Importance of natural resources relative to cyclical fluctuations in rural household security in the Kilombero Valley, Tanzania

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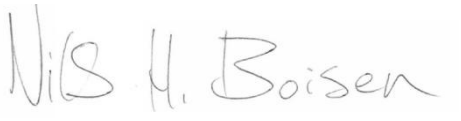
Master Thesis 60 credits 2009

PREFACE

This work is my Master of Science thesis which completes my Master's degree in Natural Resource Management at the Norwegian University of Life Sciences. The fieldwork for this thesis was funded by the NUFU bilateral cooperation project between Sokoine agricultural university in Tanzania and the Norwegian University of Life Sciences. Fieldwork was carried out during the summer of 2008 and the thesis was written during the school year 2008/2009.

Several people have contributed to the work of this thesis. Foremost, I express sincere gratitude to my wife who has aided and supported me more than any other in the completion of this theses and my academic career altogether. I thank my supervisor, associate professor Stein R. Moe for his helpful council and facilitation of this study. I further thank secondary advisors for their important roles in making this study a success; Professor Pantaleo Munishi for facilitating and advising the fieldwork, associate professor Vidar Selås for his statistical assistance, and Dr. Mariel Støen for her helpful input in planning this study. Furthermore, Samora Macrice, was an invaluable member of the fieldwork team for his remarkable logistic support and all around assistance. Andrew Mwakisu and Pharles Magai did an extraordinary job in conducting this study's household surveys, and I valued their friendly company during the fieldwork. The assigned driver Mr. Homa contributed long hours of tedious driving to this study and I am thankful. I appreciate all the assistance I have received from fellow students, hereunder especially Hartvig Velund.

May 14th, 2009
Ås Norway



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ABSTRACT

Natural resources are important among the world's subsistence-agriculture populations. Such societies are more vulnerable to steep fluctuations in food and financial security, as well as sudden shocks. Thus, the importance of natural resources is augmented as a means of coping. Though empirical documentation of this relationship is common regarding stochastic shocks to household security, it is less so for cyclical fluctuations and thus the related implication this has for annual peaks in natural resource exploitation. Freshwater tropical wetlands, if distinct seasonal climatic variation is present, likely offer good examples of regions where this seasonal variation results in cyclical food and/or income security deficits. This study attempts to quantify the important socio-economic and biophysical influences on rural perceived importance of natural resources in the Kilombero Valley, Tanzania, and the potential conservation implications of this. This study intends to chiefly address how socio-economic and biophysical variables influence the perceived value of natural resources relative to a potential cyclical fluctuation in the region's rural household security. Evenly distributed across a biophysical and socio-economic range, 90 rural households were interviewed about their natural resource utilization. Chi-square analysis, analysis of variance, and ordinal logistic regression were used to statistically quantify the gathered data. On a general level, the value natural resources for consumption and income generation in the Kilombero Valley is negatively associated with food and purchasing power security. Based on the premise that higher valuation is synonymous with greater extraction levels, this study demonstrates that natural resource extraction should be greatest during a "low security" season each year. Though household wealth was expected to carry the greatest influence, the major lesson learned from this study is that education, even on a slight scale, can inflict a dominant influence on the patterns of natural resource exploitation. Hereunder, Kilombero Valley households can be separated into two demographic groups. First, households headed by an individual who has not completed primary-school dominantly value natural resources as a means of coping with the annual nadir in household security, and in addition consume the most natural resources. Second, households headed by an individual who has completed the standard seven years of primary-school (but not gone further with their education) highly value their natural resources irrespective of the region's annual nadir in household security, and generate income from the most natural resources. The specific resources most strongly valued for coping with the annual household food deficit are all mostly wetland derived. On the contrary, specific resources most strongly valued for coping with the purchasing power security nadir are derived from both wetland and dryland. However, irrespective of household security the economically important natural resources are, with the exception of fish, mostly dryland derived; poles, thatch, firewood, and charcoal. Conservation stakeholders will best strengthen the preservation of the Kilombero Valley ecosystem in the long run by lifting the human population's lower socio-economic and educational stratum out of subsistence livelihoods and dependence on natural resources for food and income generation. Educational opportunities must be fortified, internal population growth must stagnate, and economic prospects must be augmented to even out the region's strong cyclical fluctuation of household security

CONTENTS

1 Introduction

Reliance on natural resources for foods, fuels and medicines, remains increasingly important among rural populations in developing countries, and it is common to argue that this dependence is most important for the lower end of the socio-economic scale in these societies (Byron & Arnold 1999; Corbett 1988; Dorward et al. 2001; Vedeld et al. 2007). The livelihoods of the world's rural poor are highly vulnerable to food and financial setbacks, forcing appurtenant households to be constantly active in pursuing methods of coping with this susceptibility (Wood 2003). The importance of natural resources for poor rural societies is thus often augmented for coping with shocks to household insecurity. The negative relationship between rural household security and wild natural resource dependence in the third world has been widely documented and discussed in relation to the role of natural resources as "safety nets" during stochastic falls in rural household security. Stochastic falls could be odd periods of poor harvests/food shortages and/or household income shocks (Delacote 2007; Delacote et al. 2009; Eriksen et al. 2005; Foppes & Ketphanh 2004; Harris & Mohammed 2003; Odebode 2005; Pattanayak & Sills 2001; Paumgarten 2005; Takasaki et al. 2004). This can also be due to morbidities/mortalities (e.g. HIV/AIDS; Hunter et al. 2007; Kaschula 2008; Shackleton & Shackleton 2006; Shackleton et al. 2007), or combinations of different causes (Angelsen et al. 2008; Arnold 2008; de Sherbinin et al. 2008; McSweeney 2005). Angelsen et al. (2008) lists several reasons why the world's rural poor turn to natural capital in the face of risks; they are divers and close in proximity, often easily obtainable due to lacking management regulations/control, and their extraction requires little skill or capital.

Relative to predictable cyclical food and income deficits resulting from annual climate variation, documentation of this negative relationship between rural household security and dependence on natural resources is less widely discussed, most often anecdotal, and otherwise too old to be easily traced down. Furthermore these studies generally focus on direct consumption rather than income generation. However, fairly recently in the Democratic Republic of Congo, de Merode (2004) observed that though wild foods are generally not a major component in rural household diets, they do become important during a four month "lean season" characterized by scarcity in agricultural products and vulnerability to food shortages. Another recent study from west Cameroon found that diversity of collected non-timber forest products (NTFPs) varied significantly between wet and dry seasons, but not derived income (Ambrose-Oji 2003). In a study from Zimbabwe the likelihood of rural households falling below the poverty threshold during an observed low security season was ca. 70% if no wild fruits were available, and ca. 30% if they were (Mithöfer et al. 2006).

If distinct seasonal climatic variation is present, freshwater tropical wetlands with poor infrastructure and moderately high human population densities likely offer typical examples of how this seasonal variation results in cyclical food and/or income security deficits. Moreover, tropical wetlands are unique in their environmental heterogeneity, and are often hotspots for biodiversity as well as important ecosystem services (Junk 2002; Myers 1997). Socio-economic variables, for instance income and population density, are often absent from studies analysing the value of wetland resources, but when included are shown to inflict an important influence (Brander et al. 2006). African wetlands are further good examples being inextricably linked to cropping and livestock management systems which due to escalating populations are under pressure of expansion in conjunction with efforts to increase food security (Schuyt 2005). Moreover wetland resources are crucially linked to the survival of millions of people throughout southern and eastern Africa by providing rural populations with water, food, medicines, construction material and fuel (Roggeri 1995; Schuyt 2005). Overexploitation can result in extensive negative repercussions on appurtenant natural resources and ecosystem services that wetland residents, as well as human society at large, are socially and economically directly dependent on (Junk 2002; Schuyt 2005).

Such consequences provoke questions addressing the need for empirical knowledge on the socio-economic and biophysical patterns of wetland natural resources, hereunder especially how local exploitation of these resources contributes to coping with cyclical food and financial insecurity. The confirmation of a natural resource's cyclical role in coping would imply an annual period of intensified exploitation. This study therefore attempts to quantify the important socio-economic and biophysical influences on the perceived importance of natural resources among the rural inhabitants of a high profile wetland dominated region of Tanzania. Hereunder, this study chiefly addresses how these variables influence the perceived value of natural resources relative to a potential cyclical fluctuation in the region's rural household security.

More specifically, if a year in this wetland region can appreciably be divided into periods of high and low food and purchasing power security, do resident rural households most value the consumption of, and income generation from, natural resources during the annual nadir in household security? What socio-economic and biophysical household characteristics most influence food and purchasing power security, and potentially further influence the temporal importance of natural resources? Moreover, are certain resources more important than others for coping with this period by merit of their specific utility?

Irrespective of food and purchasing power security, does socio-economic status and biophysical residence influence whether households mainly exploit their non-agricultural natural resource directly in contrast to purchasing? Hereunder, are specific resources directly exploited or purchased more than others? Does socio-economic status and biophysical residence influence whether households principally obtain their resources from wetland vs. dryland habitat? Are there factors that influence the quantity of natural resources and contributing species that these rural households utilize? In addition, what resources, if any, are habitat-specific? Based on these findings, how could conservation in the short and long-term be adapted?

2 Study area

The Kilombero Valley (08°40'S 036°10'E) in Kilombero District, Morogoro Region, Tanzania (Figure 1), possesses the largest lowland freshwater wetland in East Africa, and the valley's floodplains form overall one of Africa's biggest wetlands (Kangalawe & Liwenga 2005; Starkey et al. 1997). The wetland area covers 7,967 km^2 with a catchment area of about 40,000 km^2 (Booth et al. 2008). A short rainy season occurs from October to December and a longer one from February to June, with mean annual amounts ranging from 1,200 to 1,800 mm (Hetze et al. 2008; McCartney & van Koppen 2004). Flooding of the plains usually occurs from January to April when rainfall exceeds potential evapotranspiration. Mean annual temperature is approximately 26° C (Hetze et al. 2008). The region's main river channel is the Rufiji, fed by the Luwengu, which is in turn fed by the Kilombero (Booth et al. 2008). These main meandering channels in addition to a plethora of lesser ones dominate the floodplain with widely fluctuating seasonal variations in hydro-dynamics (Booth et al. 2008; Starkey et al. 1997). Thus the floodplain and surrounding hills and valleys consist of a diverse mosaic of wetland and dryland habitats (Starkey et al. 1997).

The Kilombero Valley Wildlife Project report (Starkey et al. 1997) has documented diverse and unusual flora within eight distinct plant communities which correspond to a hydrological gradient (catena) from the centre of the flood plains up to the valley margins. Approximately 350 species of plants have been identified (Starkey et al. 1997). The Kilombero River and its tributaries constitute an important breeding ground for fish throughout the whole Rufiji basin, containing a diverse fish population (with two endemic species) (Booth et al. 2008), and is one of Tanzania's biggest inland fisheries (Kangalawe & Liwenga 2005).

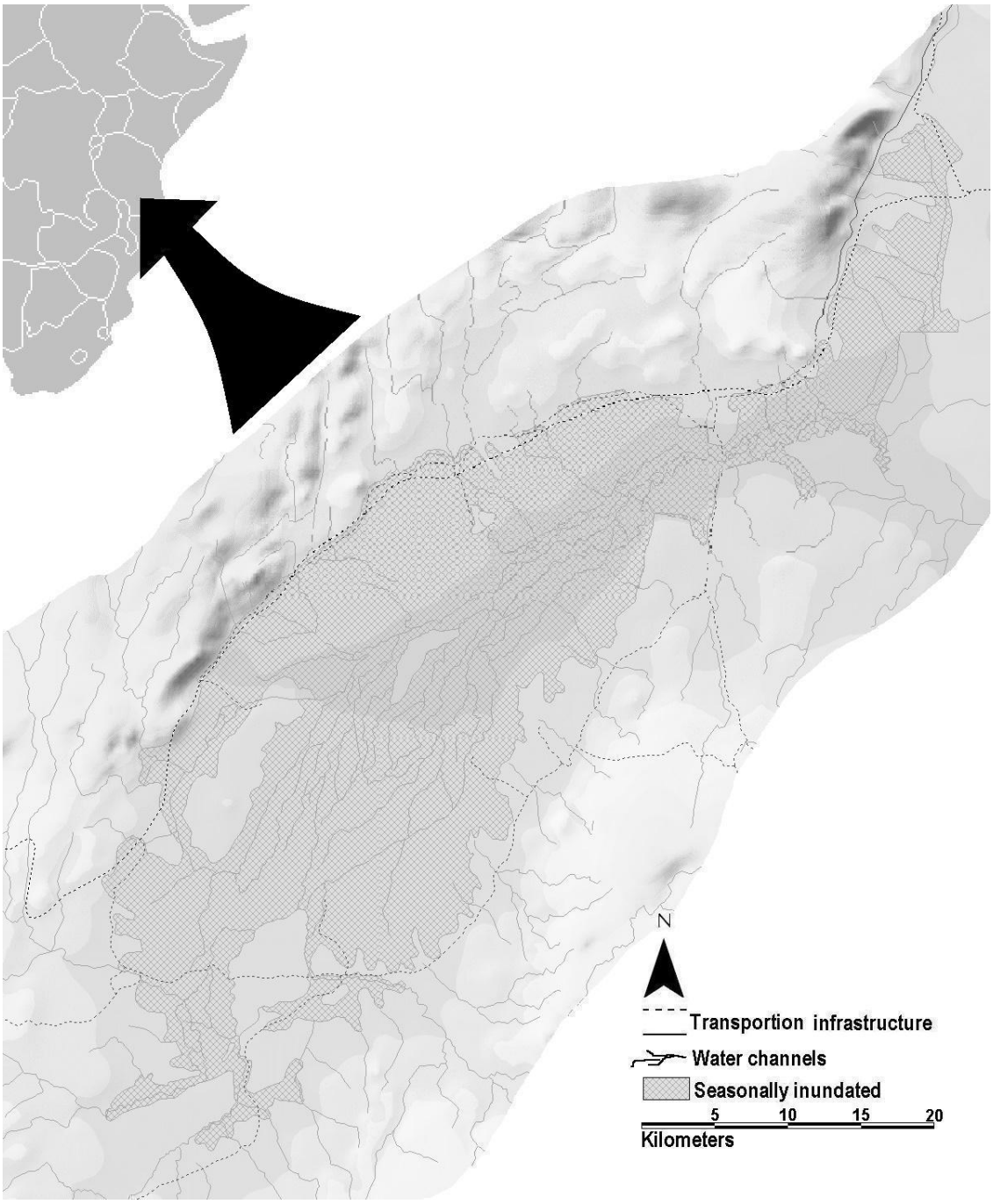

Figure 1 Kilombero Valley, Tanzania .

This wetland is recognized as having global importance by the International Union for Conservation of Nature (IUCN), and is included in the Greater Selous Ecosystem, a World Heritage Site. Tanzania ratified the Ramsar convention in 2000, and in 2002 the Kilombero Valley Flood Plain Ramsar Site was designated and added to the Ramsar Convention's list of international important wetlands. The inner part of the valley is designated as the Kilombero Game Controlled Area (KGCA), and otherwise contains a great diversity of animals including many large megafauna populations (Starkey et al. 1997). Among these it is worth noting that the Kilombero Valley contains ca. 75% of the remaining global population of Puku antelope

(*Kobus vardoni*), and is otherwise an important wetland for antelope (*Bovidae*) conservation in East Africa (Jenkins et al. 2002). General poaching pressures have drastically increased since in the 90s (Haule et al. 2002). Kilombero Valley conservation thus far has focused principally on large mammals, though the Kilombero Valley Wildlife Project report (Starkey et al. 1997) reinforces that the valley is also significant for the diversity of other species groups, particularly birds and plants, both regionally and globally.

Smallholder subsistence farming of the staple crops rice and maize, mostly rain fed though also irrigated, as well as some livestock keeping constitute the chief forms of land use. The majority of Kilombero inhabitants rely on wetland cultivation for their nutritional and monetary needs (Kangalawe & Liwenga 2005; Starkey et al. 1997), with crop surplus as the primary source of income. The majority of villages have conspicuously distorted welfare distributions with most of the valley's population subsisting at the lower end of the of the socio-economic, agro-technological, and educational scale, and are dependent on renting cultivation plots from wealthier village members (Booth et al. 2008; Harrison 2006; Haule 1997; Kangalawe & Liwenga 2005; Starkey et al. 1997). Wetland cultivation occurs chiefly during the latter wet season between February and June (Hetze et al. 2008). At this time of the year most able household members permanently move into their wetland rice paddies (shambas) where they reside in raised temporary shelters to protect them from water and wild animals (Hetze et al. 2008) (Figure 2). Among the farming population this period is characterized by empty pre-harvest food stocks (food insecurity), labour stress due to intensive work, and poor access to health services, clean water, and sanitation because of shamba remoteness (Hetze et al. 2008).

Figure 2 Typical wetland rice paddy (shamba) and dwellings. Dry season.

3 Methods

3.1 Data Collection

3.1.1 Commencement

In August and September 2008, 90 households in the Kilombero valley were interviewed about their natural resource utilization. Contact was made with Kilombero's District Natural Resource Office in Ifakara where the purpose of this study was presented to the district managers and assistance was requested in exchange for paid reimbursement. Two educated, highly experienced and extroverted district natural resource officers were assigned to this study by the office to function as logistical counsel during the data gathering in addition to being Swahili interviewers for the household surveys. This supplemented assistance from another individual already aiding the study on behalf of the project. Data gathering was implemented after training the district natural resource officers in the intended interview technique.

Each study village's representative was contacted several days prior to arrival and informed about our pending arrival and briefed on our intentions. Upon arrival we met with the village committee and properly introduced ourselves, informed them in detail of our study and its intentions, and assured them that the study was for their benefit emphasizing that there would be no negative repercussions from the obtained information. Great effort was taken to gain the confidence of the village chairmen, who were reimbursed for their time during these preliminary meetings as well as for individual help during the survey.

3.1.2 Household Sample

The sample of 90 households is evenly distributed across a biophysical gradient and socio-economic range that is representative of the region. Three distinct biophysical gradient categories describe the wetland vs. dryland composition within the boundaries of the three study-villages. The first village's biophysical-gradient category is wetland (mostly inundated during the rainy season, terra firma during the dry season). The second's is transitional being a mixture of wetland and dryland, and the third's is dryland (mostly terra firma during the dry season). To be certain that these three villages were representative of Kilombero villages along the respective biophysical-gradients they were chosen after careful consideration by managers at the District Natural Resource Office. Thirty households were interviewed from each village.

The sample's three separate socio-economic classes are categorized as lower-wealth, medium-wealth, and upper-wealth based on 30 households each (ten for each category from

each of the three villages). The parameters which define a household's socio-economic status were locally stipulated, since that which defines a household as upper-wealth is not necessarily the same between two separate rural populations due to differing local influences on wealth such as infrastructure. Thus, to obtain three well defined socio-economic groups, each individual village committee was first asked to define characteristic parameters that distinctly stratified village households in their particular village. The village chairmen were then asked to list households which fit into each category from the hamlet they each represented. Care was taken to prevent village chairmen from nepotisticly recommending households, and households which clearly belonged to a different socio-economic category than stated were either appropriately re-categorized or removed from the sample. For the purposes of avoiding stigmatism, households were not informed that they were interviewed based on socio-economic status.

Enforcement of natural resource exploitation laws in the region has an accountable reputation among the rural populations as being harsh, at times brutal (Booth et al. 2008; Brehony et al. 2001; Harris & Mohammed 2003; Respondent 2008; Starkey et al. 1997). Thus the identity of these villages and their respondent households have been kept confidential due to the sensitive nature of the survey.

3.1.3 Survey

The survey itself consisted of two parts, was conducted privately per household, took an average of one hour to complete, and was answered by a household head which most often was male between the age of 35 and 50. After being introduced to an interviewee by the hamlet representative we proceeded to reemphasize the benefits of responding honestly and the implausibility of negative repercussions for information obtained from them. Furthermore, expressions with which the survey operated on were explained (*e.g.* agricultural resources vs. natural resources). *Natural resources* are hereby defined as those which people, in contrast to *agricultural resources*, have not invested time, energy, or money into the cultivation / rearing of.

The first portion of the survey gathered general information on the household regarding how their food and purchasing-power security progressed throughout the year, their resource opinions, and household demography. The household's degree of farm capital technology was also recorded either as low-tech (No inputs (fertilizer &/or pesticide), all work done by hand), medium-tech (some locally produced inputs, some mechanization), or high-tech (inputs are common and purchased (often the chemical kind), motorized farm machinery). Perceived

household security for food and purchasing power were, based on subjective description from the household head, drawn on a grid as two separate Y-axis lines on an X axis that represented the duration of one year. The year's axis consisted of 12 months, each divided further into 4 segments (i.e. 48 in total). The security axis ranged from 0.5 to 24 with greater value representing increased security. Thus the year's average progression of perceived household security could be calculated based on the household sample's averaged security values within each of the 48 segments.

The second portion of the survey asked the household head to sequentially list the types of natural resources that they utilize by order of importance, first by resource type, then by appurtenant species / varieties per resource type. Thus resource types were by household allotted sequential ordinal importance ranks relative to one another, as were each resource type's species. *Resource type* hereby defines the function of a given utilized species. For example, the wildlife species of African buffalo (*Syncerus caffer*) and puku antelope are utilized for bushmeat and are thus species of this resource type. Furthermore, though *Dalbergia melanoxylon* and *Brachystegia spiciformis* are all utilised as charcoal, they can also potentially be used as firewood, construction poles, and/or construction timber within one household. Thus a single species could be listed more than once per household in relation to its functions, *i.e.* the types of resources it constitutes. This only applies to plant species in this study, as fish and bushmeat species contribute only to these two resource types.

Further data was gathered on the species of each resource type. Exploitation distinction was recorded, denoting whether the household directly exploits (produces) and/or purchases given resource. Resource origin was recorded, denoting whether the given resource is extracted from habitat in the wetland, dryland, or both. In addition each constituent species was given a resource temporal importance rank for (perceived) low, intermediate, and high household security seasons. These rankings were *not utilized*, *less important*, *intermediately important*, and *very important*, denoting the given specie's consumption and income generation importance by resource type relative to security season for the household.

3.2 Data Analysis

The occurrences of high (17-24), intermediate (9-16), and low (0.5-8) food and purchasing power security values were evaluated across the year's 48 stipulated segments in a chi-square analysis to test if perceived security levels significantly peak and nadir in during the course of a year. Chi-square analyses were also used to test for significant influences of biophysical

gradient and socio-economic status on the exploitation distinction and origin of individual resource types.

Analysis of variance (ANOVA) was used to uncover what influences household food and purchasing power security. In these tests the response variables were food and purchasing power security indexes. These indexes were created by summing a household's security values for the six month period most strongly associated with low security within the entire sample divided by a value equal to maximum security throughout this same period ([household security sum]/[maximum potential security]). The aforementioned six month period is from the start of November to the end of April and was defined by comparing chi-square values for the high, intermediate, and low, food and purchasing power security value occurrences among the individual 48 stipulated segments of the year. ANOVA analyses were also conducted to uncover potential influences on the quantity a household's utilized resource types, and gross total of utilized species. Ordinal logistic fit was used to uncover the potential associations of background variables with socio-economic status.

To test for influences on the household temporal importance of natural resource consumption, a multiple ordinal logistic model with the best AIC value was used. The risk of over-dispersion (outside 0.5-2) was tested for and dismissed at 0.9. To test for influences on the household temporal importance of natural resources for income generation, an additional multiple ordinal logistic model with the best AIC value was used. The risk of over-dispersion in this model was tested for and also dismissed at 1.1. The statistical tool JMP (©2008) was used for ANOVA, ordinal logistic fit, and the ordinal logistic regression models. The statistical tool MINITAB (©1972 - 2003) was used for chi-square analyses.

4 Results

4.1 Household security

Both food and purchasing power security are highly analogous with each other, and the annual peak and nadir of their values are significantly different in addition to being associated with specific times of the year (χ^2 = 4189; DF = 94; P = <0.000). This supports the division of the Kilombero Valley year into security seasons. Average food and purchasing power security values peak between the dry months of June through August (high security season), and descends to a nadir during the torrentially rainy months of January through March (low security season), with intermediate security periods during seasonal transitions (Figure 5). During the Kilombero Valley's low security season, food security is explained best by socio-economic status and relative village dryland composition, respectively (ANOVA χ^2= 4.51;

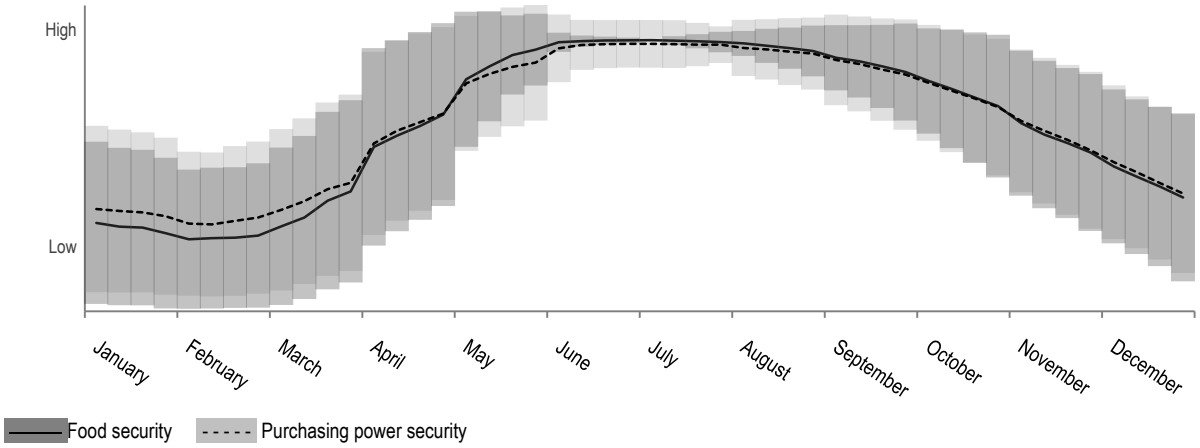

Figure 3 Average perceived rural household security in the Kilombero Valley. Grey tones denote standard deviation.

DF= 89; P= <0.000). During this time, food security increases from lower to upper-wealth households and from the wetland to dryland villages. Similarly, purchasing power security correlates positively with socio-economic status and farm capital technology, respectively (ANOVA χ^2= 4.71; DF= 89; P= 0.002). Here, purchasing power security during the low security period is similarly high for lower- and medium-wealth households, but increases for upper-wealth households. Furthermore it increases most from agriculturally medium- to high-tech households.

4.2 Strong associations with socio-economic status

Farm capital technology most strongly depicts socio-economic status in this study, showing a positive association (χ^2 = 16.98; DF = 2; P = 0.002). Regarding demographic patterns relative, neither household size nor sex ratio differentiated by socio-economic status. However, ratio of potential household providers (members aged 20 - 45) relative to total household size is far less for the lower-wealth households relative to the middle and upper-wealth, which are more similar to each other, led slightly by the upper-wealth. This pattern is especially true for female providers compared to male (χ^2 = 5.68; DF = 1; P = 0.017). The relative quantity of potential household dependents (members aged ≤ 15 & ≥ 75) is highest for upper and lower-wealth, slightly lower for medium-wealth (χ^2 = 8.56; DF = 1; P = < 0.003). Subsequently, the socio-economic status with the greatest deficit of providers *vs.* dependents is the lower-wealth, followed slightly by the medium-wealth (χ^2 = 8.83; DF = 1; P = 0.003). Furthermore, household total farm acreage increases greatly from lower to upper-wealth. When broken into wetland and dryland plot size, this trend is especially true for wetland farm size, while dryland plot size is high only for upper-wealth households (χ^2 = 6.2;

DF = 1; P = 0.0127). The household head's level of education shows no association with socio-economic status.

4.3 Coping and temporal importance of natural resources

When casually asked how they cope with insecurity the lower- and (to a lesser degree) medium-wealth households predominantly answered selling of labour as well as reduced food consumption. Business diversification and reverting to savings was most common among upper-wealth households. Strangely, other than fishing, none of the households stated any kind of natural resource usage when directly asked to describe their main low security season coping methods. Nevertheless, when asked to state whether or not they agreed with a series of statements (Appendix 1), 74% of the households agreed that non-agricultural natural resource are increasingly important to their food and monetary needs when agricultural resources become increasingly depleted. Furthermore, 66% agree that non-agricultural natural resource utilization is critical to the survival of their household during the most insecure part of the year.

4.3.1 Dominant influences natural resource valuation irrespective of security season

Alone, the household head's level of education is second in significantly explaining natural resource consumption value (Table 1), and fourth in explaining income generation value (Table 2). In total, five distinguishable education levels were recorded, however only three dominated the sample, these being primary-school/incomplete, and primary-school/standard-7 followed very moderately by secondary school. Both for consumption and income generation, natural resources are dominantly valued intermediately to less important among those households headed by individuals that have not completed primary-school (irrespective of security season). Additionally, these households consume the most resources. Household headed by an individual who has completed the standard 7 years of primary-school dominantly value their resources as very important, and sell more natural resources (irrespective of security season). The natural resources of household headed by individuals who have completed secondary-school are also dominantly very important, though to a lesser degree than the primary-school/standard-7 headed households (Figure 4a).

The income generation value of natural resources is explained thirdly by the type of natural resource in question, and foremost best explains consumption value. This is also irrespective of security season. The total valuation of natural resources is very disproportionate by type.

Table 1 Factors explaining the temporal importance of natural resource consumption for rural households in the Kilombero Valley (multiple ordinal logistic regression model).

Independent variables	DF	Likelihood ratio chi-square value	P
Natural resource type	18	324.78	<0.000
Household head's level of education	7	231.71	<0.000
Security season*Household head's level of education	14	198.94	<0.000
Security season*Natural resource type	36	194.45	<0.000
Security season*Natural resource type ordinal importance rank	24	70.92	<0.000
Security season*Farm capital technology	4	70.04	<0.000
Socio-economic status*Biophysical gradient	4	62.75	<0.000
Biophysical gradient	2	58.44	<0.000
Natural resource type ordinal importance rank	12	48.17	<0.000
Socio-economic status	2	47.72	<0.000
Security season*Socio-economic status*Farm capital technology	8	45.52	<0.000
Security season*Biophysical gradient	4	43.87	<0.000
Security season*Farm capital technology*Wetland farm size	4	43.71	<0.000
Security season*Socio-economic status*Biophysical gradient	8	37.77	<0.000
Natural resource species gross total	1	35.91	<0.000
Socio-economic status*Farm capital technology	4	32.68	<0.000
Food insecurity index	1	30.04	<0.000
Security season*Wetland farm size	2	29.99	<0.000
Security season*Socio-economic status*Dryland farm size	4	24.97	<0.000
Security season*Food insecurity index	2	23.58	<0.000
Security season*Natural resource species gross total	2	19.80	<0.000
Socio-economic status*Providers vs. Dependents index difference	2	17.84	<0.000
Agricultural resource total	1	14.08	<0.000
Dryland farm size	1	13.52	<0.000
Security season	2	12.83	0.002
Socio-economic status*Dependency burden index	2	9.71	0.008
Security season*Dependency burden index	2	9.66	0.008
Dryland farm size*Wetland farm size	1	7.88	0.005
Farm capital technology*Dryland farm size	2	7.00	0.030
Farm capital technology*Wetland farm size	2	6.82	0.033
Security season*Socio-economic status	4	2.89	0.577
Dependency burden index	1	1.88	0.170
Wetland farm size	1	1.35	0.246
Socio-economic status*Dryland farm size	2	1.14	0.566
Security season*Dryland farm size	2	1.11	0.573
Farm capital technology	2	0.76	0.684
Providers vs. Dependents index difference	1	0.19	0.659
Entire model	**191**	**2419.29**	**<0.000**

*Bold script indicates the individual variables. * denotes interaction between variables.*

Furthermore, the sum of recorded species per household for each natural resource type demonstrates that many resource types are more highly exploited than others (Figure 4b). Fish and firewood contain a dominantly large amount of consumed and sold species per household in addition to being dominantly ranked as very important for consumption. For income generation these two resources are in total, more intermediate to very important. Likewise, the consumption value of wild vegetables and bushmeat are in total dominantly less to intermediately important, while for income generation this is the same case for bushmeat but not wild vegetables. Thatch and poles appear to be more important for income generation than consumption regarding species sum per household, while the opposite appears true for

Table 2 Factors explaining the temporal importance of income generation from natural resources for rural households in the Kilombero Valley (multiple ordinal logistic regression model)

Independent variables	DF	Likelihood ratio chi-square value	P
Security season*Household head's level of education	8	220.26	<0.000
Security season*Natural resource type	32	160.62	<0.000
Natural resource type	16	108.36	<0.000
Household head's level of education	4	87.34	<0.000
Biophysical gradient	2	61.22	<0.000
Security season*Biophysical gradient	4	55.95	<0.000
Security season*Farm capital technology	4	43.46	<0.000
Security season*Dependency burden index	2	38.41	<0.000
Security season*Providers vs. Dependents index difference	2	34.28	<0.000
Farm capital technology	2	30.60	<0.000
Dryland farm size	1	28.89	<0.000
Socio-economic status*Dryland farm size	2	21.74	<0.000
Security season*Dryland farm size	2	21.02	<0.000
Security season*Socio-economic status*Dependency burden index	4	19.50	0.001
Security season*Socio-economic status*Providers vs. Dependents index difference	4	19.43	0.001
Security season*Socio-economic status	4	16.09	0.003
Agricultural resource total	1	7.20	0.007
Buying power insecurity index	1	5.56	0.018
Socio-economic status	2	2.36	0.307
Socio-economic status*Providers vs. Dependents index difference	2	1.52	0.467
Socio-economic status*Dependency burden index	2	0.62	0.735
Providers vs. Dependents index difference	1	0.28	0.594
Dependency burden index	1	0.13	0.719
Security season	2	0.00	1.000
Entire model	**105**	**761.57**	**<0.000**

*Bold script indicates the individual variables. *denotes interaction between variables.*

bushmeat, wild vegetables and fruit. Of the other resources with a higher number of species exploited per household, fish and firewood are of relative equal importance for consumption and income generation.

4.3.2 Dominant explanations of natural resource valuation in relative to security season

As predicted, security season best explains how household value the importance of consumption and income generation of their natural resources, and interacts with all except six of the explanatory consumption variables (Table 1) and all except three of the explanatory income generation variables (Table 2). The individual security seasons show strongly distinctive value ratios of natural resources. Natural resources are predominantly valued as very important during the low security season, intermediately important during the intermediate security periods, and less important during the high security season (Figure 5a).

For the dominant interactions with security season the importance of natural resource type approximately ties with the household head's level of education for consumption, though education is a more important interaction regarding income generation (Tables 1&2). Species

of bushmeat, wild vegetables and thatch followed by firewood, respectively are the resource types valued most importantly for consumption during the low security season compared to the high security season (Figure 5b). Fish is valued more importantly for income generation than consumption during low vs. high security season, while poles are valued most importantly for sale in the high security season, and equally for consumption between the high and low security season. Charcoal, bushmeat, and fish species, respectively are more valued in the low security season relative to the high security season for income generation followed moderately by thatch and firewood. Furthermore, regarding species sum per household, thatch and poles, respectively appear more important for income generation than consumption. Lesser recorded natural resource types such as wild fruit or matting material will not be discussed in relation to security season due to their lacking frequency among the household sample and therefore lack of certainty in the actual roles that they play.

Regarding education, the significantly higher value of natural resources during the low vs. high

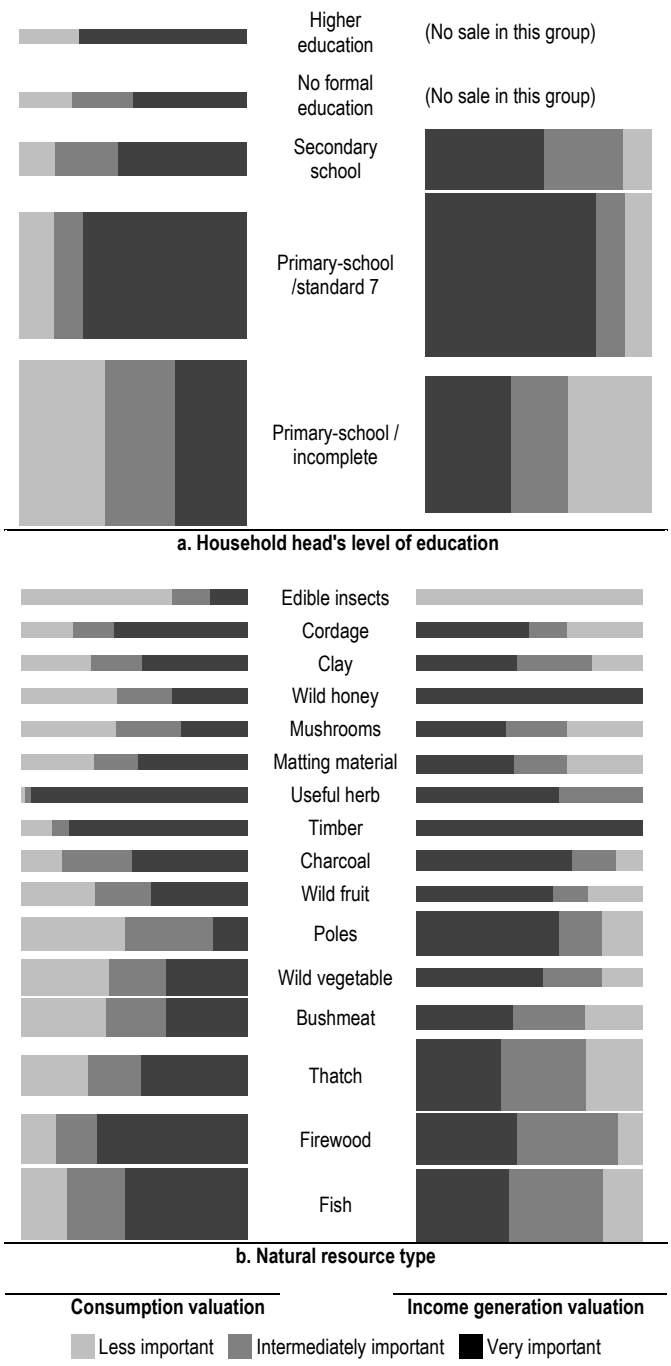

Figure 4 Household valuations of natural resource species/ varieties by **a)** Household head's level of education and **b)** Natural resource type. Irrespective of security season. The temporal importance rank of *not used* is excluded from these figures as this rank plays a negligible role.
Figure interpretation: Value ratios per variable are interpreted horizontally by colour tone, the sum of species is interpreted vertically by relative height. Example: Greater height for the value of consumption vs. income generation of natural resources among primary-school/incomplete households indicates that these households consume a larger amount of species than is generation income from. Additionally, one can tell that primary-school/incomplete households consume a larger amount of species than primary-school/complete households, though the latter value their natural resources more as indicated by the wider black area.

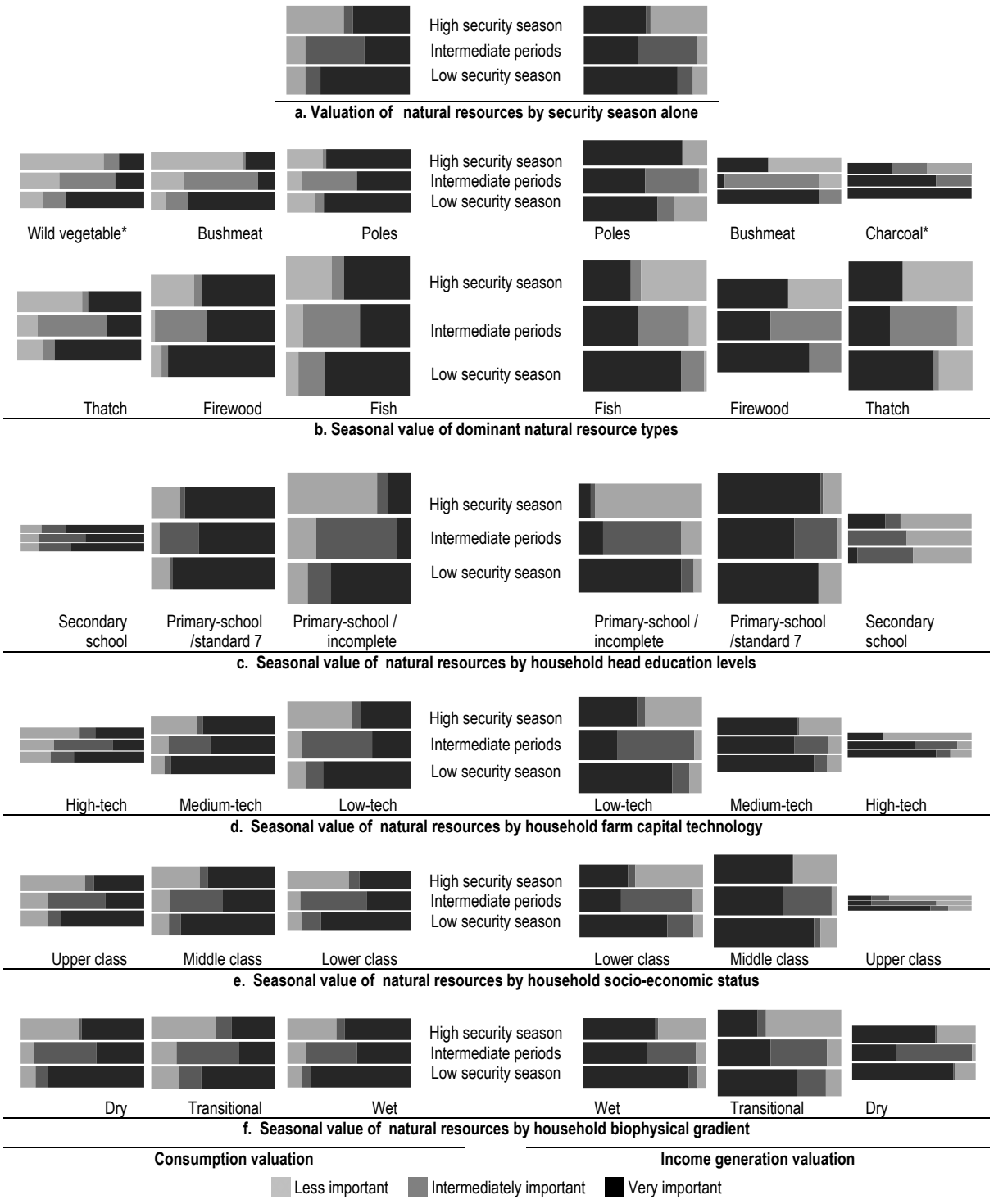

Figure 5 Household valuation of natural resource species/varieties by security season's most significant interactions with other influential variables. The temporal importance rank of *not used* is excluded from these figures as this rank plays a negligible role. *By number of species charcoal takes the place of wild vegetables regarding income generation.
Figure interpretation: Value ratios by season and variable are interpreted horizontally by colour tone between bars. The sum of species per variable is interpreted vertically by relative collective height of each three bars. Example: Income generation from fish is most valued in the low vs. high security season as indicated by the wider back area in this season's bar. Additionally, one can tell that more fish species are consumed than firewood species are generated income from by comparing the height of these two variables.

security season is demonstrated only for households headed by individuals who did not complete primary-school, particularly regarding income generation. Moreover, households

headed by individuals who did complete primary-school, appear to highly appreciate natural resources throughout the year (Figure 5c). In addition, more species per resource type and household appear to be sold by primary-school/standard-7 headed households, while primary-school/incomplete headed households consume the greatest amount. Consumption importance of natural resources by security season among the secondary-school headed households is comparable to the primary-school/standard-7 headed households, though are rather negligible in relation income generation despite the slight impression that sale is valued more during the high security season.

Both for consumption and income generation, households from all three farm capital technology categories value their natural resources most during the low security season, though it is the natural resources of the medium-tech households that have the highest values across all seasons (Figure 5d). Low-tech households consume and generate income from the most species per resource type followed respectively by medium- and high-tech households.

Like with farm capital technology, all three socio-economic categories value their natural resource greater during the low security season, with the natural resources of the medium-wealth households having the highest values across all seasons (particularly in the sale model) (Figure 5e). While all three socio-economic status categories are somewhat equal in their consumption of species per resource, the medium-wealth households stand out as generating income from the most, while upper-wealth households are barely recorded as generating income from natural resources at all.

All three biophysical gradient categories also value their natural resource greater during the low security season. However here it is the natural resources of households in the transitional gradient which are valued least across all seasons both for consumption and income generation (Figure 5f). Especially for income generation, the dry- and wetland gradients, respectively value their natural resources the most in all seasons, while the transitional gradient shows the highest degree of importance in the low vs. high security season. Similar to socio-economic status all three biophysical gradient categories are somewhat equal in their consumption of species per resource, though transitional gradient households stand out as generating income from the most.

The order in which households list their natural resources from most to least important proves to have an important relationship with how households value the consumption of, but not derived income from, these resources relative to security season (Table 1). Natural resources which households value most during the low vs. high security season are the first and second natural resource that the household sample lists, and these two positions consists

mostly of fish, firewood, or thatch (Table 3). After the second listed resource, the variation of common resource types for subsequent ordinal ranks increases between households. The resource types that households list approximately third, are despite the high degree of type variation between households, a resource that the given household appears to value highly all year round for consumption. After the third resource type, the greater value in the low vs. high security season increases again, though as mentioned with increased resource type heterogeneity per ordinal rank across the sample of households. Wetland farm size also is strongly negatively associated with the importance of natural resource consumption, particularly in the low security vs. high security season (Table 1). Principally in the low vs. high security season, the importance of natural resources for income generation is negatively related with the number of household dependents relative to total household size, and positively associated with an increased relative number of household providers vs. dependents (Table 2). The relative number of household providers alone is not significant in comparison to its role relative to the number of household dependents.

Table 3 Resource type information by household (n=90)

		Mode of ordinal	Individual	*Species /	Mean household	% Origin		% Consumption	
Resource type	% Households	importance rank	species / varieties	variety *n*	species total	Wetland origin	Dryland origin	Directly exploited	Purchased
Firewood	92	2	33	152	3	11	93	91	18
Fish	90	1	14	220	3	100	0	36	83
Thatch	74	1	26	126	2	57	55	95	11
Wild vegetables	67	5	37	116	3	84	35	99	5
Bushmeat	56	4	20	118	3	89	36	39	77
Poles	54	2	23	101	3	16	90	94	12
Charcoal	41	3	13	66	2	24	80	17	85
Wild fruit	38	7	27	74	3	15	90	99	1
Matting materia	28	4	3	27	1	67	44	74	30
Wild honey	24	4	1	22	1	9	95	32	73
Timber	20	1	11	41	3	11	89	32	68
Mushrooms	19	8	9	26	2	16	88	96	12
Useful herbs	19	6	26	36	3	6	97	83	17
Clay	16	8	1	15	1	47	73	87	13
Cordage	13	2	8	13	1	45	55	92	8
Edible insects	3	6	2	4	2	0	100	100	0

*Corresponding rows in origin and consumption columns are not always = 100 because some households utilize the same constituent species in both subordinate categories. *Sum of recorded species/varieties per household of all utilizing households.*

4.4 Supplementary characteristics of natural resource use

The mean total of utilized resource types per household is seven, and the mean gross species total per household is 16. In all, 16 resource types are recorded. The natural resources stated by >40 percent of the household sample are firewood, fish, thatch, wild vegetables, bushmeat, construction poles, and charcoal, respectively (Table 3; Figure 6). The mode of their natural resource type ordinal importance ranks illustrates the greatest

Table 4 Information on the ten dominantly exploited species / varieties by household (n=90)

	Total household responses	Mode of species rank	% Origin		% Consumption		% Food resource			% Fuel resource		% Shelter resource		
			Wetland	Dryland	Directly exploited	Purchased	Bush-meat	Fish	Wild vegetable	Charcoal	Fire-wood	Poles	Timber	Thatch
Brachystegia spiciformis	97	1	16	88	68	35	–	–	–	30	54	13	1	–
Pericopsis angolensis	79	1	18	86	62	46	–	–	–	27	51	22	–	–
Rufigi tilapia (*Oreochromis urolepis hornorum*)	64	1 & 2	100	0	28	84	–	100	–	–	–	–	–	–
Catfish (*Clarias mossambicus*)	59	1	100	0	39	80	–	100	–	–	–	–	–	–
Mbassa*	55	1	55	53	96	11	–	–	–	–	–	–	–	98
African buffalo (*Syncerus caffer*)	39	1	82	15	28	79	100	–	–	–	–	–	–	–
Mlenda*	33	1	82	36	100	03	–	–	97	–	–	–	–	–
Dogfish (*Bagrus orientalis*)	31	3	100	0	35	87	–	100	–	–	–	–	–	–
Puku antelope (*Kobus vardoni*)	23	2	70	35	48	74	100	–	–	–	–	–	–	–
Hippopotamus (*Hippopotamus amphibius*)	20	1	90	15	40	70	100	–	–	–	–	–	–	–

*Corresponding rows in origin, consumption, and resource columns are not always = 1 since some households utilize constituents from both subordinate categories. *Local vernacular pertaining not to specific species, but rather similar varieties that could not be closer defined.*

use and preference of these resource types among the households in light of their dominant frequency per household, as well as containing the highest number of species per household. Certain resource types on average contain more species per household than others despite being recorded less frequently, as can be seen when comparing the respective percent of responding households with the sum of species per all appurtenant households (*e.g.* fish *versus* firewood) (Table 3). The mean number of species per resource topic ranges from one to three. It appears that resources originate dominantly from dryland habitats, though when broken down by resource type it is clear that out of the seven prevalent resource topics, three are wetland specific (fish, wild vegetables, and bushmeat), and one (thatch) is apparently neutral (Table 4).

The quantity of resource types per household is related to an interaction between socio-economic status and household head's level of education (ANOVA χ^2= 415.39; DF=89; P= 0.003). Medium-wealth households lead by heads with a secondary school education are predicted as consuming a greater variety (larger amount) of resources. The same relationship is expected regarding household gross species total (ANOVA χ^2= 3212.4; DF=89; P= <0.000). Ten

species dominate the study irrespective of resource type (Table 4). Of these, the mode of their species importance ranks are one, with higher modes (2 - 3) belonging to species that share resource types with other more importantly ranked species (Table 4). For consumption, resources derived from six of the dominant ten species are primarily purchased and happen to also be the survey's wild sources of protein. However, among these six, the two bushmeat species of puku antelope and hippopotamus (*Hippopotamus amphibius*) also maintain a relatively high degree of direct household exploitation. This despite being both lesser ordinally ranked and lesser recorded than the other wild sources of protein. Thatch and wild vegetables each had no main species, but rather main varieties of similar qualities described by their names in local vernacular. The quantity of responding households for these two varieties (*Mbassa* and *Mlenda*) is relatively low in relation to the frequency that their respective resource types were recorded (thatch and wild vegetable), indicating that there is no major species preferences within these two types of resources, *i.e.* a wide variety of thatch and wild vegetable species are commonly used .

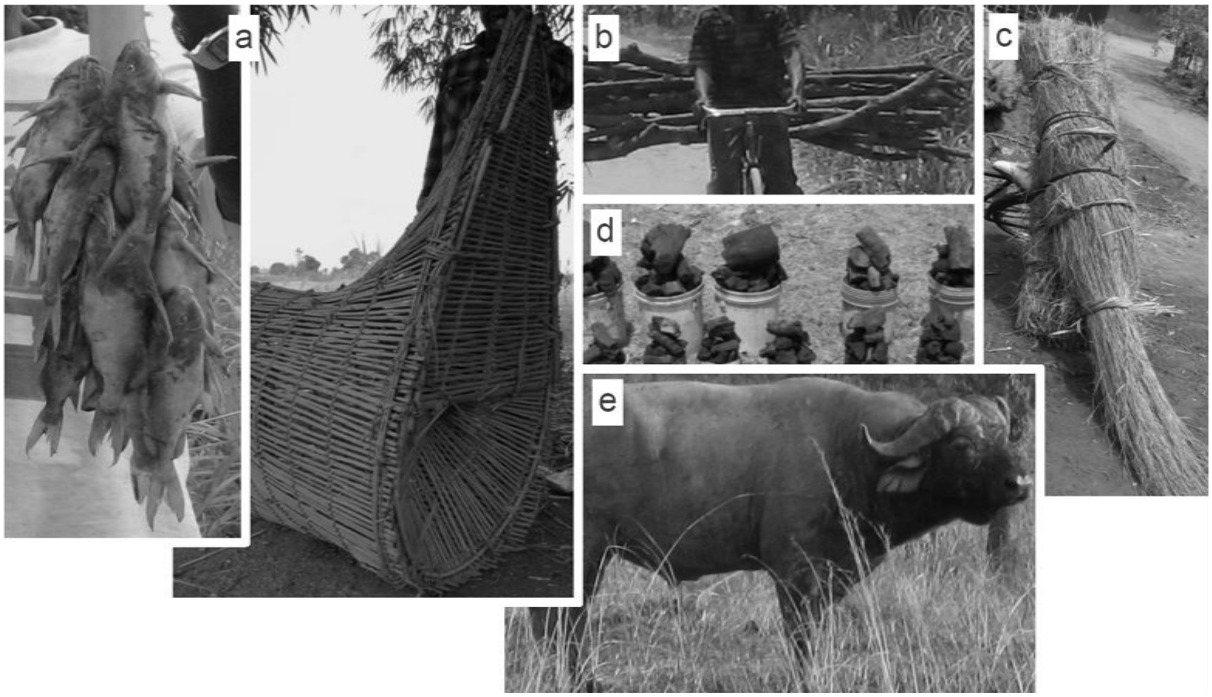

Figure 6 Dominant resource types. a) Fish (species unknown) and common fish trap. b) Wood gathered to be used as firewood or poles (species unknown). c) Thatch grass (species unknown). d) Charcoal (species unknown). e) Bushmeat (African buffalo (*Syncerus caffer*)). Image of a typical wild vegetable not available.

Direct household exploitation of each individual natural resource type by biophysical gradient is greatest, respectively in the wetland and dryland villages, predominantly for firewood, thatch, and wild vegetables (χ^2 = 184; DF = 30; P = <0.000). By socio-economic status, direct household exploitation is greatest, respectively in the lower- and medium-wealth households, predominantly for the same resource types as by biophysical gradient (χ^2 = 48;

DF = 28; P = 0.010). Purchasing of natural resource types relative to biophysical gradient is greatest in the intermediate biophysical gradient, predominantly for fish and bushmeat (χ^2 = 77; DF = 20; P = <0.000). By socio-economic status purchasing is greatest in the middle and upper-wealth households, predominantly again for fish and bushmeat (χ^2 = 62; DF = 20; P = <0.000).

Wetland origins of the individual natural resource types relative to a household's biophysical gradient is greatest in the wetland village, predominantly for (after fish) bushmeat, wild vegetables, and thatch (χ^2 = 52; DF = 18; P = <0.000). By socio-economic status the wetland origins of resources are relatively low among the upper-wealth households, with wild vegetables and bushmeat being the predominant wetland resources (after fish) (χ^2 = 38; DF = 24; P = <0.033). Dryland origins of natural resource types by biophysical gradient are greatest in the dryland village, predominantly for firewood and construction poles (χ^2 = 131; DF = 28; P = <0.000). By socio-economic status dryland origin is greatest among the medium-wealth households for the same resource types as by biophysical gradient (χ^2 = 48; DF = 28; P = 0.012).

5 Discussion

5.1 The influence of education

It is very interesting to find in this study that, within a small educational threshold, natural resources go from being a highly consumed important safety net, over to an apparently lesser consumed, but highly important economic livelihood base. Although lesser valued, the higher overall consumption of natural resources as well as their primary safety-net role among households headed by an individual who has not completed primary-school corresponds well with related literature. Here the apparent consensus is that lesser educated rural populations are ultimately more dependent natural resources for their subsistence. Initially however, this does not appear to correspond with the higher valuation and higher economic exploitation of natural resources among households headed by an individual who has completed primary-school.

Forest reliance in general is observed as negatively related with education in studies from Malawi and Sri Lanka by Fisher (2004) and Gunatilake (1998), respectively. From India, Narain et al. (2008) found that households with more educated heads were less likely to be dependent on, and participate in, collection of natural resources, especially fuelwood. Adhikari et al. (2003; 2004) made a parallel observation in Nepal. In northeast India, wild meat extraction negatively correlated with education level, but demand was positivly

correlated with income (Hilaluddin et al. 2005). In reference to earlier studies, Shackleton et al. (2007) states that small-scale vendors of forest resources reported that their initial impetuous to vend was household hardship, especially among those with lesser education (Ndabeni 2001; Rogerson & Sithole 2001; Shackleton & Shackleton 2004 cited in Shackleton, et al. 2007). In the Chiradzulu District of Malawi, larger households headed by younger and less educated men had had significantly higher total forest income (Kamanga et al. 2009). Remarkably, a study in Honduras found that each year of primary-school lowered a person's likelihood of clearing old-growth forest by about 5%, a further 4% for every middle school year, and a further 3% for every high school year. Furthermore, with the exception of De Boer & Baquete's (1998) study, even attitudes regarding the conservation of natural resources appears to be positively correlated with education (Do & Bennett 2009; Mehta & Heinen 2001; Sah & Heinen 2002). An earlier socio-economic study in the Kilombero region observed problems in raising awareness of useful innovations, and associated the difficulty of grasping and developing new ideas with the region's generally poorly educated population (Harrison 2006).

The majority of these studies associate education's negative correlation with natural resource dependence as a result of higher educated households being proximal of a higher socio-economic status. This is to say that households which are headed by higher educated individuals likely maintain greater access to livelihood activities which are profitable enough to release the household from consumption and income dependence on natural resources (Adhikari 2003; Adhikari et al. 2004; Godoy et al. 1998; Hilaluddin et al. 2005; Narain et al. 2008). This is a logical explanation, however, education level in this study does not significantly correspond with socio-economic status. The reason for this is likely the relatively low education level in the Kilombero Valley in general, with the majority of households falling into the incomplete vs. complete primary-school category. Households headed by an individual with better education are likely wealthier, but are few and far between and were thus not captured to a large degree by this study's sample of households. With very few livelihood prospects in the valley it can further be assumed that individuals given the opportunity for higher educating do not return to settle. This seems to concur with an earlier census conducted in the area (Harrison 2006), and therefore, in line with logic and available literature, education past primary-school in the Kilombero Valley is likely associated with socio-economic status. For the fraction of households headed by an individual with secondary educations or higher, sale likely desists while purchasing-driven consumption

increases for some natural resources (e.g. wild protein sources, charcoal, timber, burnt bricks & pottery, honey), relative to others (e.g. firewood, thatch, poles, wild fruits & vegetables).

5.2 Patterns of household natural resource exploitation and valuation

In this study, the comparative consumption importance by security season of the dominant natural resources relative to their ordinal succession of importance depicts the strong pervading function that natural resources constitute for rural household security. Furthermore, this is despite the heterogeneity of needs between households as demonstrated by the aforementioned ordinal succession's increasing variation in commonly resource types. The manner in which individual households rank the importance of specific resources temporally as well as ordinally depends on the specific household's needs which again mirror a number of characteristics that the literature most often relates to socio-economic status. Region, and study methodology are also an important influence in light of the highly assorted research findings regarding socioeconomic influence on rural natural resource use. Kangalawe (2004) found in two Kilombero Valley villages settled in the transitional gradient that the medium-wealth households made the greatest use of wetland natural resources as a safety net and the lower-class households the least. The findings of this study partially correspond, with more resources being consumed by the medium- as opposed to the lower wealth households, though the relative seasonal importance of natural resources is not different between the two wealth groups. This could be the result of the medium-wealth group apparently generating the most income from natural resources, and likewise exploit a greater variety.

Natural resources of this study fit into three categories reflecting their fulfilment of fundamental household needs; food, fuel, or construction material (perhaps with the exception of useful herbs being medicine). Not surprisingly the majority of the recorded resource types in this study are plant derived, since plants offer a wider array of applications. Ambrose-Oji (2003) found in south-west Cameroon that floral rather than faunal resources were most important for income generation, though income derived from bushmeat, especially agricultural pest species, was particularly important for the poorer households. De Boer & Baquete (1998) observed a similar trend relative to consumption. A meta-analysis of non-timber forest products found that wild foods and fuelwood are the two most important resources for income generation (Vedeld et al. 2007). Of the seven dominant resources recorded in this study, poles, firewood and fish, maintain a high degree of consumption and/or sale importance irrespective of the household security nadir, while others are a clear safety net for smoothing out the annual gap in security. Furthermore the importance ratios by

security season of a given resource type appears to also be influenced by utilization distinction (income generation vs. consumption importance).

Beginning with animal protein sources, de Merode et al.'s (2004) findings from Democratic Republic of Congo that bushmeat and fish were far greater valued both for consumption and sale during the "lean season" corresponds quite well with this study's findings in Kilombero Valley. Fish are without doubt the Kilombero Valley rural household's number one source of animal protein. This has also been the consensus of earlier studies in the region (Booth et al. 2008; Haule 1997; Kangalawe & Liwenga 2005; Starkey et al. 1997), and from other wetlands (Sah & Heinen 2002; Terer et al. 2004). Though fish are only slightly more valued during the low security season, in terms of income generation (sale), fish are more important as a safety-net. Fish, as well as the other main source of protein in the Kilombero Valley diet, bushmeat (discussed below), are predominantly stated as purchased vs. directly exploited, indicating that these are important economic resources. Moreover, these are economic resources which require a relatively greater degree of skill and capital investment in their procurement (fishing and hunting gear), refinement (butchering and curing), and sale.

Bushmeat appears to be slightly more important for consumption than sale. Though recorded as lesser utilized relative to fish or firewood, bushmeat (ca. tied with wild vegetables for consumption) is the resource type that demonstrates the highest degree of importance in the low vs. the high security season irrespective of consumption or income generation. This could indicate an important coping strategy regarding bushmeat in smoothing out the annual nadir in food and buying power security. However, the role that bushmeat plays in this respect may be somewhat coincidental. In agreement with this study, a previous Kilombero Valley study found that hunting activity is likely highest at the peak of the rainy season (Haule 1997), just after peak vulnerability in the low security season. This corresponds with inundation of the wetland, and is the time of year when most adult household members have semi-permanently moved out into temporary shelters in their shambas (rice paddies), weeding and protecting paddies from wildlife raids (Hetze et al. 2008). Simultaneously, the populations of large mammals in the wetland at this time are more densely grouped as well as inhibited in their escape capabilities due to flood waters, making them far easier to hunt.

Jenkins et al. (2002) speculates that crop damage in the Kilombero Valley by the large mammals puku, buffalo, and bush buck (*Tragelaphus scriptus*) could be the catalyst for increased poaching on these animals. Haule (1997) found however that the most significantly recorded crop pests were in fact Bush pig (*Potamochoerus porcus*), Baboon (*Papio*

cynocephalus) Birds (*Aves spp.*) and Cane rat (*Thryonomys swinderianus*). Though Bush pig, was Haule's (1997) most recorded bushmeat species, it seems that the other dominant bushmeat species from his, and this study, do not quite fit into the crop-pest assumption. This study finds Bush pig to be among the minority of exploited species, with buffalo, puku, (second and third in Haule's (1997) study) and hippopotamus (*Hippopotamus amphibious*) being respectively the highest. While the three main bushmeat species of this study could be important in damaging rice paddies specifically, it seems evident that they are most exploited by merit of their sheer abundance and worth as bushmeat, which is catalyzed more by their coincidental proximity to humans during that time of year when they happen to be easiest to exploit. Of further concern, all the dominant wild protein sources (fish and bushmeat) are mainly purchased within the sample of households, though puku and to a lesser degree hippopotamus are singled out as having particularly high direct exploitation percentages as well.

Though approximately 69% of the households stated some form of domestic animal protein (mainly poultry) as important for their household, it is still quite likely that fish, and bushmeat respectively are the valley's most important sources of animal protein. Regarding the position of bushmeat, this presumption is backed up by the topic's clandestine nature among households since this wild resource is more often than not illegally exploited/sold (Haule et al. 2002; Starkey et al. 1997). It was indicated by respondents that households generally butchered their own poultry for special occasions. An earlier study (Haule 1997) further indicates that bushmeat, though more expensive than fish, is a more economical option than consuming one's own domestic animals, and observed that far more adolescents reported one of three dominant species of bushmeat in their last meal compared to domestic animal protein sources. Sources of domestic protein other than poultry (e.g. pork, cattle) are consumed even rarer and generally allocated among the upper class. The Kilombero Valley Wildlife Project observed that the consumption of fish and domestic protein (animal & plant derived) was significantly greater for wealthier households, with the lower wealth households consuming domestic protein three times per week compared to six for the middle wealth households and almost daily for the wealthiest (Starkey et al. 1997). While information on bushmeat consumption was difficult to gather by that project, locals did express a preference for female (especially pregnant) puku, and a wide availability of Puku in local restaurants was otherwise observed. Under an informal conversation, a village chairman in this study answered to a comment on the healthy appearance of village children that, aside from fish,

bushmeat is usually a weekly supplement in their diets. Taken into consideration, bushmeat is therefore likely far more important than this study was able to record.

Wild vegetables are the least of the dominant resource types in terms of consumption importance, and are ousted by charcoal out of the six dominant resource types for income generation. Although wild vegetables also demonstrate a very high degree of importance during the low vs. high security season, just like bushmeat its role as a consumption-smoother may be somewhat coincidental. A number of households commented that the reason they collected wild vegetables more during the low security season was mainly because it is that time of year when (phenologically speaking) wild vegetables are most available (Respondent 2008). Weight is added to this explanation by a detailed book on wild vegetables in Tanzania which tells that many wild food plants are only seasonally available, with wild vegetables being most abundant between December and June (i.e. the low security season in the Kilombero Valley) (Ruffo et al. 2002). Furthermore, while weeding of the shambas is an ongoing activity during this time, it is possible that a number of palatable weed varieties end up in the "stewpan". The occurrence of naturalised weeds being important wild vegetables/herbs has been observed elsewhere (e.g. Dovie et al. 2007; Harris & Mohammed 2003; Kaschula 2008)). Unfortunately for reflection at the species level, the utilized wild vegetables could only be recorded in the local vernacular which was not possible to further translate into explicit species. It has, however, been indicated than many of the recorded vernacular names were reference not so much to explicit species as they were to varieties of species with similar wild vegetable characteristics. Among the recorded natural resource types, wild vegetables have the highest number of recorded varieties. *Mlenda* is the only predominately recorded variety despite constituting a fraction the recorded varieties by household. This indicates that wild vegetables are perhaps the resource type with the greatest richness in commonly used varieties.

All three of the main wild food resources are predominantly wetland derived and are most important during the low security season. This is likely associated with the high degree of movement into the wetland during this period, and is a testament to the high value of the wetland's ecosystem for rural food security in the region. An earlier study from the Kilombero region observed (anecdotally) that most of the respondents reported dependence on forests for nutrition during food shortages (Harrison 2006). However, Harrison's (2006) notion of food shortages was not in respect to the annual household security cycle as reported in this study, but was in relation to drought years when flooding of the wetlands was sub-sufficient for rice cultivation. For the most vulnerable households this could extend their

reliance on natural resources longer into the year. With the important wetland resources likely being more difficult to exploit outside of the rainy season, Harrison's (2006) observation regarding forests could be correct.

Regarding fuel resources, rural households in the Kilombero Valley are virtually entirely dependent on wood burning. As far as fuel needs are concerned, firewood has the widest variety of applications and is far cheaper and obtainable than charcoal. For those who can afford it, charcoal is used exclusively for cooking, being a relatively clean and highly effective heat source. Firewood on the other hand is extensively important for warmth during the colder/wetter season, followed by campfire light and brick/pottery burning, besides being ubiquitously used in the lower- and middle-wealth households for cooking. Charcoal production is conducted on the ground, in the open, in remote areas (due to its illegality), and is time consuming. Thus charcoal is likely produced mostly during the dry season, despite its more important role for income generation during the rainy season. Explanations for why firewood and charcoal are most important during the low security season are obscure and speculative. The key explanation may in fact lie in charcoal's higher status for income generation during the low security season, which also depicts a stronger demand for charcoal use during this period. Due to charcoal's narrow application, this greater demand further indicates a higher necessity for cooking heat. A higher necessity for cooking heat during the low security season seems most logical considering that meal preparation by household during this time is not conducted under one roof. Meal preparation is split between those members dwelling in the shamba, and those remaining at home such as school children (mandatory primary-school attendance), elderly, and the ill (Hertze et al. (2008) observed a peak in household illnesses during this period). This phenomenon could double a single household's fuelwood (both charcoal and firewood) needs for cooking. For example, Shackleton (Shackleton & Shackleton 2003) found that the amount of fuelwood used for cooking correlates more to the number of meals cooked, rather than the amount of household members partaking. Furthermore, with wild foods requiring longer preparation than that of safer staple foods, and with most household diets relying more on these food resources at this time, the consumption of fuelwood per meal is also likely to increase. Inadequate cooking time (lees fuelwood used) can result in mal-nutrition and illness (Arnold 2008; Byron & Arnold 1999), especially for meals derived from wild foods.

Specific necessity for firewood during this time could have additional explanations such as a possible increased need for warmth as well as campfire light in the shamba dwellings. Though brick/pottery burning does consume massive amounts of firewood, this type of

livelihood activity is not likely to be carried out during the rainy season when need for bricks and pottery is low. Hetze et al. (2008) observed that access to clean sources of water during this time of year is highly restricted for shamba dwellers. Firewood could thus be important for sterilizing drinking water, however knowledge of this practice is not widely known to exist in the region. Furthermore, one logistical issue seems to contradict the greater importance of firewood for shamba dwellers during the low security season; with waste-high water and crude shelters on stilts, where/how are campfires being burned? Charcoal burning on the other hand could be easily conducted inside the shelters due to its easily containable use.

Construction and maintenance of structures is an activity allotted to the latter half of the high security season when agricultural activity is at its lowest. This is reflected in the greater importance of poles (for income generation) and timber (direct use of of) during the higher security season. This has also been observed by Fisher & Shively (2005). Lower- and middle-wealth households respectively construct their homes as well as shamba shelters mostly from poles with raw clay walls and thatched roofs. Timber, burnt bricks, and iron roofing are materials almost exclusive of homes belonging to the upper-wealth households. Taken into consideration that such buildings are longer lasting than those constructed of poles and raw clay, it is not surprising that timber and burnt bricks are so infrequent among the household sample. The greater importance of thatch during the rainy season however, is likely related to the heavy rains. The relative minority of households stating that they purchase thatch is puzzling in comparison with its relatively high status for income generation during the low security season. Moreover it is hard to imagine that the lower and middle wealth groups are buying thatch considering the low general level of purchasing power during this time. Since iron roofing, when used, is generally for homes, the probable explanation is that wealthier households are buying thatch to maintain the roofing of additional non-residential structures (stands/shops, workshops, storage huts, latrines, etc.). As far as income generation is concerned, thatch nevertheless appears to be very important for smoothing out the annual purchasing power nadir.

Two species of tree single themselves out as most exploited; *Brachystegia spiciformis* and *Pericopsis angolensis*. Had Timber been more highly observed among the 90 households, *Pterocarpus angolensis* would come third. This corresponds with findings from the Kilombero Valley wildlife project (Starkey et al. 1997). With the wide variety of main applications recorded for these species, in addition to a plethora of smaller applications recorded by others (e.g. Hines & Eckman 1993; Starkey et al. 1997)), they are certain to be

under great pressure of exploitation. Like with wild vegetables the main species of thatch could only be recorded in the local vernacular which was not possible to further translate into explicit species. The Kilombero Valley project (Starkey et al. 1997), however, names *Panicum fluviicola* and *Hyparrhenia collina* as the most commonly used grass species. Palm leaves from *Phoenix reclinata* are also to a lesser degree used as thatch, but are the main material used for matting (baskets, mats, hats, etc.), and though less important in this study, these are reported by Haule (1997) as economically important in the region.

5.3 Patterns observed by socio-economic status and biophysical gradient

Some literature speaks of this unimodal relationship between social status and natural resource dependency, demonstrating that rural medium-wealth households to the greatest degree include natural resource exploitation in their consumption and especially income generation portfolios (Ambrose-Oji 2003; Godoy et al. 1995; Kamanga et al. 2009; Vedeld et al. 2007). According to Dorward (2001) greater capital in addition to livelihood diversification is favourable for consumption smoothing and risk management. Rural middle class households are perhaps those with the most diversified dependency on natural resources. This group is possibly less dependent than the lower class on remittances from relatives and friends in the form of goods and/or money. Moreover, this group could be more self-employed than the lower class and less dependent on selling their labour to wealthier farmers, while likewise still lacking the equivalent capital of the upper class that would free them from smoothing household resource needs with a larger spectre of natural resources types. This may explain why middle class households in this study sell a wider variety of resource types and species, and is supported further by considering that middleclass households are the only group that have a prominent status both for direct exploitation as well as purchasing of their natural resources.

Still, many authors find a bimodal socio-economic relationship (most important for the poor and wealthy) with natural resource dependency, though with generally greater weight placed on the poorer households ((Harris & Mohammed 2003; Kaschula 2008; Narain et al. 2008; Paumgarten 2005; Shackleton & Shackleton 2003; Shackleton & Shackleton 2006)). Furthermore, Shackleton (2006), and Narain et al. (2008) found a bimodal socio-economic relationship with purchasing natural resources, and the lower-class households of Narain et al. (2008) were uncovered as the least likely to directly exploit (collect), contrasting Takasaki et al.'s (2004) observation from Peru that poor households collected more. And, not to be confused with dependence, the consumption quantity and/or demand for natural resources has

been observed to be positively associated with wealth (Cavendish 2000; Hilaluddin et al. 2005; Neil & Arnold 1997). There are however studies which find no apparent association between socioeconomic status and patterns in natural resource dependence (e.g. Hunter et al. 2007; Wickramasinghe et al. 1996).

Socio-economic related dependence on natural resources is also discussed as related to the specific resources in question. A positive association between wealth and the importance (income generation and consumption) of those natural resources which require more skill and capital investment in the collection, refinement and sale of, e.g. fish, bushmeat, charcoal, etc. (de Merode et al. 2004; Do & Bennett 2009; Hegde & Bull 2008; Paumgarten 2005). An opposite association is often observed for resources which require little skill and capital investment in the collection and sale of, e.g. fuelwood, wild vegetables, thatch, etc. (de Merode et al. 2004; Do & Bennett 2009; Hegde & Bull 2008; Narain et al. 2008; Neil & Arnold 1997). This particular pattern appears to be unimodal in this study, i.e. medium-wealth households derive income from more exclusive/refined resources. The explanation here is likely that upper-wealth households in the Kilombero Valley use their capital assets to specialize on that which brings the greatest returns (cash cropping), leaving the medium-wealth households with greater opportunity to fill the niche. Likewise the lower-wealth households lack the necessary capital associated with exploiting the more exclusive resources. Therefore they exploit simple natural resources, hereunder mostly as a means of coping when they must since they are the group most employed as farm labour by the upper-wealth households (Booth et al. 2008; Kangalawe & Liwenga 2005; Starkey et al. 1997).

This study's observations of households coping through selling labour, business diversification and reverting to savings dependent upon socio-economic status corresponds with Dorward et al.'s (2001) meta-analysis remarks, and are relatively in line with observations from the region (Harrison 2006; Haule 1997; Kangalawe & Liwenga 2005; Starkey et al. 1997). Regarding wealth, its positive association with food security as well as and relative village dryland composition in the Kilombero Valley corresponds with other studies, both from the Kilombero region (e.g. Harrison 2006; Starkey et al. 1997), and elsewhere (Negash & Niehof 2004). It would seem that visible characteristics of wealth in the Kilombero Valley are proximal to internal agricultural and demographic patterns at the household level.

This study's documentation of the strong positive influence that increased farm capital technology inflicts during the low security season on purchasing power, and not food security, demonstrates its far greater important for cash crop production than for subsistence crops.

This is logical considering that agricultural inputs are expensive in the Kilombero Valley (Booth et al. 2008; Kangalawe & Liwenga 2004; Starkey et al. 1997), and the consumption of crops that are subjected to expensive inputs would mean that households are eating their investments.

Though this study found the ratios of household providers and dependents to be different by socio-economic status, it contrasted other studies (e.g. Kadigi et al. 2007; Kamanga et al. 2009; Mung'ong'o 1998; Negash & Niehof 2004) in not differing by size or sex ratio. Kadigi et al. (2007) also found that household vulnerability in Tanzania's Great Ruaha Catchment was positively associated with the amount of dependants (in contrast to this study), and that female- relative to male-headed households were more likely to be vulnerable. The female-relative to male-headed household trend for vulnerability was also observed by Haule (1997) in the Kilombero Valley, though the number of female headed households in this study's sample is negligible to deduce any similar trends. Poor rural families are according to Dorward et al. (2001) characteristically acutely short of labour. It can be presumed that rural households in general which, relative to total household size, are less burdened by dependent members and otherwise have a high number of providers relative to dependents will have greater farm labour capacity and income diversification potential. This can result in greater yields, larger food stores, and greater earning which is in turn proximal to greater food and buying power security. The ratio of male *vs.* female providers can also have an important influence on food and buying power security. Literature from the Kilombero Valley (Haule 1997) and elsewhere in East Africa (McCartney & van Koppen 2004) indicates that females are especially important in the case of rural households for hard physical farm labour while males tend to be more important for off-farm income generation.

Fisher & Shively (2005) explains the seasonal variability of forest product exploitation as positively corresponding with the amount of labour available to natural resource exploitation which correlates negatively with agricultural activity. This is to say that labour availability for natural resource exploitation is low when people are preparing fields and harvesting crops, and high otherwise. The author underlines this by stating that rates of forest extraction were observed to be greatest in the "non-agricultural period". This does not appear to apply to the Kilombero Valley, as the annual zenith in agricultural activity, i.e. the valley's most intense period of rice paddy preparation and to some degree early harvest (Booth et al. 2008; Harris & Mohammed 2003; Haule 1997; Hetze et al. 2008; Kangalawe & Liwenga 2004; Starkey et al. 1997), is also the annual nadir in household security when the exploitation of many natural resources, both for consumption and sale, have hereby been documented as more important.

It is clear that the wealthier households in the Kilombero Valley dominate land that offers the best cash crop potential, considering that dryland cash crop (maize) cultivation is an excellent option during the flood season to fill annual gaps in production. Furthermore, suitable dryland plots are a limited resource relative to wetland plots that produce cash crops (rice and maize) post-inundation. While increased rice paddy (wetland) acreage increases a household's total annual income, an additional increase in dryland acreage is likely a strategy to increases a household's coping potential with the annual nadir in purchasing power security. Furthermore, a rural household's farm plot size for cash crops in areas with low farm capital technology indicates greater household labour potential and food security (Fisher 2004; Mung'ong'o 1998). The strong positive association of wetland farm size with socio-economic status in this study very likely explains the strong negative association between wetland farm size and the importance of natural resources (discussed in greater detail below).

The patterns and relationships of agriculture natural resource exploitation are according to Scherr (2000) fundamentally influenced by biophysical conditions (e.g. soil characteristics, rainfall, topography etc.). Furthermore, the conditions of rural infrastructure (e.g. roads, water supplies, schools, research institutions, extension services etc) are also discussed as highly important by Mung'ong'o (1998). These influences also affect the patterns and relationships of non-agricultural natural resource exploitation. Thus, the influences a village's dryland composition inflicts on increasing food security, as well the unimodal relationship with income generation from natural resources are the result of interactions between two main aspects of the region's biophysical and -geographical influences.

Firstly, though the underlying positive relationship between wet- and dryland farm size with socio-economic status is important for income, the actual wet/dryland composition of the given village may be more important for consumption of agricultural products than income for those households which are more vulnerable. During the low security season vulnerable households in wetland villages, and to a slightly lesser degree villages with mixed wet/dryland composition are coping with flooding while preparing their rice paddies and surviving on dwindling food stocks and remittances from fellow villagers and relatives (Hetze et al. 2008; Kangalawe & Liwenga 2005). Simultaneously, a greater majority of potentially vulnerable households in villages along the dryland gradient are likely more food secure during the low security season as a result of their relative greater opportunity to cultivate food for direct consumption directly prior to and during this time.

Secondly, a main road and railway (with a station in Ifakara) is the valley's only connection with outside commerce, electricity, welfare support, and information exchange.

This (mostly) dirt highway together with the railroad cuts nearly exclusively through the valley's transitional gradient and villages here are thus advantageously situated alongside the aforementioned benefits it brings. This is a good explanation for the dominant importance that sale of natural resources has along this gradient compared to consumption. Anecdotally, the omnipresent sale of charcoal and fish along the main road in contrast with side-roads into the wet- or dryland villages bears whiteness to the transitional gradient's importance for natural resource commerce. Nielsen (2006) observed that villages with better infrastructure and markets increased the economic gain from hunting in the in the Udzungwa Mountains lying adjacent to Kilombero Valley.

In view of the visible characteristics of wealth as stipulated separately by chairmen of the three villages, the valley's infrastructural influences make households in the transitional villages relatively the wealthiest, followed by dryland and wetland households, respectively. Wetland and dryland villages are difficult to access being mostly situated at the end of extremely poor dirt roads that meander long distances off the transitional tract's main infrastructure, nor are they bare and/or driveable throughout the year. Furthermore, wet and dryland villages do not have electricity, or year round access to markets, acute medical services, nor safe drinking water. Moreover, middlemen traders pay less for their produce (Booth et al. 2008). Therefore one may expect the transitional villages to be most food secure during the low security season. However, while wetland villages during the low security season likely produce the least amount of consumption vs. sale food, and are simultaneous acutely isolated due to floods, dryland villages are cut off only from motorized transportation due to road damage caused by the rainy season's heavy precipitation and concurrently likely produce the greatest amount of consumption food. This is likely why upper-wealth dryland village households appear most equipped to best cope nutritionally on subsistence crops. Kadigi et al. (2007) uncovered a similar pattern between an opposite annual environmental stressor, i.e. drought, and the influence of biophysical gradient and infrastructure on household vulnerability. Here, wetland households were best equipped to cope with drought for approximately the same reasons as dryland households in this study are able to cope with flooding. In the vicinity of Peru's Pacaya-Samiria National Reserve, Takasaki et al. (2004) found that households who were distanced from good agricultural land or rich fishing waters were also to a higher degree dependent on gathering natural resources.

5.4 Population problem

The establishment of the main road and railway, and the availability of arable land in the Kilombero District, has resulted in a significant immigration to the valley from other portions of the country (Kangalawe & Liwenga 2004). In 1967 the district of Kilombero alone had a human population of 71,826 which has more than quadrupled to 322,779 in 2002 (Kangalawe & Liwenga 2004). During the last two decades the utilization of the wetlands for agriculture has amplified due to an augmenting population and the resultant necessity for greater food production (Kangalawe & Liwenga 2004). The increasing subsistence-based population of the Kilombero Valley up to now and into the future is very likely corresponding with increasing pressure on, as Schuyt & Brander (2004) puts it, "biodiversity, scientific, socio-cultural and other important wetland values as well as the integrity of ecological processes provided by the wetland". Kangalawe & Liwenga (2004) state that the Kilombero Valley's problems do not appear to be alarming in most places for the time being, however there are indications that conflicts among different resource users are rising due to lacking institutional frameworks governing resource utilization. Fishing conditions were easier in the past and the greatest changes occurred after the 1980s (Kangalawe & Liwenga 2005). Increased number of fishermen is also seen as resulting smaller catch at a greater effort (Kangalawe & Liwenga 2005). The Kilombero Valley Wildlife Project (Starkey et al. 1997) has found that widespread (illegal) hunting in the valley in addition to the increased amount of cattle has contributed to reduced wildlife populations, particularly of puku and buffalo. Local government officials in the Kilombero Valley feel that poaching had increased dramatically since 1994 based on the amount of confiscated animal derivatives (Haule et al. 2002).

6 Conclusions and implications for conservation

On a general level, the value of natural resources for consumption and income generation in the Kilombero Valley is negatively associated with food and purchasing power security. Based on the premise that higher valuation is synonymous with greater extraction levels, this study demonstrates that the intensity of natural resource extraction should be greatest during the low security season.

The major lesson learned from this study is that education, even on a slight scale, can inflict a major influence on the patterns of natural resource exploitation. Regarding the level of consumption and the importance of natural resources chiefly as a means of coping with the annual nadir in household security, Kilombero Valley households can be separated into two groups; those headed by an individual who hasn't completed the standard seven years of

primary-school, and those who have (but not gone further with their education). Within this small educational threshold, natural resources go from being a highly consumed important safety net, over to an apparently lesser consumed, but highly important economic livelihood base. Moreover, it can be assumed that the influence of education on natural resource utilization is far more wide-reaching than has been captured in this study.

Households headed by an individual who has not completed primary-school are the most likely of all to be heavily reliant on specific natural resources for their household's food and fuel needs, and to a lesser degree income generation, during the annual season when the valley's food and buying power security nadirs. This association is further enhanced if the wetland cultivation plots of these households are relatively small and if these households practice relatively low-tech farming methods, and if they reside in the transitional biophysical gradient regarding the seasonal importance of income generation.

Households headed by an individual who has completed, but not gone further than primary-school, place a high degree of value on their resources throughout the year irrespective of the valley's annual cycle of household security, especially for income generation. The importance of economically exploiting natural resources is likely further augmented if their household consists of a relatively low number of household dependents, a high number of potential providers, practice medium-tech farming methods, belong to the medium-wealth group, and reside in the transitional biophysical gradient.

The specific resources most strongly valued for coping with the annual household food deficit are all predominantly wetland derived; fish, bushmeat and wild vegetables. On the contrary, specific resources most strongly valued for coping with the purchasing power security nadir are derived from both wetland and dryland. However, irrespective of household security the economically important natural resources are, with the exception of fish, mainly dryland derived; poles, thatch, firewood, and charcoal. Otherwise, bushmeat (in particular buffalo, puku antelope, and hippopotamus) wild vegetables (consisting of a large variety), and firewood (in particular *Brachystegia spiciformis* & *Pericopsis angolensis*) are respectively most important for direct consumption during the low security season. Irrespective of security season, the sequence of most important resources for consumption is mirrored by the most to least recorded resources in this study. The most important natural resources for income generation during the low security season are charcoal (same species as for firewood), bushmeat, fish (in particular rufigi tilapia, catfish, and dogfish) and thatch (consisting of a large variety), respectively. However, the sequential importance for income generation among resources relative the number of species exploited and irrespective of security season is fish,

thatch, poles (*Pericopsis angolensis* & *Brachystegia spiciformis*) firewood, bushmeat, and charcoal respectively.

The potential ecological implications of these patterns in natural resource utilization are multiplied by the share in the population that these two main groups constitute. Considering the dominant relationship that households in the lower end of the Kilombero Valley's socio-economic and educational scales have with exploiting natural resources, especially during the annual household security nadir, it can thus be deduced that these households inflict the greatest pressure on the Kilombero Valley's natural resource base, with particularly high pressure on favoured species and wetland resources. Furthermore, these pressures will not wane with the constantly increasing population of the region.

In addition to current projects at hand, governmental and private conservation stakeholders in the Kilombero Valley will (based on the findings of this study) best strengthen the preservation of the Kilombero Valley ecosystem in the long run by successfully implementing three sequential measures. First and foremost, conservation investments will yield the greatest long-term returns if made in the fortification of educational opportunities internally in the region. Secondly, effective measures must be taken to decelerate the region's internal population growth. Hereunder, the influence of greater education, especially for females, will likely have a bonus effect (Sen 2008). Thirdly, the economic prospects and agricultural productivity of the valley must be augmented to even out the region's cyclical fluctuation of household security while lifting the lower socio-economic stratum out of subsistence livelihoods and dependence on natural resources for food and income generation. Also here the influence of greater education, especially for females (Sen 2008), will likely have a bonus effect inspiring higher levels of ambition and ingenuity of the rural population as well as open-mindedness to new ideas. This economical and agricultural productivity augmentation must be environmentally sound, and would do especially well for the region's conservation goals by not attracting further immigration from other areas of Tanzania. Considering the region's unique environment and international importance for biodiversity conservation, a great opportunity likely exists for further developing the region's currently limited tourism market.

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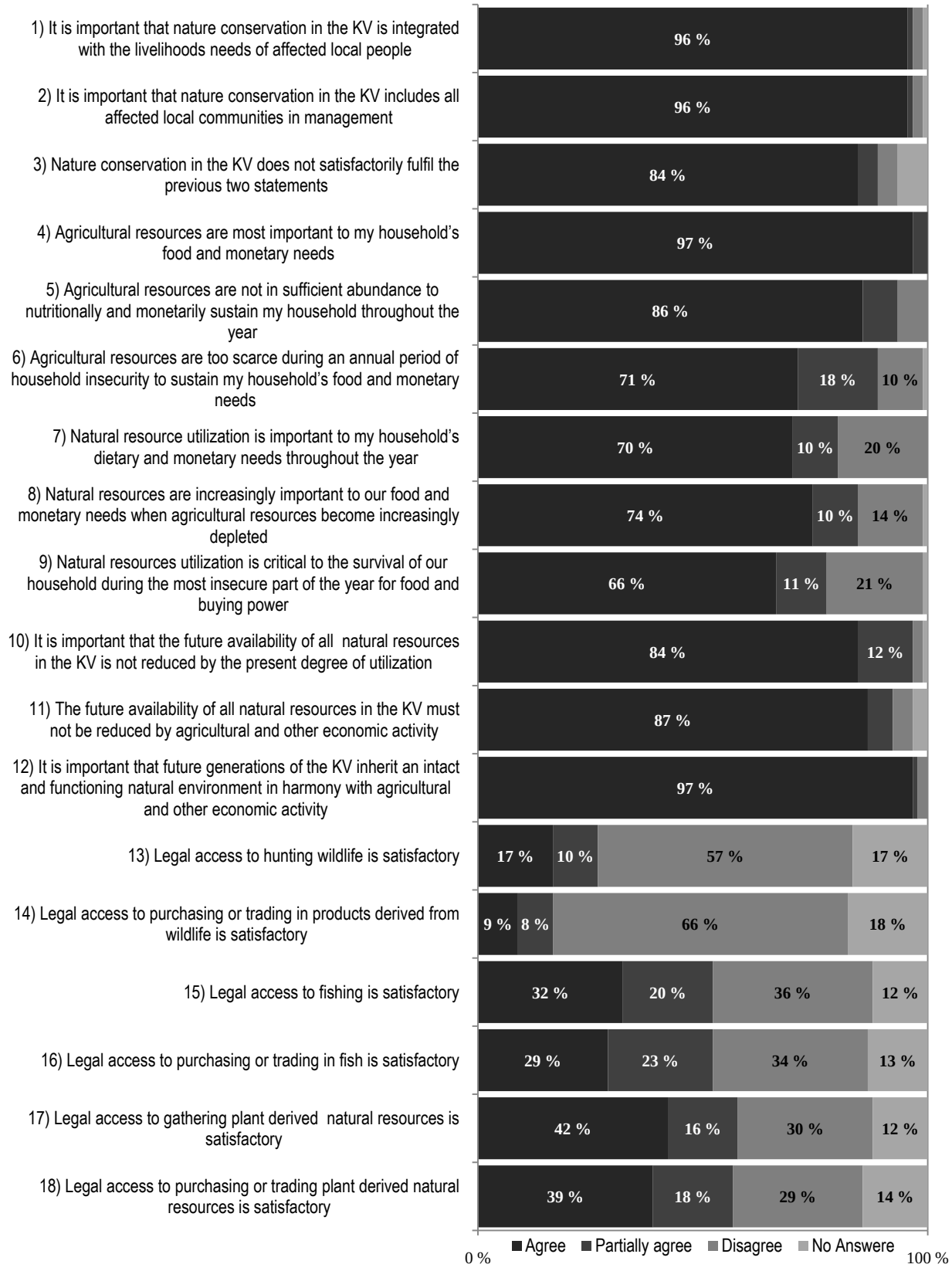
APPENDIX



Appendix 1 Rural household (n=90) opinion ratios of natural resource statements for the Kilombero Valley (KV). This data was not utilized in statistical analysis nor widely included in this thesis due to limitations on time and work load.