18.6	0	35.5	21.1	26.5	2.5	0	0
□ Vwaza	20.2	2.4	0	0	0	64.5	90.0	6.0	16.0	0



	K	L	M	N	O	P	Q	R	S	T	U	V	W
■ Mulanje	0	0	0	0	0	6.8	1.4	0	2.5	0.5	0	4.6	0
□ Liwonde	0	7.8	4.7	0	9.4	0	0	0	0	1.2	0	0	4.5
▧ Dzalanyama	2.9	0	0	11	0	0	2.2	1.4	0.6	1.7	2.3	0	0
□ Vwaza	0	0	0	0.9	0	0	0	1.5	0	0	0	0	0

FIGURE B.15. PER CAPITA PROTECTED AREA THATCH UTILIZATION.
A = *Dactyloctenium aegytium* (L.) Willd., B = general thatch grass, C = *Helictotrichon elongatum* (Hochst. ex A. Rich.), D = *Heteropogon contortus* (L.) Beauv. ex Roem. and Schult., E = *Hyparrhenia filipendula* (Hochst.) Stapf, F = *Hyparrhenia gazensis* (Rendle) Stapf, G = *H. nyassae*, H = *H. rufa*, I = *Themeda triandra* Forsk., J = chambundu grass, K = *Beckeropsis uniseta* (Nees) Stapf, L = *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf, M = *Chloris gayana* Kunth., N = *Digitaria diagonalis* (Nees) Stapf, O = *Echinochloa colona* (L.) Link, P = *Hyperthelia dissoluta* (Nees ex Steud.) W. D. Clayton, Q = *Imperata cylindrica* (L.) Beauv., R = *Panicum maximum* Jacq., S = *Pennisetum purpurium*, T = *Setaria palustris* Stapf, U = *Setaria sphacelata* (Schumach.) Stapf and C.E. Hubbard ex M.B. Moss, V = chilambulire grass, W = chisungumbe grass.

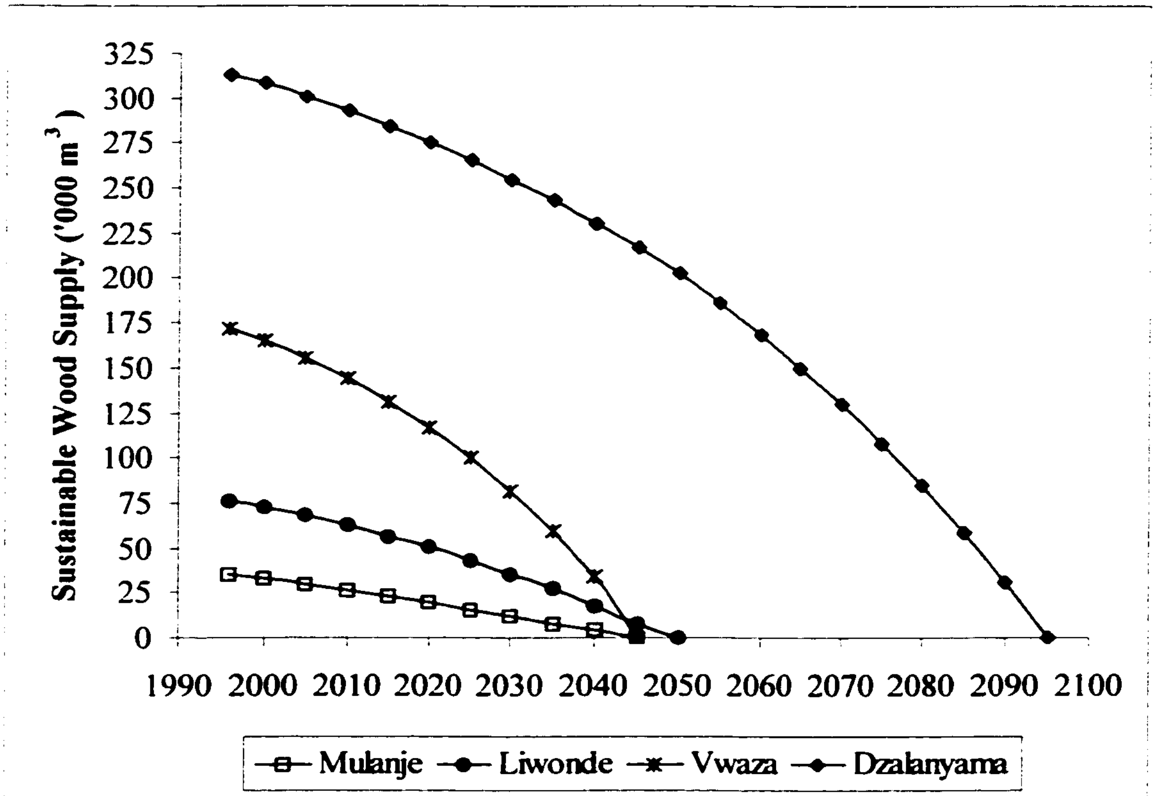


FIGURE B.16. PROJECTED DECLINE IN THE SUSTAINABLE SUPPLY OF WOOD (MAI ROUNDWOOD EQUIVALENT) AS POPULATION GROWS.

C. APPENDIX C: CHOOSING BETWEEN FOREST AND AGRICULTURE: THE EVOLVING ECONOMIC ROLE OF PROTECTED AREAS

Title Page

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C.1 ABSTRACT

As population densities and the demand for land resources increase, local inhabitants risk the loss of ecological resources when land is cleared for cultivation. This dilemma is investigated through a multidimensial socioeconomic and ethnoecological assessment of 427 households in communities adjacent to four protected areas in Malawi. The research demonstrates that poorer households are more reliant on protected area proceeds ($R^2 = 0.84$), which also significantly improve equality in the distribution of income. Ecological resources are shown to meet demand for more people and for a longer time frame than permitted cultivation on agriculturally suitable land. Yet per hectare values are 2 to 3.5 time greater for agriculture than for consumptive ecological resource use. Spatial analysis suggests points of negative land cover change (1984-94) were associated not with concentrations of population but with the agricultural suitability of the land. The results suggest the kinds of decisions people will make under extreme stress, when the consideration of potential impacts is overwhelmed by the need to survive.

C.2 INTRODUCTION

Developing nations with predominantly agrarian economies face a difficult natural resource dilemma. Food and Agriculture Organization (FAO) estimates suggest these countries lost 14.9 million hectares of forest area annually between 1980 and 1995 (1). Particularly in Africa, the driving force was generally the expansion of subsistence agriculture. Thus, as population densities and the demand for *land* resources increase, local inhabitants risk the loss of *ecological* resources when land is cleared for cultivation.

Increasing population densities can also precipitate what Boserup hypothesized as a spontaneous movement towards agricultural intensification (increased average inputs of labor or capital in order to increase the value of output) in response to shortened fallow periods and declining yields (2,3). New technologies demand more farm labor and investment in land that lead to higher crop yields and household income. In a more technocentric approach, Simon suggests this process is driven by invention, a function of population density where more people produce more ideas, thus driving growth (4). Tiffen, Mortimore, and Gichuki argue that it is the combination of growth in population and markets that leads to intensification, and that land scarcity is an incentive for conservation (5).

Indeed, among the numerous studies tying high levels of resource degradation to population growth, (e.g. 6), African examples of successful agricultural intensification (7), lower rates of erosion (5), and the improvement of forest resources (8,9) are being documented more frequently. However, Boserup concedes that agriculture intensification is weak in much of Africa, due in part to poor infrastructure, extension, marketing, and increased migration (3). Where soil degradation and the loss of soil fertility arising from more frequent cropping occurs at a rate that overtakes intensification, policy intervention may be necessary to prevent environmental damage (10). Unfortunately the combination of fragile soils and government policies that tend to discourage improvements in smallholder agriculture are all too common in Africa.

Under these conditions rural households may attempt to augment income through diversification, either to reinvest in agriculture, or simply to survive (11). Often such efforts to diversify income exhibit production linkages' to local agriculture (12) and actually help prevent environmental degradation when proceeds are invested in soil conservation (13). This would suggest the potential for harmony between ecological and livelihood sustainability, defined as "stable and growing total factor productivity" (14). However, the ecological and socioeconomic aspects of sustainability are not always compatible, particularly where perception of risk leads rural households to invest the proceeds of off-farm earnings *away* from agriculture (11).

Income diversification occurs when local alternatives to subsistence production are available at relatively limited risk. The use and sale of protected area natural resource products (15,16) can provide such an opportunity because the natural resources and the knowledge necessary for production are locally available. Exploiting protected area resources is generally viewed as an innovative and relatively low risk livelihood strategy. However, where population density and agricultural land demand is high, using this strategy to alleviate poverty may have limited long term potential, whether or not the proceeds are reinvested into agriculture. The dilemma this strategy presents is that the protected area natural resources must be sacrificed if the expansion of agricultural land continues.

Where land is scarce and the combination of low soil fertility and limited policy support impedes the agricultural intensification process, one could assume that dependence on protected area resources would provide an incentive for conservation, particularly where local inhabitants "see the relevance of conservation for themselves and the future of their children" (17). These conditions are prevalent in Malawi (18), where we investigated the importance of protected area natural resources on the livelihoods of those living nearby. Our research on the communities surrounding four protected areas in Malawi demonstrates that, *ceteris peribus*, local forest utilization is sustainable in the medium term (~50 years), and that poorer households are more reliant on protected area proceeds than wealthier households. Indeed, protected area-based income results in an overall more equitable distribution of income and can actually halve the number of people who would otherwise sink below the basic needs poverty threshold. Yet in spite of this reliance, given a choice between land and ecological resources from the protected area, expansion of cultivation wins out. This presents a dilemma for policy makers who want to encourage spontaneous strategies for poverty alleviation. The very strategies that support the poorest households are jeopardized by an overriding need for land.

C.3 STUDY AREA

The population of Malawi is predominantly rural, with smallholder farmers (averaging 1.0 ha of land under cultivation) constituting 90% of the nation's poor (19). The agroecosystems in Malawi are dominated by a sub-humid tropical, uni-modal rainfall system (ranging from 700 to 1400 mm annually), with loamy sand soils characterized as having "low" to "sufficient" nutrient levels (20). High population growth rates have led to small land holdings (21), and continuous cultivation (limited or no fallow), whereas in 1938, plots were farmed only 3 to 5 years before extended rest (22). However, the conditions necessary for autonomous agricultural intensification and conservation remain weak.

Where agricultural intensification has occurred (mainly burley tobacco), it was a result of policy change rather than technological innovation, and where it has not (hybrid maize), transaction costs limiting market access were a major impediment (23). Among Malawi smallholders, the adoption of better soil management practices is limited not by socio-economic barriers to participation or perception or risk, but instead by poor access to information (24). Over 90% of smallholders do not follow government extension recommendations for improved soil management, in part due to unsuccessful transfer of knowledge, and perhaps also in part because some of the innovations proposed have been shown to produce uneconomic gains in yield (25).

Finally, the use of agricultural inputs, free or purchased, is on the decline in Malawi. Following the removal of farm input subsidies in the early 1990's, the smallholder sector decreased its use of fertilizer by almost 75%, purchased only enough hybrid seed to plant 7% of the maize area, and reimbursed creditors for only 20% of the inputs purchased on credit (26).

In 1997, 19% of Malawi's 94,000 km^2 of land was under protection in the form of four wildlife reserves, five national parks, and seventy-seven forest reserves (27). This percentage is not exceptional in Africa or elsewhere. However, in the same year, 86% of the country's 9.65 million people lived in rural areas (28). The associated population density translates into intense pressure on the 495 km^{-2} of protected areas, primarily in the demand on new lands for cultivation. However land demand is not the only pressure. In Malawi, 98% of rural and 94% of urban energy demand is satisfied through fuelwood and charcoal (29). Land and fuel pressures have contributed to an estimated 50% decline in the forested area of Malawi between 1946 and 1996. (30,31,32). This has had the effect of increasing the importance of the remaining forested land area, 53% of which is found in protected areas (27).

In response to the acknowledged pressure to convert protected areas to agricultural lands, the Government of Malawi commissioned a Public Lands Utilization Study (PLUS) in 1996 to study both the environmental risks of conversion and the importance of the reserves and their resources to adjacent communities (27). The study was guided by a national Steering Committee on Land, which was made up of 60 government and non-government stakeholder agencies. The Committee selected four protected areas for intensive study, including Mulanje Forest Reserve, Liwonde National Park, Dzalanyama Forest Reserve and Ranch, and Vwaza Wildlife Reserve.

Mulanje Forest Reserve, located in southeastern Malawi (centered on 15°57'S, 35°39'E, covering 56,314 ha of mostly mountainous terrain) has vegetation ranging from montane woodland and grassland on the plateau to miombo woodland (mesic-dystrophic savanna, dominated by *Julbernardia* and *Brachystegia* species) on the lower slopes. The reserve protects a number of catchments from erosion and supplies both hard and softwood timber. It also shelters considerable biological diversity that includes a greater variety of wildlife than any other forest reserve in Malawi and over thirty endemic flora species (33). Mulanje lies in the most densely populated area of the four reserves (211 km^{-2} in 1997).

Liwonde National Park is located in south central Malawi (centered on 14°50'S, 35°21'E, encompassing 54,633 ha of predominantly flat topography) in an area of high population density (166 persons km^{-2}). Liwonde protects biodiversity and wildlife in the Upper Shire and one of the few Malawian examples of mopane woodland (a broad-leafed, drought deciduous woodland and savanna dominated by *Colophospermum mopane*) (34). It is the most important location for ecotourism in Malawi. Enforcement of protection is stricter in Liwonde than anywhere else in Malawi, due in part to a wildlife fence on the more densely populated western edge of the Park. It is also the base of operation for the nation's wildlife scout training program.

Dzalanyama is unique in that it is the largest forest reserve and agricultural scheme in Malawi (35). The Forest Reserve is in the central, western part of Malawi, (centered on 14°20'S, 33°22'E). It encompasses 98,827 ha of terrain, two thirds of which is co-managed with Dzalanyama Ranch, located in a mostly low lying area of open miombo and dambo (grasslands in seasonally inundated drainage lines). Cattle are excluded from the remaining western third, which is close-canopy, upland miombo that borders a forested area of Mozambique that has seen limited use over the past 25 years. The rest of the reserve is bounded by a population averaging 119 persons km^{-2}. Dzalanyama watersheds, including two dams, supply 30% of all water needs for Lilongwe, as well as a large portion of urban fuelwood needs.

Vwaza Marsh Wildlife Reserve (centered on 11°00'S, 33°28'E) primarily serves to protect biodiversity and wildlife, though levels of ecotourism are well below that of Liwonde. Vwaza also serves to contain the tsetse fly; *Trypanosomiasis* of cattle is endemic and an increasing number of sleeping sickness cases among humans have been reported since 1980 (36). The majority of Vwaza Marsh is composed of miombo woodland, though some montane woodland, dambo grassland, mopane woodland, and thicket are also present. The eastern, Zambian side of the reserve is sparsely populated, while the land surrounding the Malawian boundary averaged 95 persons km^{-2} in 1996. This density is greater than much of northern Malawi, due in part to the creation of numerous tobacco estates over the past 20 years, limiting customary land expansion.

C.4 METHODS

Our study was based on the integration of qualitative and quantitative socioeconomic data concerning household agricultural production and the use of protected area species utilization, as well as spatial analysis of biophysical data. Field data collection was conducted in 1996-97 with a multidimensional approach that combined participatory techniques with a quantitative household questionnaire and an ecological resource assessment. The approach involved baseline livelihood security data collection methods developed in the Sahel and Haiti (37) that were adapted to evaluate secondary forest product utilization (38). The results of the household and species work were then integrated into a spatial database using a geographic information system (GIS) and the results of satellite imagery change detection.

To capture household production and protected area resource utilization, we used a mix of overlapping qualitative and quantitative techniques. These included surveys both inside the home (where both male and female members participated), and inside the protected area, where activities could be observed and measured. Results based on respondent recall were calibrated with an inventory analysis of resource utilization zones. Other than the formal survey, data collection was participatory in nature: local inhabitants carried out the investigation, presentation, and preliminary analysis under the guidance and training of a local research team (39). The field research team was made up of four Malawian male and female enumerators conversant in the key local languages (primarily Chichewa, Chiyao, and Chitumbuka), as well as a botanist and two forest mensuration specialists from the Forestry Research Institute of Malawi (FRIM).

Research began with a rapid appraisal of communities within a 5km zone of influence around each protected area designed to capture variation among localities and agroclimatic zones. In all, results from 138 villages provided the patterns of livelihood systems and natural resource utilization that were subsequently incorporated into participatory and formal survey instruments specific to each protected area. This included compilation of local species names and uses, which were later verified by the botanist and natural resource experts from the village itself during the resource assessment. From the rapid appraisal, four to five villages were selected for intensive study around each protected area.

Intensive field study included a participatory mapping exercise to delineate past and present vegetation and natural resource utilization zones, a protected area resource assessment (eight 10m x 10m plots per village), key respondent interviews, and a formal, quantitative survey designed to capture intra-locality variation (Table C.1). The final data set for the formal survey included 427 households comprised of 2,205 individuals, while 228 key respondents provided qualitative data on specialized resource use (i.e. charcoal making, healing, etc.).

TABLE C.1. SUMMARY OF DATA COLLECTION METHODS.

Data Gathering Activity	Primary Objectives
Rapid Appraisal (138 villages)	
Interviews with traditional officials	• Village list, locations, resource patterns
Community meetings	• Patterns of livelihood strategies • Patterns of protected area use • Crop, livestock, wild resource species list
Focus group interviews (men and women separately)	• Qualitative specialized use • Land and resource tenure • Attitudes towards protection • Changes in resource availability/access
Intensive study (17 villages)	
Participatory mapping	• Present and past resource utilization
Key respondent interviews	• Quantitative specialized use *(223 respondents)* • Local unit volume and weight conversions • Local market retail prices
Resource assessment *(136 plots)*	• Vegetation measurements • Local name / Latin name verification
Formal survey *(427 households)*	• Income (agriculture production, livestock, remittances, off-farm activities, etc.) • Protected area resource utilization

The socio-economic analysis was intended to capture two key variables. The first addressed *household well being*, expressed in terms of both direct and non-direct household income. The second addressed *household protected area natural resource utilization*, broken into seven major use categories: food, fuelwood, fiber, tools, medicinal plants, and both wood and thatch for construction.

Income estimates from all sources (direct and indirect) were compiled for each individual household and converted into per capita values (15 Malawi Kwacha = 1 USD).

Direct income was defined as the actual monetary compensation received by household members for wage labor, sale of agricultural products, remittances, and a variety of off-farm income generating activities, including sales of protected area resource products. *Indirect* income was the composite of activities that have utility to the household, each being assigned an estimated value derived from local retail market prices. The income from these activities included the value of goods intended for consumption within the household, such as subsistence maize production and protected area resource utilization. To create these estimates, it was necessary to develop volumetric and weight conversions as well as retail prices for all agricultural products and protected area resources (38).

For each protected area, the nature of the resource, pressure on the resource, and impact on the resource were assessed using the tools of geospatial analysis, and data captured and analyzed as part of PLUS (27). PLUS maps of the agricultural suitability of land in all four protected areas were generated from a Land Resources Evaluation Project (LREP) model and data produced by the Government of Malawi and FAO (40,27). In order to be considered suitable for agriculture, land had to fall with suitable ranges for all criteria, including length of growing period, slope, soil depth, surface stoniness, drainage, and ponding (Figure C.1). Population pressure was based on a spatial depiction of rural population in the smallest physical administrative division that was spatially available, the Environmental Planning Area (41), that was then limited to a 5 km zone of influence around each protected area. The population figures were augmented to account for urban influences (i.e. small towns), and then adjusted to 1996 levels using growth rates determined by the preliminary analysis of the 1998 census (27,28) (Figure C.2). PLUS

(27) vegetation classification and change detection between 1984 and 1994 (Figure C.3) were used to spatially quantify woody biomass and determine the relationship between negative change (decline in biomass) and agriculture suitability. Of all types of protected area resource utilization in Malawi, the greatest influence on the overall resource base is wood extraction. Therefore, estimates of sustainable wood supply were based on the mean annual increment (MAI, or annual growth) of woody biomass growing stocks (42) specific to the region and mapped vegetation class. At the protected area level, these were applied to the vegetation classifications from PLUS. At the national level, the baseline vegetation classification produced by the Department of Forestry and the Swedish Space Corporation was used (43), with an annual rate of forest area decline of 1.5% (27).

C.5 RESULTS

The first phase of research on the relationship between protected areas and the livelihoods of those living in adjacent communities focused on reliance. Reliance was defined as the share of total per capita income attributed to the direct and indirect value of protected area resource utilization, as well as associated activities such as healing with protected area medicinal plants or public land employment. The level of reliance varied between the four protected areas with respect to total income and land holdings (Table C.2). In communities around Vwaza and Dzalanyama, where population density was lower and more land available, income was higher. Reliance was greatest in communities around Mulanje and Liwonde (despite stricter protection), where land was scarcer and incomes lower.

The pattern of poverty associated with reliance on protected area proceeds was verified at the household level for the entire data set through a simple linear regression model (Figure C.4) (38). Results show an inverse income–reliance relationship: for every 100 MK increase in per capita income, the portion of income that is protected area-based can be expected to decline by 0.1%.

TABLE C.2. RELIANCE (PERCENTAGE OF PROTECTED AREA INCOME RELATIVE TO TOTAL INCOME), LAND, AND POPULATION.

	Reliance	Protected Area Income	Total Income	Mean Land Holdings	Population Density	Relative Level of Protection
	%	--MK $capita^{-1}$ yr^{-1}--		ha $capita^{-1}$	persons km^{-2}	
Mulanje	20.3	517.76	2552.95	0.146	211	Low
Liwonde	15.8	384.46	2432.42	0.194	166	Very High
Dzalanyama	10.4	536.18	5167.76	0.316	119	Low
Vwaza	13.3	763.05	5725.91	0.329	95	Medium

Protected area-based income also proved to positively influence the distribution of income (38). The most common measure of income equality is the Gini coefficient, defined as the arithmetic average of the absolute values of differences between all pairs of incomes (44). It can be generally stated that more highly developed countries tend to have lower differentiation of income (expressed as percentages, a Gini index of 25 to 40%) while developing nations tend to have higher differentiation (45 to 60%). The Gini index falls from 56.3 % on income exclusive of protected area proceeds to a more equitable 50.9% when these proceeds are included (Table C.3).

TABLE C.3. MEAN INCOME, INCOME EQUALITY, AND POVERTY WITHOUT AND WITH PROTECTED AREA-BASED INCOME.

	Mean Income	Gini Income Equality Index	Head Count Poverty Index	
	MK capita^{-1} yr^{-1}	%	(668.10 MK Poverty Threshold)	(1700.00 MK Poverty Threshold)
Without protected area proceeds	3646.65	56.3	17.5	43.6
With protected area proceeds	4320.25	50.9	8.8	31.9

A simple and intuitive measure of poverty is the head count index, which is the portion of the population that falls below the poverty threshold relative to the total population. Two such thresholds were used in this analysis. The "basic needs" poverty threshold relates nutritional requirements to the energy provided by a primary diet staple, which in turn can be converted into a value based on the market price of that staple. This comes to 668.10 MK in Malawi for the 1996/97 average price of maize. This threshold understates poverty because our research included all aspects of subsistence production and protected area resource utilization, the majority of which are not captured in national studies. We therefore calculated a second "poverty reference threshold" (1700.00 MK) to include the poorest 32% of all households to reference the national relative prevalence of absolute poverty reported by the World Bank (19).

It is not surprising that the addition of protected area income reduces the proportion of the population that falls below the poverty threshold (Table C.3). However, note this improvement differs, depending on the definition of poverty. The percentage of the population with inadequate income to meet basic needs (668.10 MK) is cut in half by including protected area proceeds (17.5 to 8.8%), while under the poverty reference threshold (1700.00 MK), the change impacts only 27% of those considered poor (43.6 to 31.9%). This suggests that in particular, the poorest of the poor use protected area proceeds as a strategy to rise out of absolute poverty.

The influence of protected area proceeds on the distribution of income and poverty alleviation is pronounced. Figure C.5 shows that the relative share of income controlled by each fifth of the population (ranked by increasing income) shifts from rich to poor. Moreover, the poorest quintile feels the greatest impact: a 40.1% increase in income share, while the richest quintile experiences a decline of 7.9%.

Though the importance of proceeds from protected area products and related activities (i.e. healing) is evident, land as a potential agricultural resource was viewed as more important, at both the village and household level. Of the 138 villages visited during the rapid appraisal 59% categorized themselves as fully dependent on the protected area for natural resource products, particularly fuelwood (all year) and wild foods during the rainy season when food stocks run low. Yet their desire to cultivate at least a portion of the protected area was more pervasive: 86% of the villages listed this as the most important issue they faced. When asked to choose between the two, 69% of the villages put protected area land above their demand for ecological resources. At the household level, 65% of respondents recommended that management of the protected areas should be adjusted to permit cultivation, compared with only 31% advocating resource access as a high priority.

These competing demands (expansion of agricultural land versus protection of ecological resources) were also evaluated in terms of sustainability, at both the national and protected area level, using population growth rates that have been adjusted to reflect the preliminary results of the 1998 census (28,45). Demand will exceed the national sustainable supply of wood will be exceeded by demand in 35 years (Figure C.6). Demand will exceed the supply of suitable agricultural land will be exceeded by land demand in only eight years (Figure C.7). The rate of future land demand is projected to flatten as land becomes more scarce, in part due to urbanization, and in part due to a reduced percentage of land allocated to infrastructure and public areas in the customary sector (46,47).

Conducting a similar analysis at the protected area level requires spatial information about agricultural suitability and woody biomass to estimate supply, as well as population growth rates based on the 1998 census to derive demand (Table C.4). The density of customary land utilization (ha capita $^{-1}$) was based on the actual 1996 land occupation figures calculated for the zone of influence, including both cultivated and uncultivated land (48).

Sustainability analysis at the protected area level shows that in 50 years, the local demand for protected area wood will exceed sustainable supply in all but Dzalanyama, where supplies will last another 50 years (Figure C.8). Resource demand was based on the average per capita wood utilization multiplied by the population in the zone of influence for each protected area. Each protected area has very different projected rates of population growth and wood consumption, resulting in varied rates of resource decline. For example, the sustainable supply of woody biomass in highly protected Liwonde is projected to last a few years longer than Vwaza, despite the much larger resource base available inside Vwaza Wildlife Reserve.

TABLE C.4. KEY INPUTS FOR THE SUSTAINABILITY ANALYSIS.

	Protected Area Land		Rate of Local Wood Utilization	Zone of Influence	
	Total Land	Suitable for Agriculture		1996 Population	1987 – 1998 Growth Rate
	ha	%	kg $capita^{-1}$ yr^{-1}		%
Mulanje	56,314	2.7%	628	135,648	0.5%
Liwonde	54,633	16.1%	327	99,604	1.8%
Dzalanyama	98,827	89.7%	730	74,868	1.6%
Vwaza	98,214	63.0%	951	43,316	2.7%

The analysis for land at the protected area level (Figure C.9) was based on a hypothetical scenario, where, in each year after 1999, protected area land that was suitable for agriculture would be made available only to new population in the zone of influence around each reserve. The rate of land consumption was a function of the population growth rate. The results show rapid conversion of land in Mulanje, despite low population growth rates, because only a small percentage of the mountainous reserve is suitable for agriculture. Liwonde's suitable land would last only eight years, while much larger Vwaza and Dzalanyama (which also have much larger per capita land holdings) would last 30, and 58 years, respectively.

Perhaps more important than difference among the reserves is the overall difference between the sustainability of woody resources noted in Figure C.8 with the sustainability of suitable agricultural land in Figure C.9. In all cases but Vwaza, ecological resource utilization can be sustained far longer than conversion of land to agriculture. In

Vwaza the difference is less significant because of higher population growth rates and a higher woody biomass consumption rate. That rate is higher in part due to recent liberalization of burley tobacco legislation (49), which has resulted in construction of tobacco-related infrastructure from protected area resources (i.e. pole and fiber-based drying sheds) that will not require replacement for a number of years.

The results of the sustainability analysis suggest that the demand for agriculture land in the protected areas is large enough to overshadow consumption patterns for all other ecological resources. This raised the question of whether the physical evidence concerning negative change (i.e. declining biomass) identified in the PLUS 1984 to 1994 land cover change detection (27) would prove to be spatially associated with population pressure from the outside or agricultural suitability on the inside of each protected area. If land cover changes were due to high fuel demands, proximity to higher population concentrations would be expected. If land cover changes were linked to agricultural potential, at minimum the negative change locations would occur more than randomly on agriculturally suitable sites than not. Results suggest greater changes have occurred on land suitable for agriculture, irrespective of population concentrations (Table C.5).

Differences in Liwonde National Park land cover between 1984 and 1994 apparent in Landsat Thematic Mapper (TM) imagery provide a graphic example of this relationship (Figure C.10), particularly in the eastern-most portion of the Park (Figure C.11). Though this area is suitable for agriculture (Figure C.13), it is considerably south of the much higher population concentrations (Figure C.14). The results of the change detection analysis show this area to have undergone a decline in natural biomass, verified by ground observation as agricultural encroachment (Figure C.15). Moreover, the land adjacent to higher population concentrations to the north of the encroached area has undergone minimal negative change.

TABLE C.5. SPATIAL RELATIONSHIP BETWEEN AREAS THAT EXPERIENCED A DECLINE IN BIOMASS (1984 - 1994) TO BOTH POPULATION OUTSIDE AND AGRICULTURALLY SUITABLE LAND INSIDE EACH PROTECTED AREA.

	Land Area Experiencing Negative Change		Spatial Association with Areas of Negative Change	
	ha	%	Areas Adjacent to High Population	Agriculturally Suitable Land
Mulanje	3666	6.5%	limited	high*
Liwonde	5021	9.2%	limited	high*
Dzalanyama	3904	4.0%	limited	high*
Vwaza	9890	10.1%	limited	high*

*all statistically significant using a Chi Squared test.

The final element of analysis involved an economic comparison of agricultural and consumptive use value of natural resource products on a land area basis in each reserve (Table C.6). This was accomplished by converting the per capita proceeds derived from agriculture and those derived from protected-area activities into per hectare values. The calculation of agricultural values included all crop and livestock production, and like the sustainability analysis, considered all land in the zone of influence outside the protected areas, rather than only land under cultivation. This was based on the assumption that converting protected area land to agriculture would result in the same land use intensity as currently exhibited in nearby customary land. Protected area values are based on the land inside each reserve, within 5 km of the boundary, because participatory maps showed the vast majority of natural resource utilization occurred within that proximity of the each village surveyed.

TABLE C.6. THE CONSUMPTIVE USE VALUE OF AGRICULTURE ON CUSTOMARY LAND AND NATURAL RESOURCE UTILIZATION ON PROTECTED AREA LAND.*

	Agricultural Value of Customary Land		Protected Area Natural Resource Utilization	
	MK ha^{-1} yr^{-1}	USD ha^{-1} yr^{-1}	MK ha^{-1} yr^{-1}	USD ha^{-1} yr^{-1}
Mulanje	3682.89	245.53	1014.67	67.64
Liwonde	2832.65	188.84	748.38	49.89
Dzalanyama	4743.45	316.23	671.69	44.78
Vwaza	4346.48	289.77	689.29	45.95

* all figures are based on gross revenues.

The agricultural value of land in Mulanje and Liwonde is more than 3.5 times that of its natural resource consumptive use value. The results are almost double that in Dzalanyama and Vwaza, where land is less scare and higher value crops or more prevalent.

C.6 DISCUSSION

These results suggest the kinds of decisions people will make under extreme stress, when the consideration of potential impacts is overwhelmed by the need to survive. There is strong indication in both the qualitative and quantitative data that those surveyed were aware of the longer term risks of converting protected areas to agriculture, and that they are equally aware of the immediate differences in consumptive use values of both the land and the ecological resources. Carrasco's (17) position that knowledge of the value of ecological resources might lead to conservation is unlikely when the difference between the value of land cultivation and consumptive use of natural resources is so large. The fact that protected area resources provide a critical income flow that compensates for insufficient land in many cases, does not compensate for short-term risk. The story is more like what Reardon (11) proposed – that the poor households in this study are thinking about survival first, that they recognize conditions are not ripe for agricultural intensification as a solution, that they are aware that protected area resources may be only a short term stop-gap. The short-term risk in investing in either farming innovation or conservation overwhelms longer-term considerations.

Unfortunately, using protected area-based income for poverty alleviation potentially has longer-term limitations as a livelihood strategy. With the exception of the national analysis depicted in Figures C.6 and C.7, all results assume a system limited to those living within a 5 km zone of influence around each protected area. Yet the supply and demand pressures on both land and resources noted in the national-level analysis underline the notion that the system is not closed. Protected areas supply products not only to local populations, but society as a whole. Moreover, the total value of protected area resources to the whole of Malawi goes beyond the economics of consumptive use, to include genetic diversity, cultural, religious, aesthetic, and intrinsic natural value (50).

Demand for land and the demand for ecological resources will result in difficult choices at the local level. Reliance on protected area resources can provide much-needed alternatives to agricultural income in the short run where land is scarce. But in the longer term, this reliance may expose poorer households to the strong possibility that land demand will eventually overtake the resource base providing the alternative income stream. Government and donor environmental policies and their prescriptive interventions must consider replacing the poverty-alleviation function of protected area resources with income alternatives that are neither land nor forest-based. Furthermore, community conservation initiated by donor projects that do not address the large financial differences between the value of land and the value of ecological resources may actually accelerate the risk faced by the very communities to gain from such measures. As suggested by Shyamsundar and Kramer (51), proceeds from protection (ecotourism, etc.) need to be reinvested in local communities to compensate for the value of foregone agricultural lands and secondary protected area products. In a country like Malawi, where conditions are not ripe for autonomous agriculture intensification, and income diversification is often through the exploitation of natural resources, investment must be directed towards the development of alternative income streams that give poorer households options. And it is essential that these options are not entirely dependent on natural resources, or exacerbate already critical land shortages.

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48. The percentage of land in the zone of influence that was cultivated ranged between 31 and 37%, and was held constant in the projections of future land use patterns posited for agriculturally suitable land inside the reserve.

49. The soils in and around Vwaza are highly suitable for tobacco cultivation, an activity that requires drying sheds. At the time of the study, many farmers were busy constructing

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C.8 FIGURES

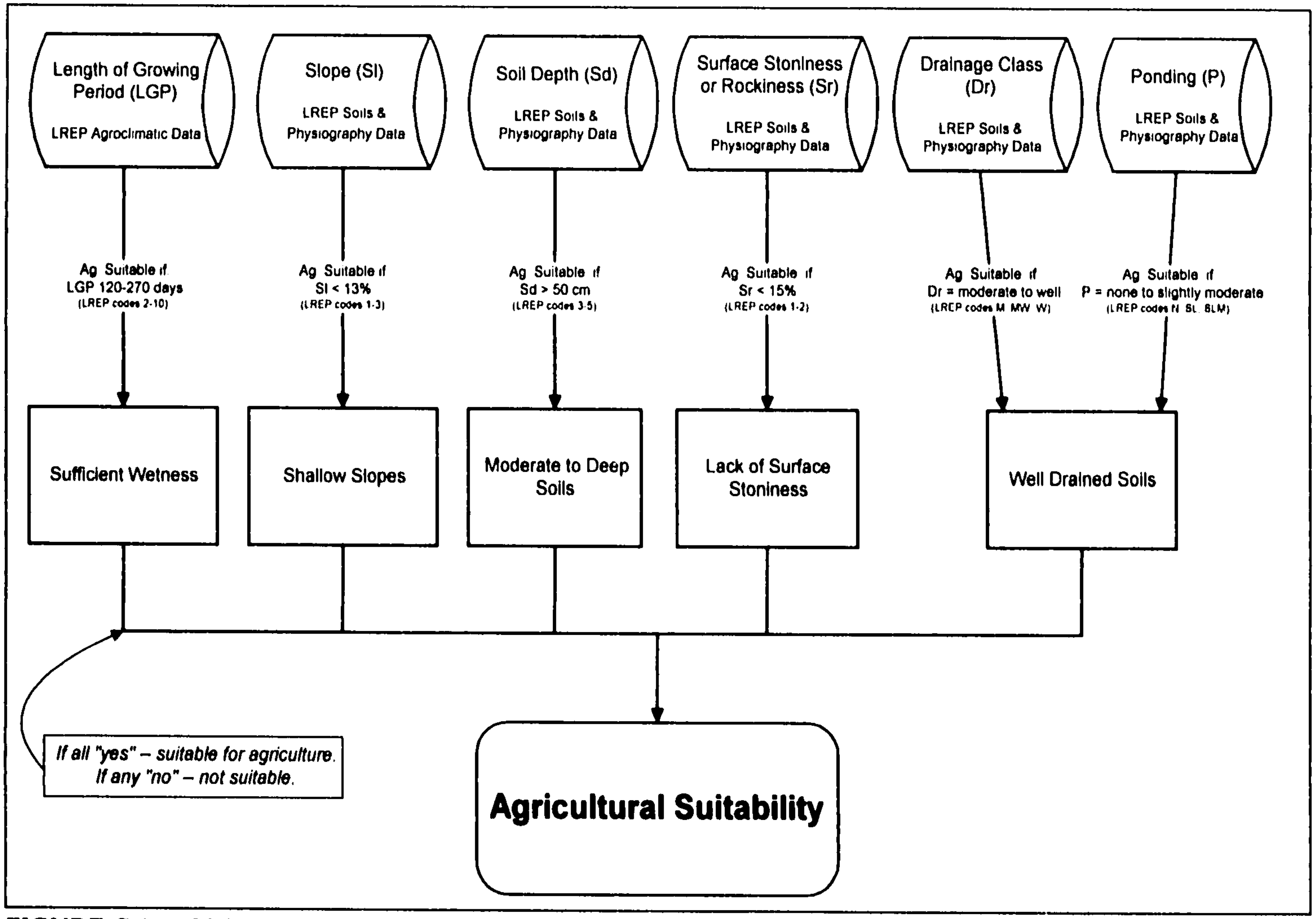


FIGURE C.1. AGRICULTURE SUITABILITY MODEL (40,27).

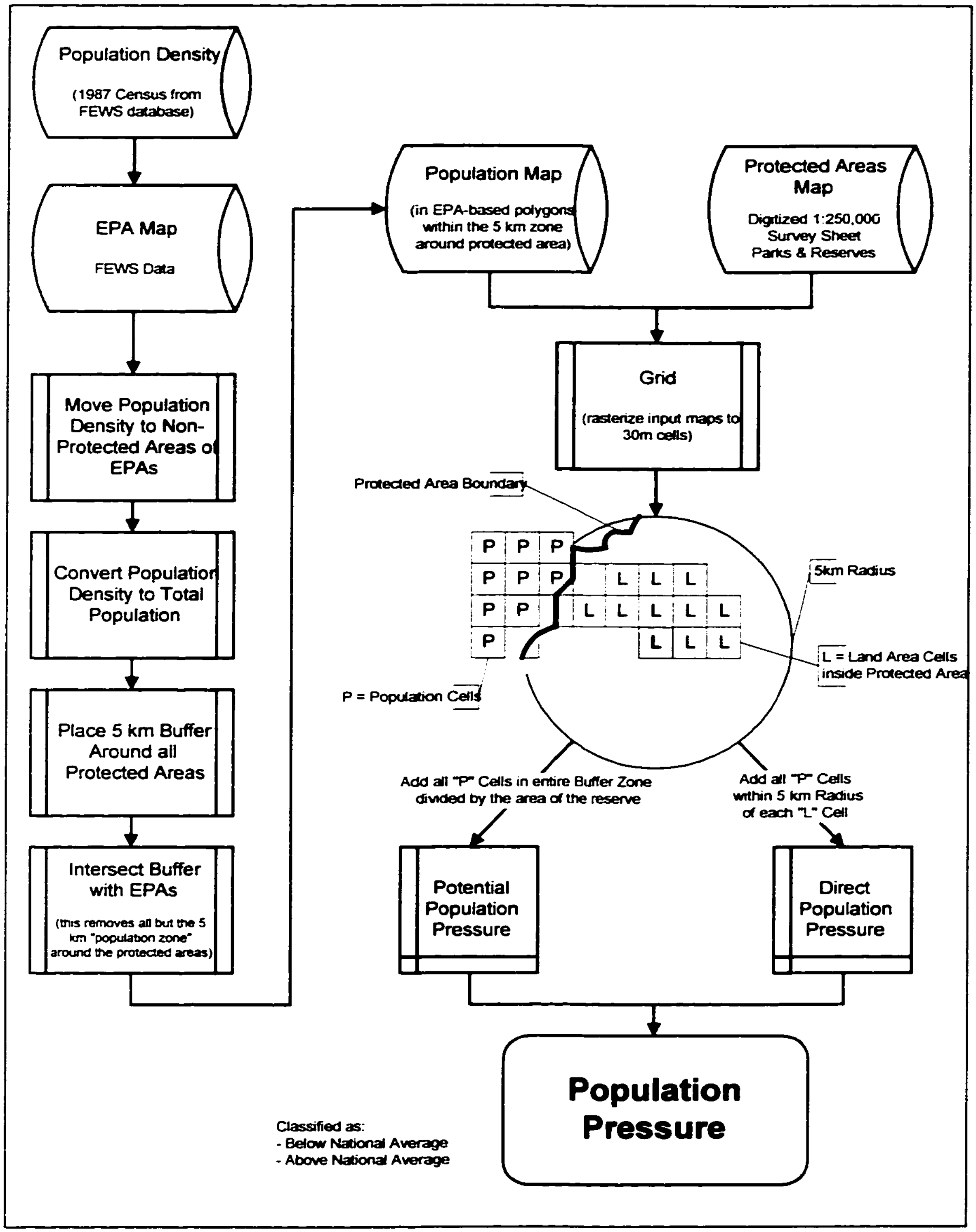


FIGURE C.2. POPULATION PRESSURE SPATIAL MODEL (ADAPTED: 27).

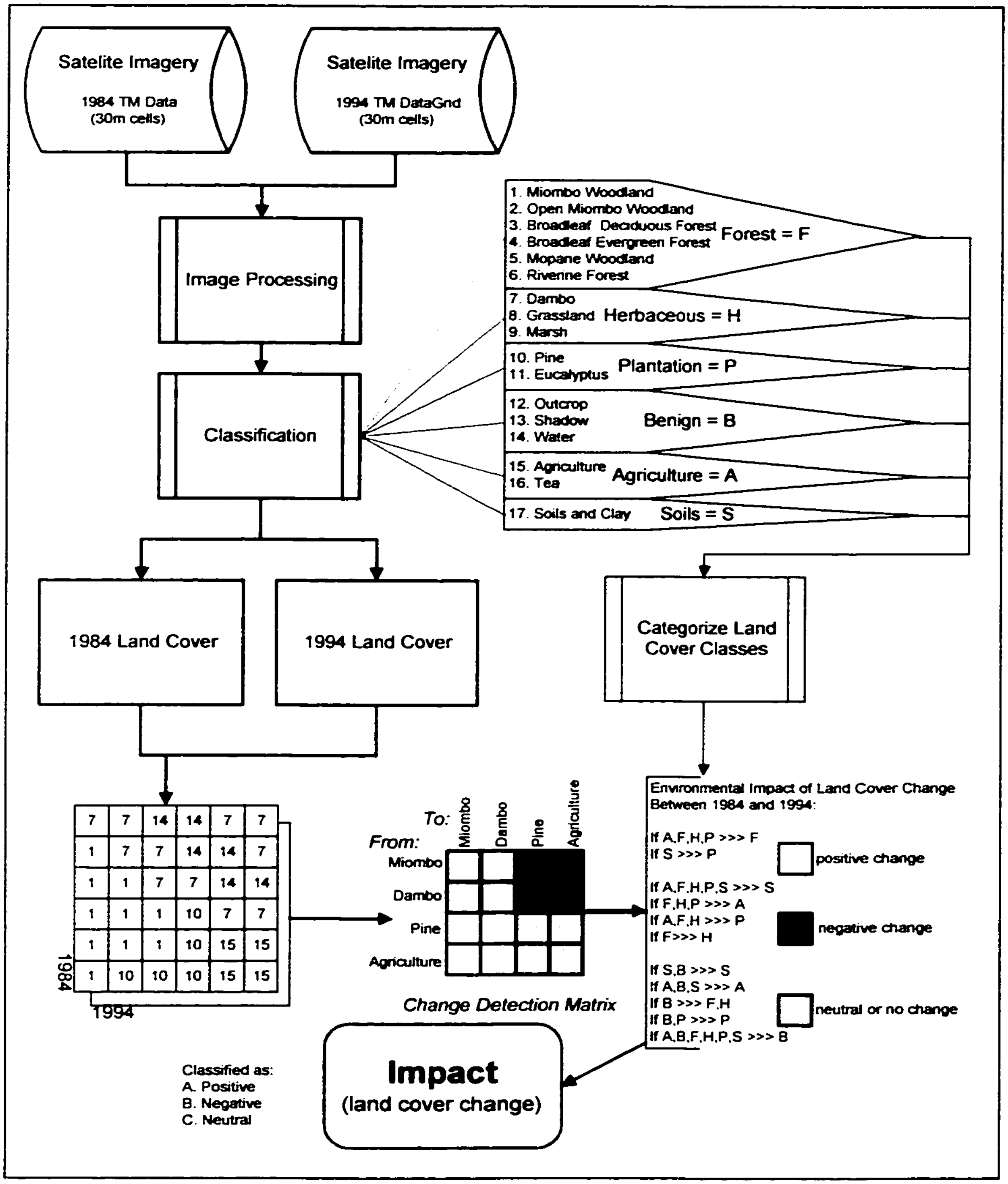


FIGURE C.3. VEGETATION CLASSIFICATION AND CHANGE DETECTION MODEL (27).

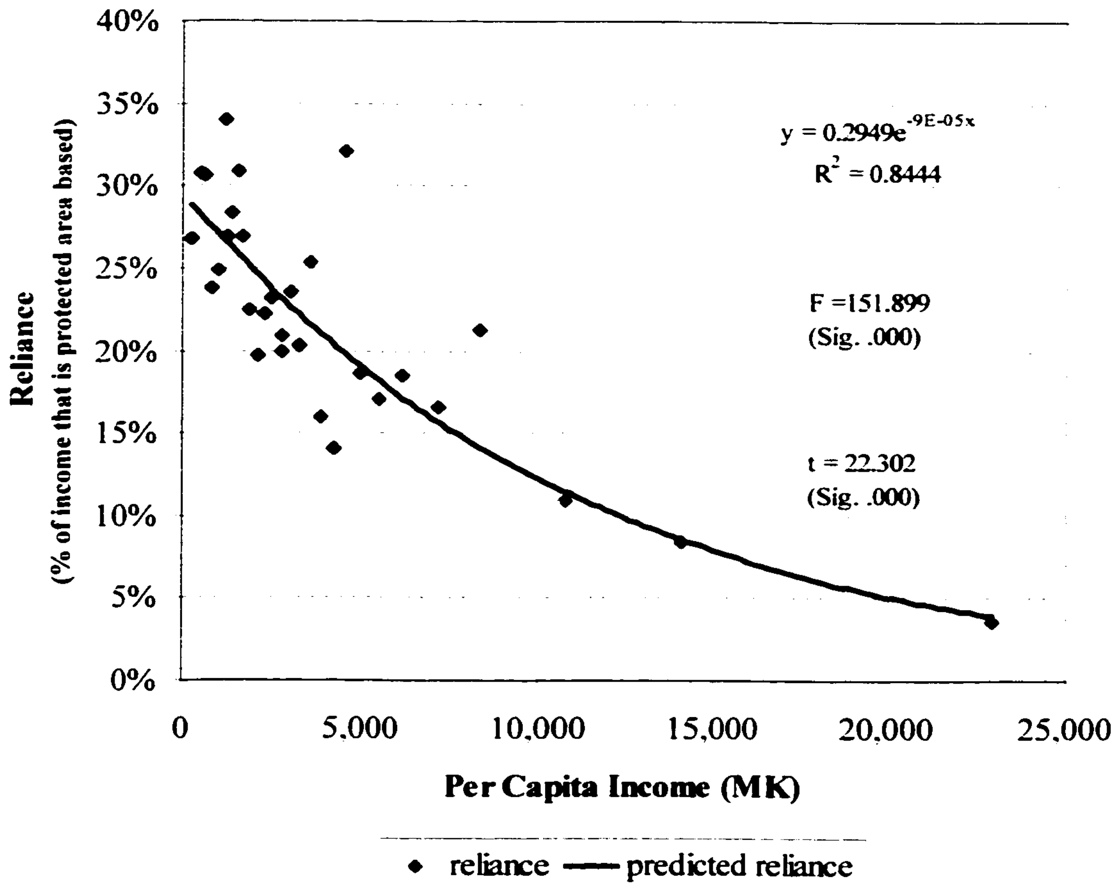


FIGURE C.4. REGRESSION FOR PER CAPITA INCOME AS A PREDICTOR FOR RELIANCE ON PROTECTED AREA RESOURCES.

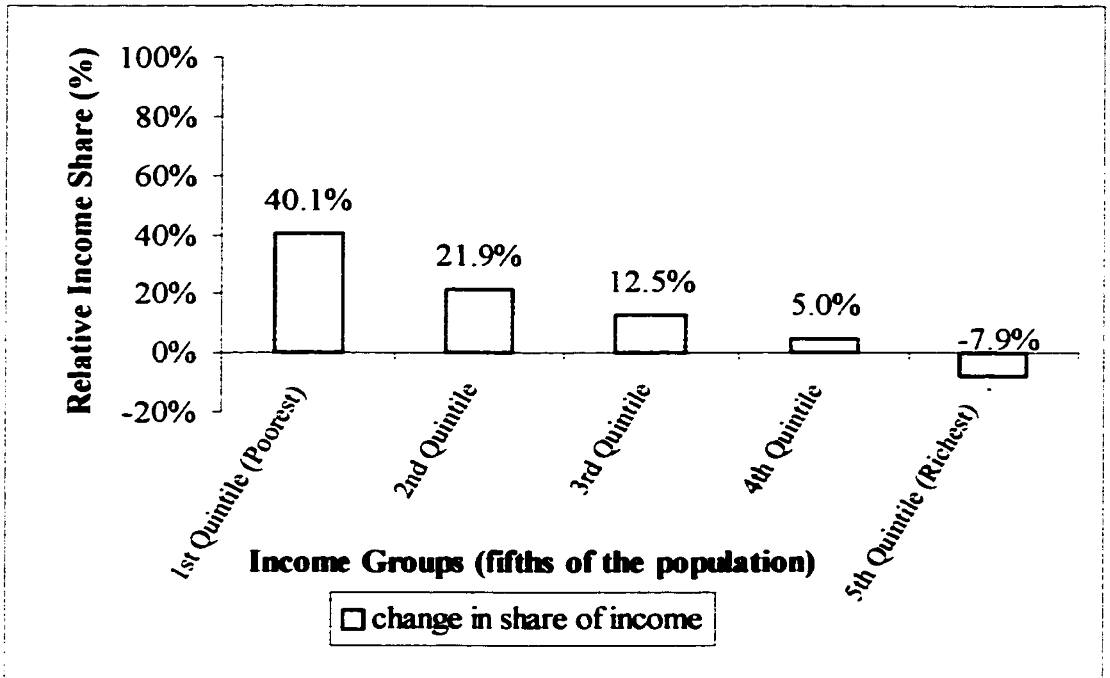
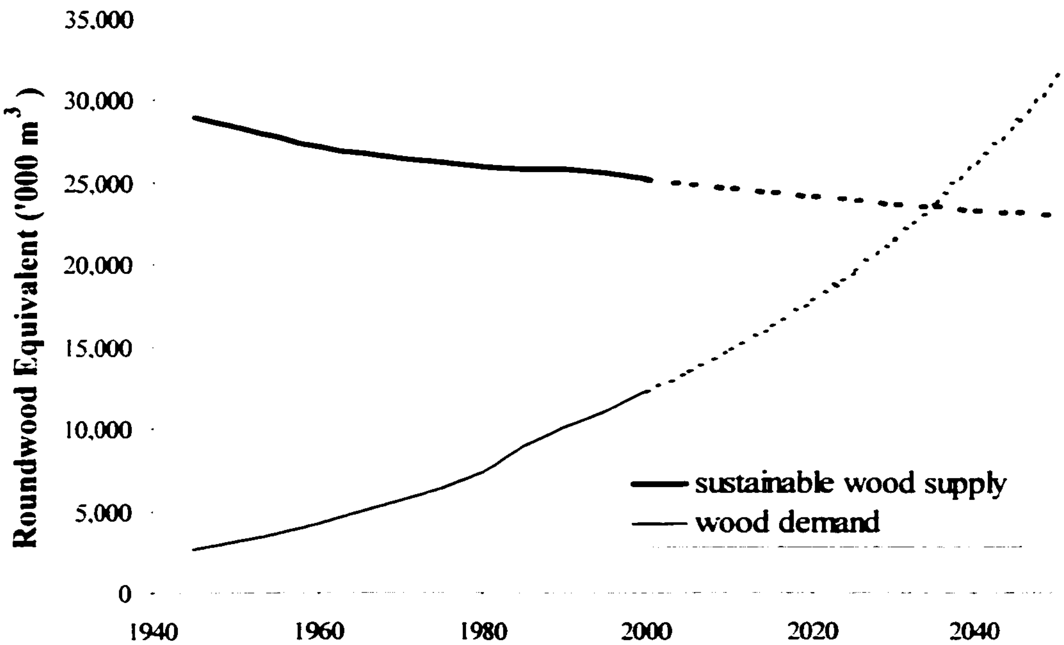
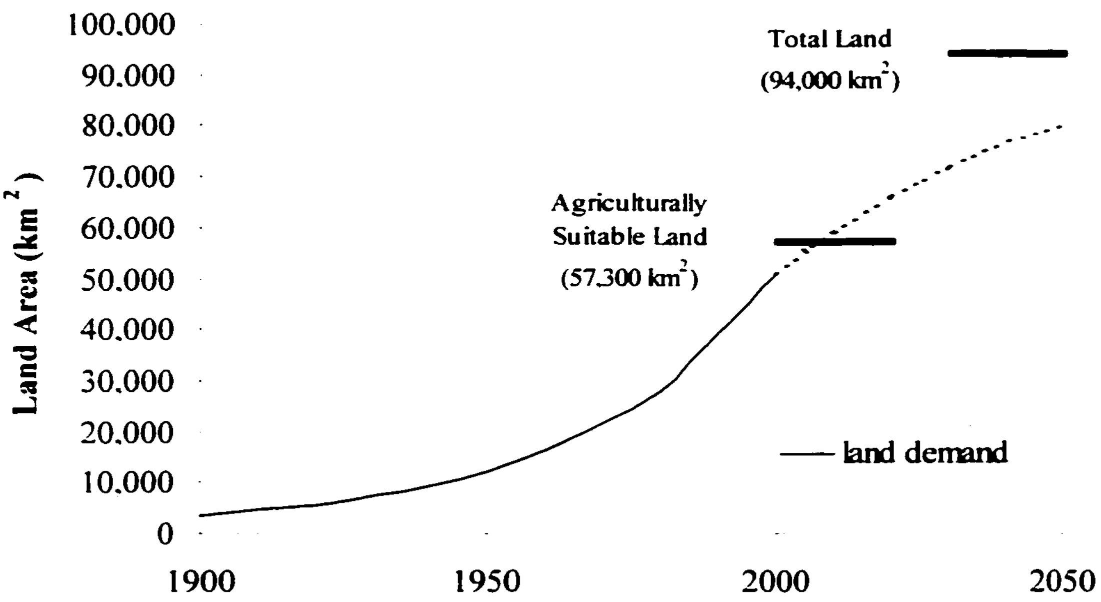


FIGURE C.5. CHANGE IN RELATIVE INCOME SHARE RESULTING FROM THE ADDITION OF PROTECTED AREA-BASED PROCEEDS TO HOUSEHOLD INCOME.



NB: "sustainable supply" refers to the mean annual increment – each year's new growth measured in $m^3\ ha^{-1}\ yr^{-1}$.

FIGURE C.6. WOOD DEMAND VERSUS SUSTAINABLE SUPPLY IN MALAWI.



NB: Land demand (ha capita^{-1}) is based on historic, actual and projected resident population figures multiplied by the relative land area per capita represented in the customary (0.20 ha capita^{-1}), urban (0.07 ha capita^{-1}) and estate (1.3 ha capita^{-1}) sectors. Added together, this amounts to land demand over time.

FIGURE C.7. LAND DEMAND VERSUS AVAILABILITY IN MALAWI.

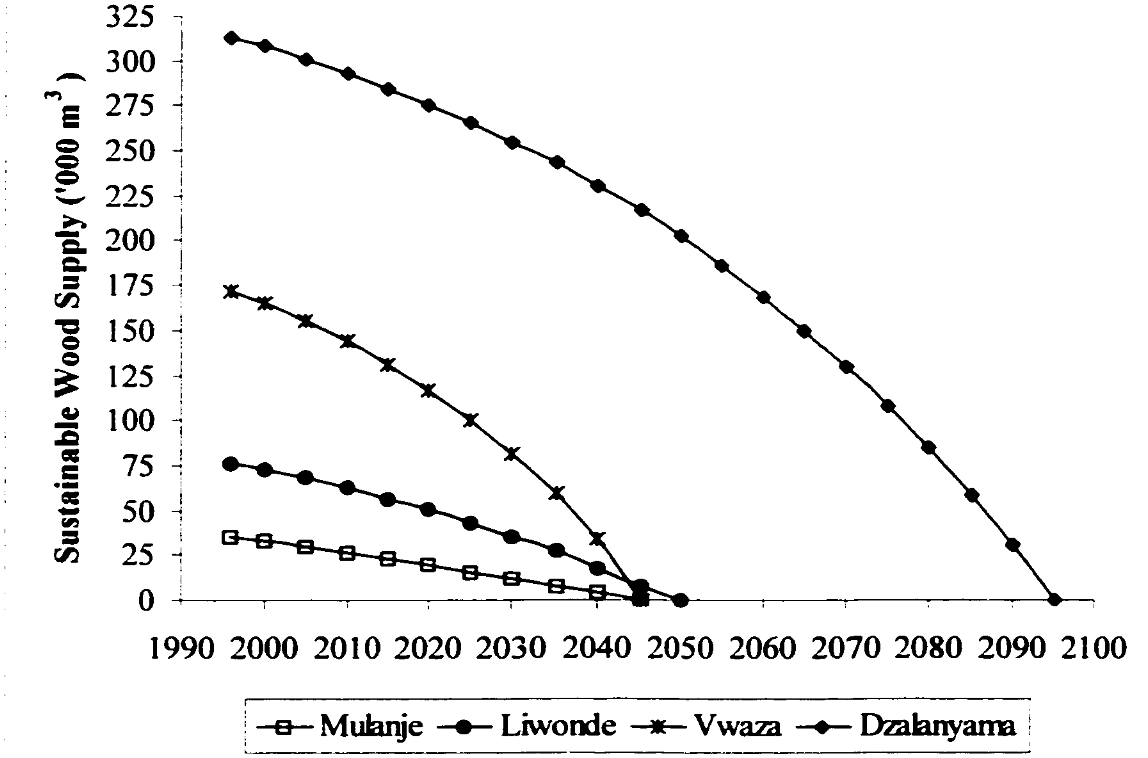


FIGURE C.8. PROJECTED DECLINE IN THE SUSTAINABLE SUPPLY OF WOOD (MAI ROUNDWOOD EQUIVALENT) AS POPULATION GROWS.

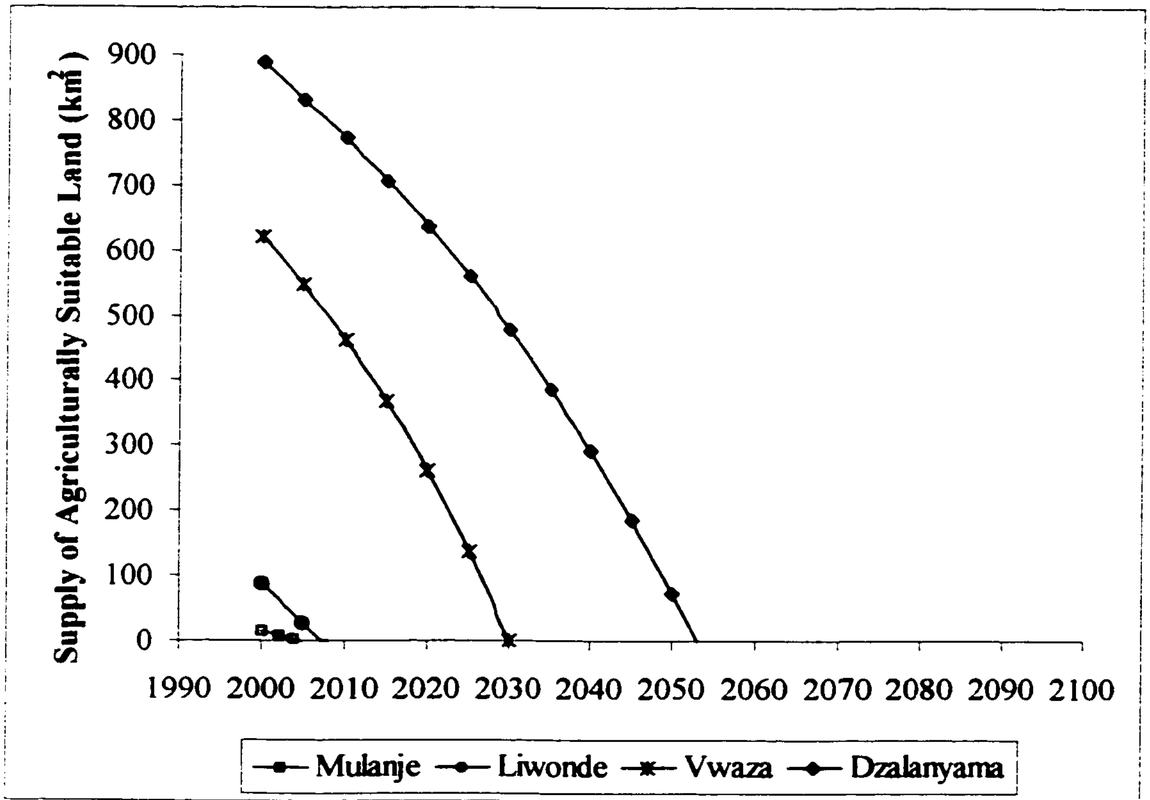


FIGURE C.9. HYPOTHETICAL DECLINE IN AGRICULTURALLY SUITABLE LAND INSIDE THE PROTECTED AREAS AS POPULATION GROWS.

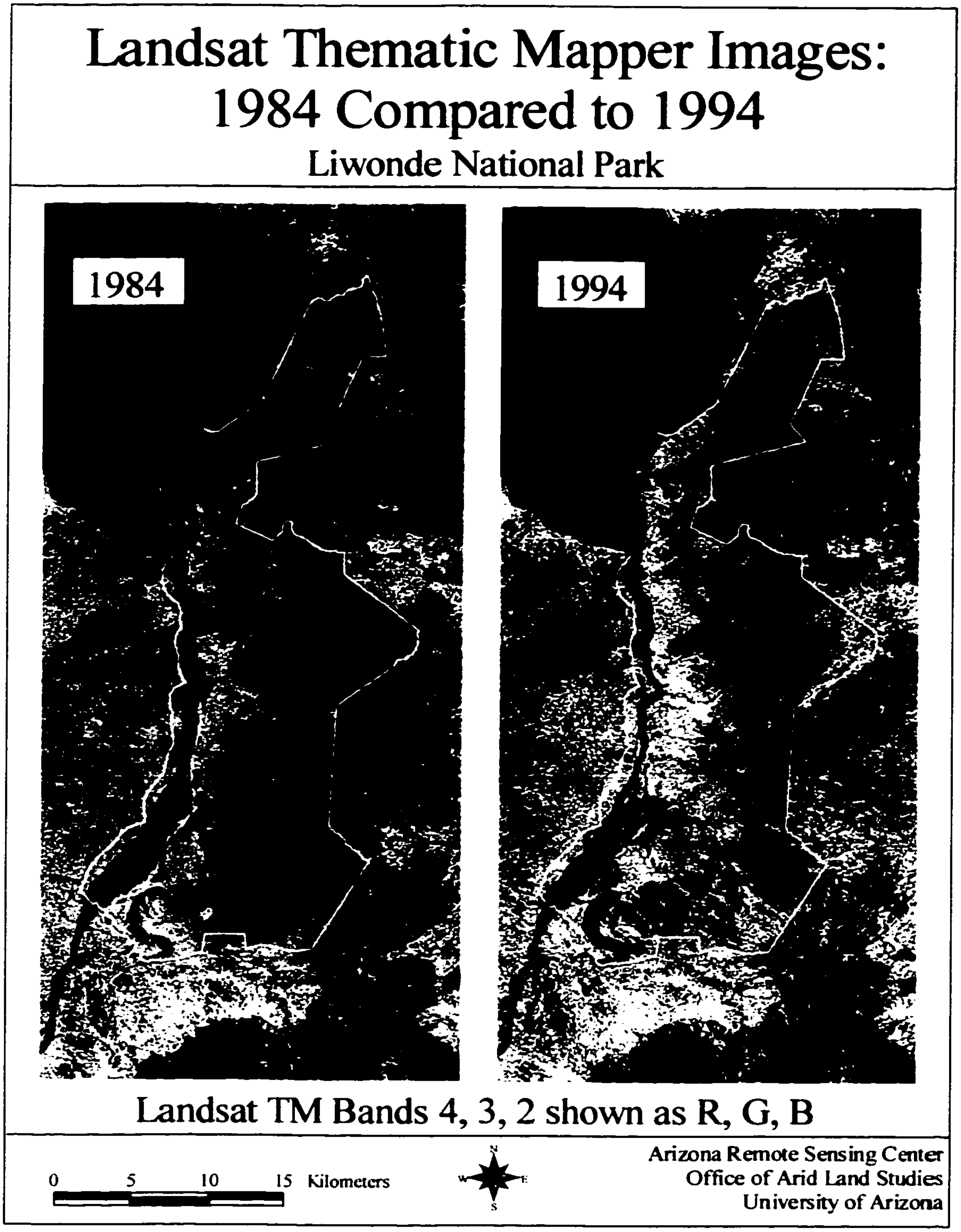


FIGURE C.10. LANDSAT THEMATIC MAPPER FALSE COLOR IMAGES OF LIWONDE NATIONAL PARK IN 1984 AND 1994 (27).

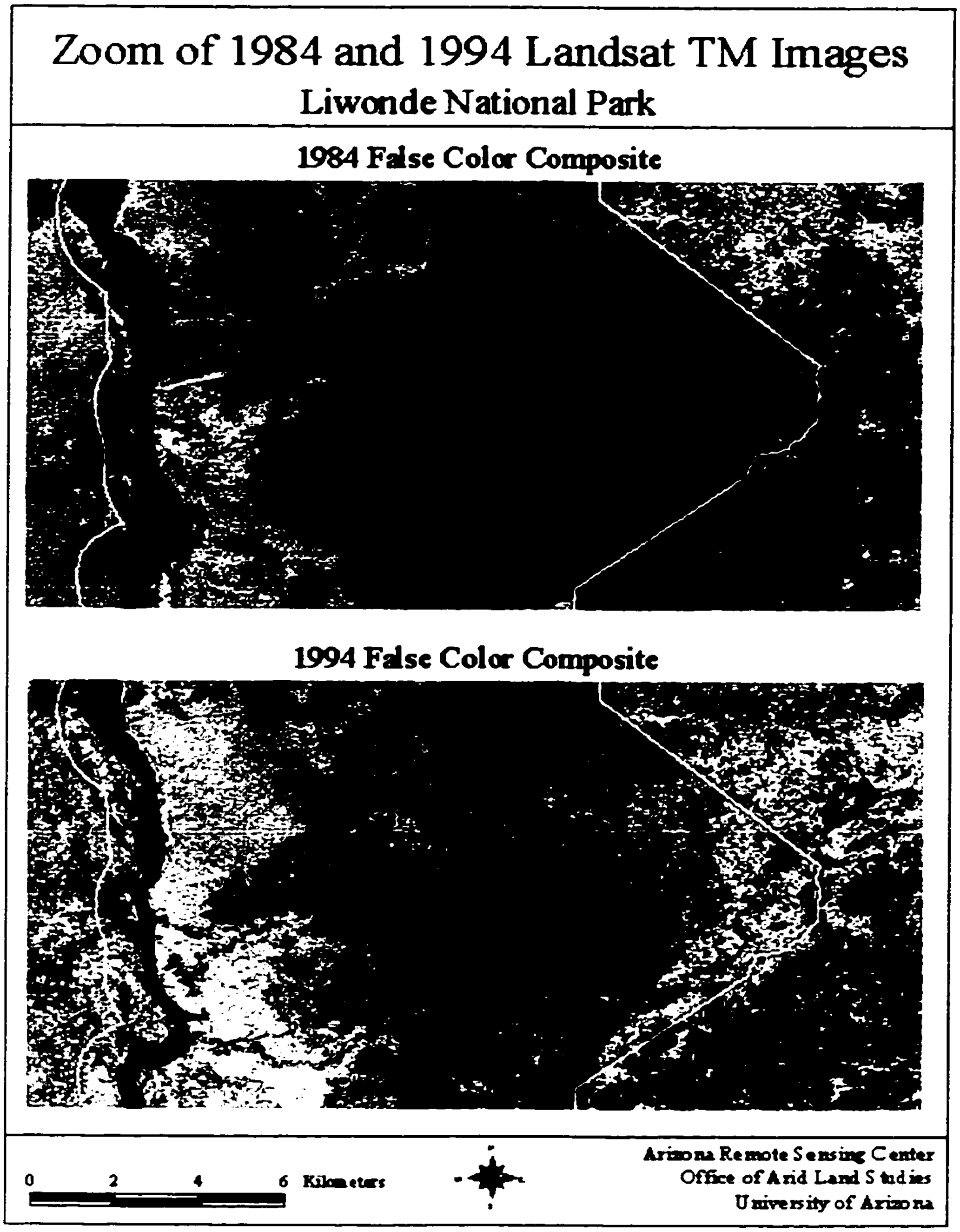


FIGURE C.11. EASTERN-MOST PORTION OF LIWONDE NATIONAL PARK IN 1984 AND 1994.

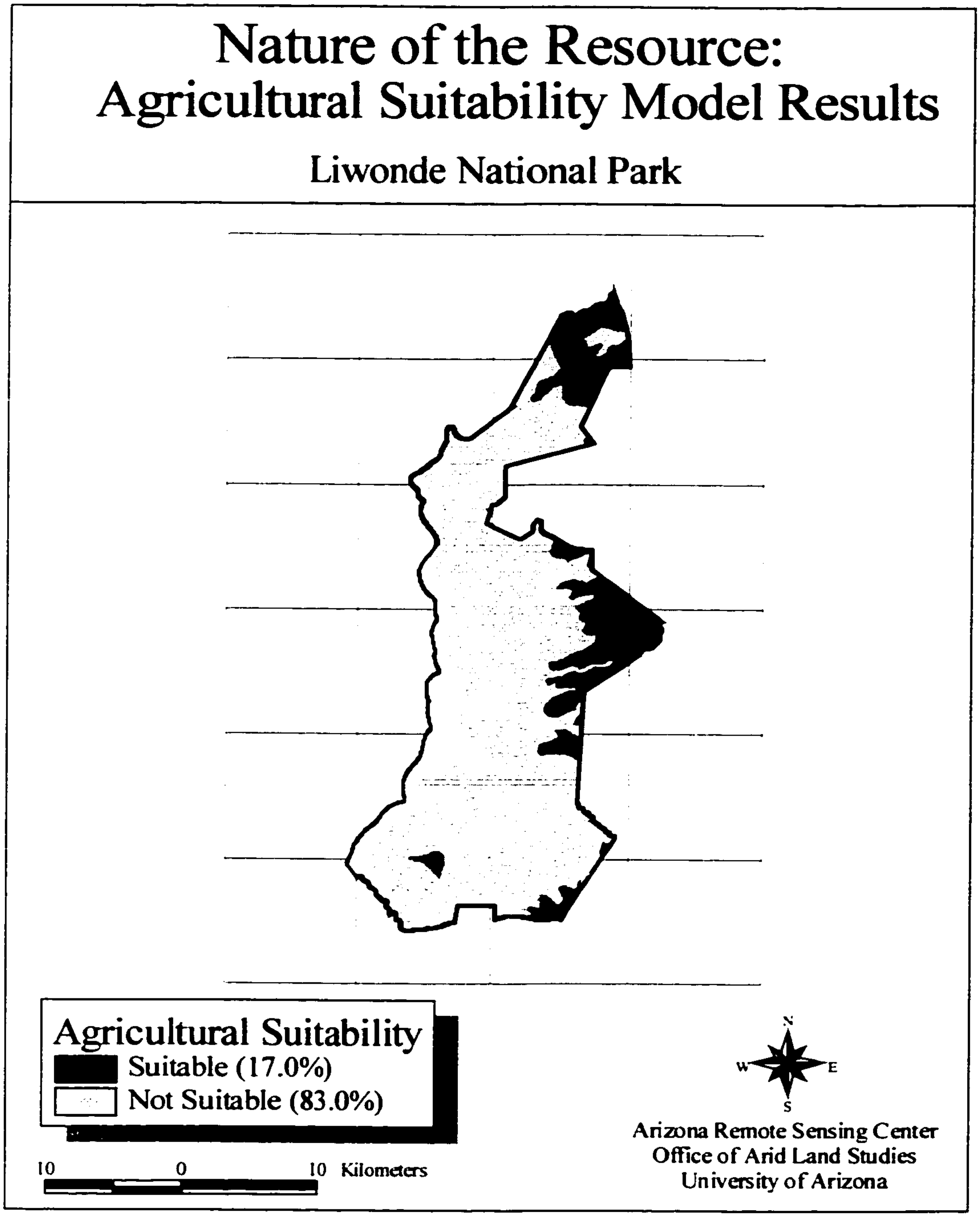


FIGURE C.12. AGRICULTURAL SUITABILITY OF LAND IN LIWONDE NATIONAL PARK (27).

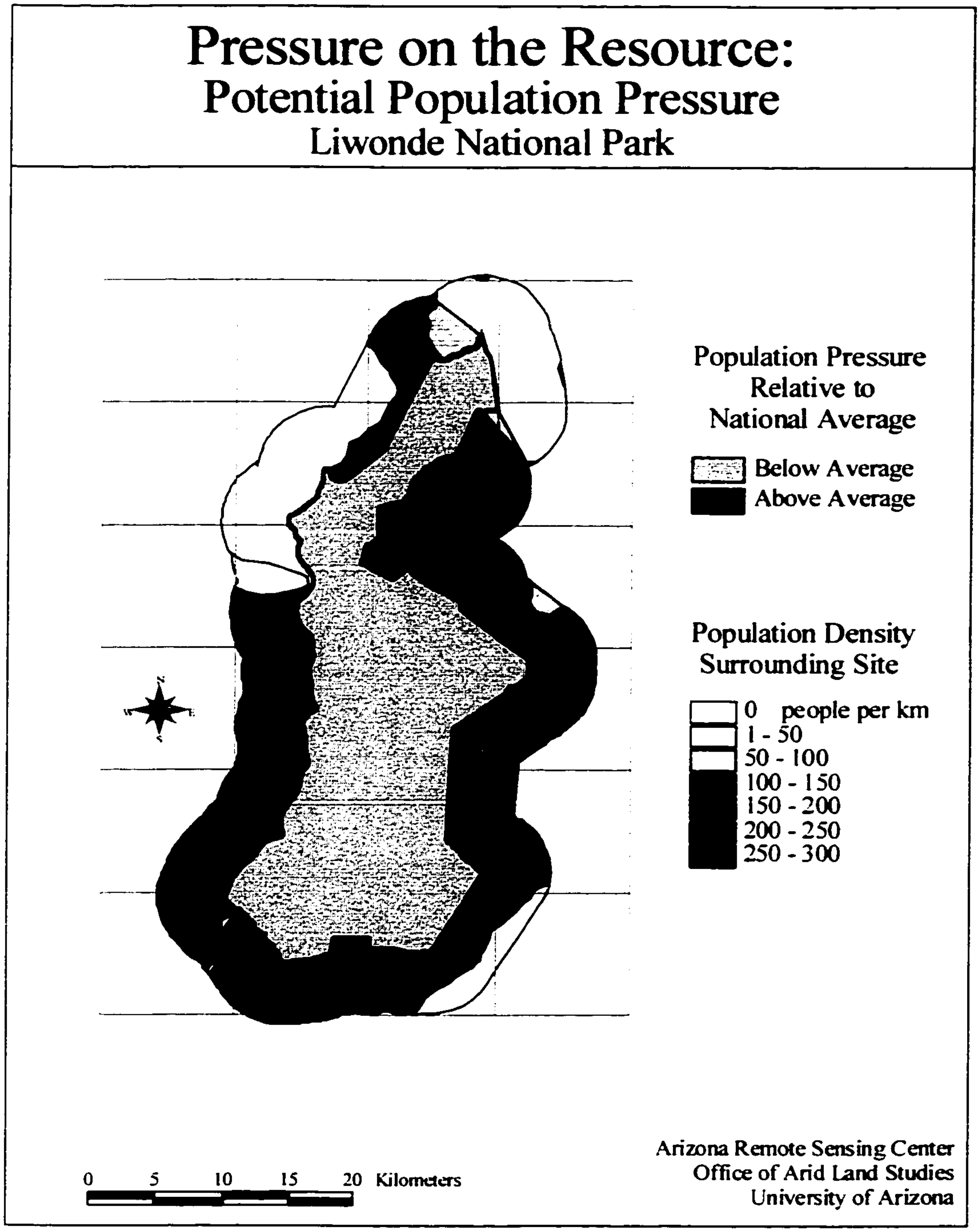


FIGURE C.13. POPULATION PRESSURE AROUND LIWONDE NATIONAL PARK (27).

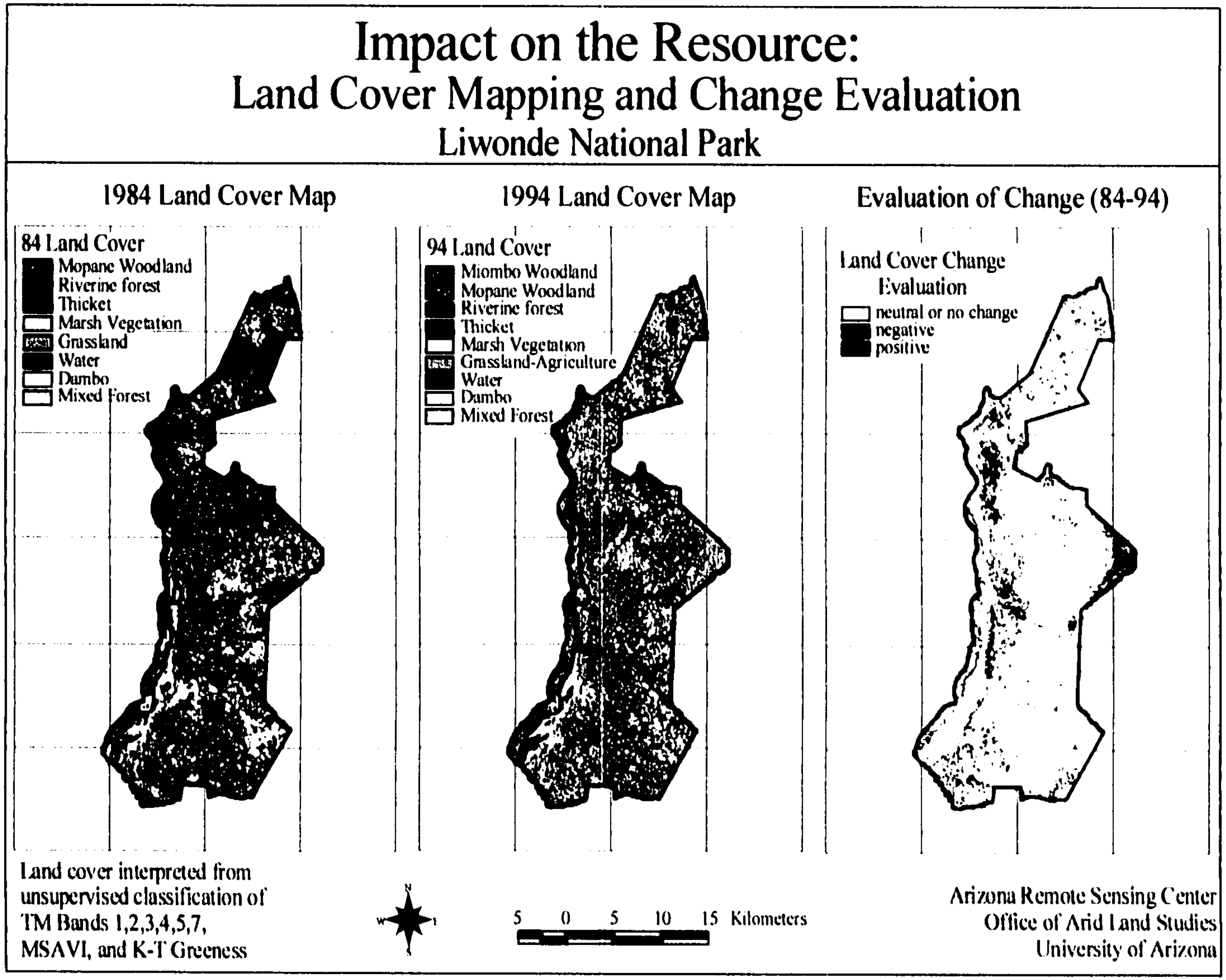


FIGURE C.14. LAND COVER CLASSIFICATION AND CHANGE DETECTION IN LIWONDE FROM 1984 TO 1994.