The Complexity of the Commons: Environmental Resource Demands in Rural Zimbabwe

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Abstract: The literature on the relationship between households and environmental change **-** commonly termed the poverty-environment relationship **-** is characterised by theoretical inadequacies and a lack of empirical verification. In this paper, we start by presenting a model which integrates a multiple-use environmental resource system within the standard agricultural household model. We demonstrate the theoretical importance of examining the way in which multifarious environmental goods interact with the household's other production and consumption decisions. Environmental goods are significantly differentiated in economic terms, so that environmental resources can be affected very differently by changes in an exogenous parameter such as income, prices, household structure, resource availability, technology and so on. It is this that endows the commons with its complexity: the range of environmental resources is wide and the set of possible responses by each resource to perturbations is large, so that characterising the poverty-environment relationship in terms of a single function, as is so often done, is wholly inadequate.

We then turn to empirical analysis using an analysis of cross-sectional demand functions for environmental goods, using a purpose-collected data set from 29 villages in Shindi Ward, Chivi District, south-eastern Zimbabwe. We find that the econometric results from these environmental demand regressions support the theoretical conclusions. Estimated income elasticities differ across goods and species, and there is clear evidence that other demand determinants such as species substitute and backstops, scarcity and household structure also affect different goods in different ways. We also examine the case study literature on rural households' resource use in Zimbabwe: this demonstrates that both environmental demands and environmental supplies are affected by a number of different factors. So we suggest that the commons is a complex place: environmental resource use and hence also environmental change will be driven by a multiplicity of factors, and these factors can differ quite considerably across different species and resources. Simplistic conceptions of the link between rural households and the environment will be quite wrong.

1. Introduction

The subject of this paper is the relationship between households and environmental change in rural Africa, what is commonly termed the poverty-environment relationship. Much has been written on this relationship, in part due to the ubiquitousness of rural poverty in Africa, in part due to rising concerns about the state of Africa's natural resources, and in part due to the role that rural households play in determining the state of natural resources. Despite this considerable literature, though, there is little consensus as to what the rural poverty-environment relationship really is. Indeed, it is quite common for diametrically opposed views to be expressed on the topic. For example, it is often argued that poverty is a cause of environmental degradation as it results in agents having high discount rates, so that as incomes fall there is a greater harvesting of renewable resources and hence a greater threat to these resources. By contrast, it is also held that affluence is a cause of environmental degradation through inducing rising resource demands and therefore greater environmental stress. These types of uncertainties and conflicts permeate the literature.

The argument of this paper is that these uncertainties in the literature reflect weaknesses on two fronts. First, there is the theoretical problem that the environment is usually assumed to be the provider of a single good. In fact, the relationship between rural households and the environment is most accurately characterised as one of multiple resource utilizations. Far from being the provider of a single good, natural resources offer rural households a range of goods, and these goods are quite strongly differentiated in economic terms. We argue that unless the way in which these multifarious goods interact with the household's other production and consumption decisions is explicitly modelled, and in particular unless attention is paid to the key point of resource differentiation, our conceptual understanding of the potential links between rural households and environmental resources will be highly limited if not downright misleading.

Second, there is the problem that the poverty-environment literature is marked by an absence of empirical verification of its main propositions. Take, for example, the question raised above of whether higher incomes improve or worsen environmental resources. In part - the part that connects income to resource demands - this is a question of the sign and size of the income elasticity for environmental goods, but nowhere are estimates provided for these elasticities. Two recent works which discuss extensively the relationship between poverty and the environment (Dasgupta 1993 ch.10, Durappiah 1996) exemplify this problem. Although both contain extremely interesting reviews of the literature and suggestions about the connections between the poor and environmental resources, the data on which their assertions are made is scanty.[1] This lacuna is understandable, and reflects a lack of data sets which genuinely integrate environmental resource use and economic decisions at the household level. But the consequence of this lacuna is that assertions in the literature are seldom subjected to proper empirical testing, with vagueness the inevitable result.

This paper tackles both these problems, using a purpose-collected data set from 29 villages in Shindi Ward, Chivi District, south-eastern Zimbabwe (for details on this see Appendix I). One of the central contentions of the paper is that in characterising the poverty-environment relationship, it is essential to focus on the environment as the provider of multiple resource utilizations. Section 2 therefore presents evidence on the extent of multiple resource utilizations found in the research area, while section 3 develops a theoretical model of multiple environmental resource utilizations by rural households. One

[1] Indeed, Dasgupta reflects this concern: "There has been a parallel weakness in academic economics on matters concerning the environmental resource base of rural production. The dependence of poor countries on their natural resources, such as soil and its cover, water, forests, animals and fisheries, should have been self-evident. Nevertheless if there has been a single thread running through 40 years of investigation into the poverty of poor countries, it has been the neglect of this base." (p273).

of the main points stressed in this section is that it is possible - and indeed rather likely - that environmental goods are significantly differentiated in economic terms, so that environmental resources can be affected very differently by changes in an exogenous parameter such as income, prices, household structure, resource availability, technology and so on. It is this that endows the commons with its complexity: the range of environmental resources is wide and the set of possible responses by each resource to perturbations is large, such that it would be folly to characterise the poverty-environment relationship in terms of a single function, as is so often done. In sections 4 and 5 we turn to empirical verification of these theoretical conjectures. Thus in section 4 we provide econometric evidence to support the claim of resource differentiation, and hence of commons complexity, via the analysis of cross-sectional demand functions for environmental goods, while in section 5 we draw on the extensive case study literature of Zimbabwean rural households' natural resource use to provide further empirical support. Section 6 concludes.

2. Multiple Environmental Resource Utilizations - The Evidence

In this section, we briefly present evidence on the range of environmental resource utilisations found in the research area, Shindi Ward, and some summary data on the importance that these resources have for Shindi households. First, though, an important issue for the analysis is to distinguish between "environmental" and "non-environmental" (or "wild" and "non-wild") resource utilizations in Shindi. The definition used here is that to qualify as an environmental or wild resource utilization, the resource must be freely provided by natural processes. Note that this definition us not the same as classifying goods according to ownership criteria ie. private or non-private. In part, this is because tenure and ownership are less clearly delineated in a rural African setting than in a Western economy: homesteads and fields are not owned in a legal sense by the households who use them, but the produce thereof is obviously not "wild." The main purpose of this emphasis on free provision is to rule out cases where the households expend labour on resource management, and rule in cases where they do not. Thus, crops in fields are clearly not wild, as they are intensively managed, whereas certain leaf vegetables grow spontaneously in fields without planting or weeding, and are considered wild. Likewise, exotic fruit trees in Shindi are planted at homesteads and tended carefully, whereas indigenous trees, also found at homesteads, are not: they are classified as non-wild and wild accordingly. Nonetheless, although under this definition it is true that some environmental resources do come from private lands (basically homesteads and fields), in fact the great majority of them derive from the commons. So it is reasonable to claim that the analysis of environmental resources contained in this paper is also an analysis of the commons.

Using this definition, table 2.1 presents a taxonomy of environmental utilizations for Shindi, with an indication given of the number of different species used in each case, and the economic role(s) each utilization plays (a long list of environmental utilizations is presented in Appendix II). Two features of this table are striking. The first is the range of resources used and, in some cases, the range of species used per utilization. Environmental resources offer rural households a wide variety of goods, including a large number of foods and non-food goods; a host of different uses for wood (construction, fuel, agricultural implements, furniture, household implements), barks, grasses, rushes, and reeds; natural fertilisers (termitaria and leaf litter); and a range of indirect values (shade, windbreaks, soil erosion protection, spiritual locations), and for many of these uses a plethora of different species can be used. The second salient point is the variety of economic functions that these resources offer Shindi households. As table 2.1 show, environmental resources offer rural households consumption goods, consumer durables, production inputs, inputs into productive capital, and even assets. The relationship between Shindi households and the environment is therefore characterised by multiple resources and

Table 2.1: A Short List of Environmental Resource Utilizations in Shindi

Environmental Resource Utilization	Number of Species Useable Per Utilization [1]	Economic Characteristics of Resource Utilization						
		Consumption good	Durable good	Agricul-tural input	Other production input	Input into asset formation	Indirect or non-use value	Output (ie. traded) good
1. Wild Foods								
Fruits	47	✓			✓			✓
Insects	15	✓						✓
Fish	7	✓						✓
Large wild animals	16	✓						✓
Mice	u/k	✓						✓
Honey	n.a.	✓						✓
Nuts	2	✓						
Vegetables	40	✓						✓
Mushrooms	12	✓						✓
Birds	8	✓						✓
Liquids	3	✓						
Wild fruit wine	1	✓						✓
Roasted fruits	1	✓						✓
Wild fruit porridge	5	✓						
Wild fruit butter/oil	2	✓						
Roots/bulbs/leaves	8	✓						
Wild soda	4	✓						
Wild fruit jam	1	✓						
2. Non-Food Direct Uses								
Medicines [2]	46	✓						✓
Soap and shampoo	2	✓						
Glues and lime	8	✓						
Tooth-cleaning twigs	8	✓						
Insect repellant	1	✓						
Fish poisons	7				✓			
Other uses	8	✓						
3. Wood Uses								
Firewood	large	✓			✓	✓		✓
Construction wood:								
- Hut walls	22					✓		✓
- Hut roof beams	28					✓		✓
- Hut cross beams	15					✓		✓
- Granary walls	22			✓		✓		✓
- Granary floor	26			✓		✓		✓
- Granary roof beams	18			✓		✓		✓
- Granary cross beams	4			✓		✓		✓
- Crop storage hut	19			✓		✓		✓
- Cattle kraal	22			✓		✓		✓
- Goat hut	5			✓		✓		
- Chicken pens	17			✓				✓
- Stover store	6			✓				
- Brushwood fencing	20			✓				
- Fencing poles	16			✓		✓		✓
- Live fencing	2			✓				
- Doors and door-frames	14					✓		✓
Scotch cart frames	3		✓	✓	✓			✓
Yokes and skeys	18		✓	✓				✓
Agr. implement handles	25		✓	✓				✓
Household furniture	2		✓					✓
Stools	17		✓					✓

Environmental Resource Utilization	Number of Species Useable Per Utilization [1]	Economic Characteristics of Resource Utilization						
		Consumption good	Durable good	Agricul-tural input	Other production input	Input into asset formation	Indirect or non-use value	Output (ie. traded) good
3. Wood Uses (cont.)								
Plates	5		✓					✓
Cook sticks	23	✓						✓
Stirring spoons	18	✓						✓
Mortars	6		✓					✓
Pestles	15		✓					✓
Knobkerries	5		✓					✓
Carvings	3	✓						✓
Drums	5		✓					✓
4. Other Tree/Woodland Uses								
Leaf litter	v. large			✓				
Livestock fodder/browse	v. large			✓		✓		
Shade at home	v. large						✓	
Windbreak at home	v. large						✓	
Rain-making rituals	5						✓	
Seasonal indicators	5						✓	
Children's play	10	✓						
Soil erosion protection	all			✓			✓	
Watershed protection	all			✓			✓	
5. Uses of Bark								
Fishing canoes	1				✓			
Ropes, fibres and string	21	✓			✓	✓		✓
Hunting nets	2				✓			
African snuff	1	✓						✓
Dyes	8				✓			
Pot-firing barks	6				✓			
6. Direct Uses of Grass, Reeds, Rushes etc.								
Thatching grass	13				✓	✓		✓
House brooms	4	✓						
Yard brooms	2	✓						
Mouse-traps	1				✓			
7. Input Uses of Grass, Reeds, Rushes etc.								
Woven hats	u/k	✓						✓
Woven mats	23	✓						✓
Baskets (multifarious)	u/k	✓		✓	✓			✓
8. Uses of Earth								
Termitaria	n.a.			✓				✓
Pottery	n.a.	✓	✓		✓			✓
Hut decoration	n.a.	✓						
9. Other								
Gold	n.a.							✓

Notes
1. The number of species which households either used in 1993/94 or indicated as useable. For a full species listing, see appendix II.
2. The number of species used as medicines does not include the large number of species used by traditional healers (n'anga), only those prepared and used by the sample households themselves.

Table 2.2 - 1993/94 Shindi Total Household Income Per Adj. Aeu By Quintile and By Income Source (1)

	Household Quintile					
	Lowest 20%	20% to 40%	40% to 60%	60% to 80%	Top 20%	All Households
Crop Income	335	930	861	1,030	3,779	6,935
Livestock Income	386	312	576	721	1,363	3,359
Unskilled Labour Income	658	696	1,292	639	992	4,277
Skilled Labour Income (Teaching)	0	520	0	0	6,015	6,534
Crafts and Small-Scale Enterprises	120	751	621	1,579	3,101	6,173
Remittances	919	2,832	3,333	8,146	13,175	28,405
Miscellaneous Cash Income	0	0	106	82	156	344
Total Cash Income (Excl Env Cash Income)	**2,418**	**6,041**	**6,789**	**12,197**	**28,580**	**56,026**
Net Private Gifts/Transfers of Cash	-121	-202	603	1,156	291	1,726
Net Private Gifts/Transfers of Food or Seed	-20	-484	-1	-181	-460	-1,145
Net Private Gifts/Transfers of Env. Goods	6	2	55	11	3	78
Net Private Gifts/Transfers of Other Goods	-31	-569	194	-21	1,845	1,418
Govt Gifts/Transfers of Cash	85	37	27	30	290	470
Govt Gifts/Transfers of Agr. Inputs	285	457	295	554	526	2,118
Total Net Gifts/Transfers	**204**	**-758**	**1,174**	**1,549**	**2,496**	**4,664**
Consumption of Own Produced Goods	5,682	7,895	8,992	10,777	16,766	50,111
Input Use of Own Produced Goods	1,289	2,130	1,867	1,765	4,092	11,143
Total Own Produced Goods	**6,971**	**10,025**	**10,859**	**12,541**	**20,858**	**61,254**
Gold Panning	1,300	1,246	2,337	2,694	4,736	12,313
Natural Habitat Utilization Cash Income	708	891	1,360	2,748	1,918	7,625
Consumption of Own Collected Wild Foods	1,334	1,668	1,919	2,183	2,453	9,557
Consumption of Own Collected Firewood	1,430	1,991	2,239	2,498	3,679	11,836
Consumption of Own Collected Wild Goods	146	187	203	192	224	952
Use of Environmental Goods for Housing	574	437	1,019	975	1,471	4,476
Use of Environmental Goods for Fertiliser	130	166	190	150	244	879
Livestock Browse/Graze of Environmental Resources	599	1,722	1,884	2,652	3,328	10,186
Total Environmental Income	**6,220**	**8,308**	**11,151**	**14,092**	**18,053**	**57,825**
Total Income	**15,813**	**23,616**	**29,974**	**40,380**	**69,986**	**179,769**
Summary Data						
Cash Income (Excl. NHU) plus Net Gifts	2,622	5,284	7,963	13,746	31,075	60,690
Ditto Plus Own Production	9,593	15,309	18,823	26,288	51,933	121,944
Total Income Excl. Livestock	15,214	21,894	28,090	37,727	66,658	169,583
Quintile Share of Total Shindi Income	8.8	13.1	16.7	22.5	38.9	100.0

Notes
1. All data are in 1993/94 Z$.

Table 2.3 - 1993/94 Shindi Household Income Per Adj. Aeu Shares By Quintile and By Income Source (1)

	Household Quintile					
	Lowest 20%	20% to 40%	40% to 60%	60% to 80%	Top 20%	All Households
Crop Income	2.12	3.99	2.80	2.60	5.51	3.42
Livestock Income	2.51	1.31	1.89	1.85	1.75	1.86
Unskilled Labour Income	4.16	2.99	4.30	1.60	1.58	2.91
Skilled Labour Income (Teaching)	0.00	1.98	0.00	0.00	4.09	1.23
Crafts and Small-Scale Enterprises	0.71	3.21	2.03	4.02	5.10	3.03
Remittances	5.28	11.90	11.26	20.09	18.06	13.36
Miscellaneous Cash Income	0.00	0.00	0.34	0.18	0.25	0.16
Total Cash Income (Excl Env Cash Income)	**14.78**	**25.37**	**22.62**	**30.34**	**36.35**	**25.96**
Net Private Gifts/Transfers of Cash	-0.89	-0.68	2.01	2.64	0.55	0.73
Net Private Gifts/Transfers of Food or Seed	-0.13	-2.19	0.01	-0.38	-0.58	-0.66
Net Private Gifts/Transfers of Env. Goods	0.04	0.01	0.19	0.03	0.00	0.05
Net Private Gifts/Transfers of Other Goods	0.00	-2.30	0.66	-0.02	1.21	-0.09
Govt Gifts/Transfers of Cash	0.56	0.16	0.10	0.08	0.46	0.27
Govt Gifts/Transfers of Agr. Inputs	1.78	1.97	0.97	1.29	0.86	1.37
Total Net Gifts/Transfers	**1.35**	**-3.04**	**3.94**	**3.63**	**2.51**	**1.67**
Consumption of Own Produced Goods	35.78	33.22	30.10	26.60	25.58	30.23
Input Use of Own Produced Goods	8.36	9.18	6.26	4.40	6.53	6.94
Total Own Produced Goods	**44.14**	**42.40**	**36.36**	**31.00**	**32.11**	**37.17**
Gold Panning	7.86	5.40	7.71	6.86	8.36	7.23
Environmental Resource Utilization Cash Income	4.99	3.75	4.47	6.80	3.12	4.62
Consumption of Own Collected Wild Foods	8.59	7.08	6.51	5.47	3.84	6.29
Consumption of Own Collected Firewood	9.08	8.45	7.48	6.22	5.57	7.35
Consumption of Own Collected Wild Goods	0.95	0.80	0.69	0.49	0.34	0.65
Use of Environmental Goods for Housing	3.72	1.76	3.36	2.46	2.22	2.70
Use of Environmental Goods for Fertiliser	0.77	0.73	0.65	0.37	0.36	0.57
Livestock Browse/Graze of Environmental Resources	3.78	7.30	6.22	6.36	5.23	5.79
Total Environmental Income	**39.74**	**37.27**	**37.09**	**35.03**	**29.04**	**35.20**
Total Income	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Summary Data						
Quintile Share of Total Shindi Income	8.8	13.1	16.7	22.5	38.9	100.0
Quintile Mean Income (Z$ per adj. aeu)	377	549	714	939	1,628	844
Quintile Median Income (Z$ per adj. aeu)	386	558	721	911	1,369	721
All Cash Income Share of Total Income	27.30	34.00	36.91	46.72	48.84	37.81

Notes

1. In this table we have calculated average income shares as the mean of the individual household's budget shres, rather than the simpler procedure of calculating the aggregate share of the income subcomponent in total income. This reduces the impact of extreme individual household values on the average budget share value.

multiple uses: not the type of system likely to be well-characterised by the standard theoretical or conceptual models of the poverty-environment relationship.[2]

Turning to the value of these resources to rural households, tables 2.2 and 2.3 summarise the contribution that these resources make to Shindi household welfare by expressing the value of household income from environmental resources as a percentage of total household income.[3] As an average across all households, roughly 35 percent of total income is derived from these freely-provided environmental goods: this figure is substantially greater than the value of cash income (with environmental cash income excluded) and roughly equal to the value of own production. Given that many of these resource values are not picked up in standard questionnaires, and given that Shindi is by no means resource-abundant, this points to a reasonably-sized hole in standard estimates of rural welfare. Examination of the income shares across quintiles show that poorer households depend more heavily on these resources: nearly 40 percent of the total income of the lowest quintile is accounted for by environmental resources, far more than these households derive from non-environmental cash income. Indeed, for the lowest four quintiles the share of total income accounted for by environmental resources is consistently greater than 35 percent. In brief, then, environmental resources are multifarious and they are significant.

3. A Model of Multiple Environmental Resource Utilisations by Rural Households

In this section, we present a model of resource use by rural households which attempts to capture in a simple way the existence and use of multiple environmental resources as charted in section 2. The structure of the model could best be described as an environmentally-augmented agricultural household model, and thus many of the features of the model will be similar to those in the agricultural household literature. In particular, the household is treated as being simultaneously both a consumption unit and a production unit. The chief difference here, though, is that environmental goods are incorporated into household decision-making through the introduction of an environmental production function, with adjustment of the relevant constraints.

.1 The Typical Agricultural Household Model

The usual method of characterising the rural household's decision-making problem is as follows:[4]

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[2] Neither Shindi nor rural Zimbabwe are unusual in having multiple environmental resource utilisations, although it is only recently that researchers have begun to chart the multifarious connections between natural resources and rural households. However, these have now been established for a variety of rural communities across Africa. See, for example, FAO 1985, Davies and Richards 1991, Falconer and Arnold 1991, Arnold 1992 and Parkin and Croll 1992.

[3] The term income is used here in its broadest sense to include both cash and non-cash transactions. Total income therefore comprises net cash income, all net gifts, the value of the consumption of goods produced by the household, and the value of the consumption of goods freely provided by natural resources. All household income figures have been made welfare-comparable by adjusting for: (i) time members spent away from the household; (ii) adult equivalent units; and (iii) economies of scale in houseold production and consumption. Thus when we refer to income, we mean income per adjusted adult equivalent unit (aeu). Detailed explanation of the derivation of these figures is contained in Cavendish (1997). Tables 2.2 and 2.3 present the household budget data at a fairly aggregated level: however they are discussed in much more detail also in Cavendish (1997).

[4] For a comprehensive analysis of the standard agricultural household model, see McKay and Taffesse (1994). The presentation here follows their's in many respects, and uses similar notation.

$$
\begin{aligned}
&\max \quad U = U(x_a, l_l, x_m) \\
&\text{w.r.t.} \quad \{x_a, l_l, x_m, q_a, L, v_m\} \\
&\text{s.t.} \quad p_m x_m = p_a(q_a - x_a) + E + p_l(L - l_a) - p_v v_m \\
&T = l_l + l_a \\
&G = G(q_a, L, v_m, K)
\end{aligned}
\tag{1}
$$

where x_i = household consumption of good i;
q_i = household production of good i;
l_i = allocation of household labour in production of good i;
v_i = household use of intermediate input i;
p_i = the price of good i (except p_v which is the price of good v_m);
E = exogenous household income;
L = total labour inputs into agricultural production;
K = a vector of productive assets (eg quality-weighted land size, large livestock, agricultural equipment etc.);
T = the household's time endowment;
i = {agricultural crops, leisure, "imported"/purchased goods}.

Standard assumptions are made concerning preferences and technology such that the utility function is twice-differentiable and quasi-concave, and the production function is twice-differentiable and convex. All markets are assumed to exist and clear, and in particular household and hired labour are assumed to be perfect substitutes in production. The results of these assumptions are well-known: first, that the programme characterised in (1) has a unique solution, second that the programme can be solved recursively, so that production decisions are separable from consumption decisions.

3.2 Incorporating Environmental Resources

A discussion of the problem

Note that the programme in (1) is a static one (or more formally, it assumes strict intertemporal separability), so that there is no role for savings or any explanation of the evolution of household assets over time. Furthermore, there is no role for risk in this model: production and consumption are known with certainty once the household has decided on its allocation of inputs. Of course, this approach is primarily taken for mathematical reasons: solving a fully dynamic, risk-augmented version of the standard agricultural household model would be far from easy, and even extension to two periods has needed artificial or simplifying assumptions (as in Iqbal 1986). The problem lies in the fact that, if it were to be rewritten as a dynamic programme with an asset equation added and uncertainty incorporated through some distributional assumption for the production function, (1) would simply have too many "degrees of freedom" such that closed form solutions would be difficult to derive. (In a dynamic programming context, this is the "curse of dimensionality").[5]

[5] This problem is only partially solved in Deaton (1991) which conducts a simulation analysis of consumption-smoothing and asset accumulation for liquidity-constrained consumers in the presence of uncertainty, but which derives results only at the price of making income an exogenous, stochastic process.

This lack of dynamics poses a substantial problem for the incorporation of environmental resources into the analysis. Overwhelmingly, the environmental utilizations presented in section 2 of this paper are derived from renewable resources, and these would appear to have an inalienably dynamic component. Thus, renewable resources are usually modelled as having a resource stock *x* that evolves according to a first-order difference equation, $dx/dt = F(x,r,N)$, where *N* is a measure of the environment's carrying capacity, and *r* is the instantaneous growth rate of the resource. *F*(.), then, is the biological growth function and, naturally enough, many different functional forms have been suggested as being appropriate for different species (see Wilen 1985).[6] Economic modelling then proceeds by adding a harvest function, $h = h(x,t)$, with various assumptions made about the form of *h*, so that the species stock evolves according to the rule $dx/dt = F(.) - h(.)$.

Following this line of thought, we may consider how standard renewable resource theory might be incorporated into the agricultural household model The first point to note is that the peasant systems under review are characterised by multiple resource utilisations, and that these resources are unlikely to have identical biological properties. For example, regrowth rates are generically higher for fish as opposed to trees, or even other wild animals. Likewise, individual tree species differ markedly in autoecological factors such as seed production and dispersal, seed survival, shooting rates and sapling growth rates (for miombo woodland species, see Chidumayo 1993). For an accurate theory, therefore, we would need to include multiple species equations so that $dx_i/dt = F_i(x_i,r_i,N_i)$ ie. even the growth functions may differ across species. Second, these species do not exist in isolation from each other, but rather are interconnected via the ecological system. Use (or perturbation) of one species affects not just the growth of that species, but often many others besides in a manner conditional on the biome in which these interactions take place. For example, at the broad level the savanna can be thought of as a system in which grass and tree species as a whole compete for available nutrients and moisture, with fire as a major perturbing factor. At the individual level, species can be thought of as attempting to maximise reproductive success given the characteristics of the environment around them. Consideration of these factors would suggest an ecosystem approach, perhaps through specification of a set of species equations of the form

$$dx_i/dt = F_i(x_i,r_i,N_i,x_j) \ , \quad i \neq j \qquad (2)$$

whereby the way in which species x_j enters the *i*th species' growth equation determines the type of biological interaction between them eg. interspecies competition, symbiosis, predator-prey, parasitism and so on.

A model of peasant environmental resource use which integrated economic and environmental considerations in an appropriate manner, then, would recast (1) in a dynamic framework through the introduction of a first-order difference equation for assets, allow some consumption goods and production inputs to be derived from the harvesting of renewable resources, and link these environmental goods to a system of resource supply equations such as (2). Such a model, while properly-specified, would also sadly be completely intractable. As we noted above, dynamic versions of the household model alone are tricky to solve. Likewise, systems of equations such as (2) must retain a high degree of simplicity if closed-form solutions are to be found. For example, simple two-species models such as the

[6] A standard form for *F*(.) is the logistic growth function, so that $dx/dt = rx(1 - x/N)$.

Lotka-Volterra predator-prey model[7] or Gauss's model of interspecific competition[8] generate a multiplicity of equilibria or even lack steady-states (Clark 1990). In consequence, the general economic-environment model proposed above cannot be implemented. However, even stripped down versions, for example with only one asset and one environmental resource, would present mathematical problems of considerable complexity, at the same time as ignoring one of the fundamental characteristics of the system, namely that of multiple resource utilisations.

The solution adopted

Faced with these difficulties, I have chosen to proceed by ignoring the dynamic aspects of the environmental resources in question, and extend the agricultural household model by using a (static) environmental production function *W*(.) similar to *G*(.) in (1). In this approach, environmental resources are treated as equivalent to a "bequest" which nature endows and which rural households are free to collect if they so desire. Since the approach is static, there are no feedback effects from consumption or use of the resource to resource supply, as there were in (2). The rural household's decision then concerns how much of the resource to collect via allocation of its labour, so that labour is the only variable input into environmental production.[9] However, environmental resources are provided only at certain locations (for example in woodlands, riverine areas or on field borders), hence the costs of collection increase the further is the household from the (spatially-fixed) supply of the environmental resource in question. Production costs are therefore increasing in distance *D*, as the household has to allocate more labour to collection *ceteris paribus*. Collection costs are also decreasing in the quality of the resource, since conditional on the distance travelled collection costs will be lower if the resource is more abundant. This is particularly pertinent in the case of woodlands: households may choose to travel to a more distant woodland as the availability of wood is greater there. So it is best to think of *D* as the quality-adjusted (or resource abundance-adjusted) distance from the household to the environmental resource in question.

With these points in mind, the environmental production function can be specified as follows:

$$W = W(q_w, q_z, l_w, D) \tag{3}$$

where q_w = household production of the environmentally-derived consumption good;
q_z = household production of the environmentally-derived production input;
l_w = allocation of household labour to collection of both environmental goods;

This function embodies two further simplifications. The first is that environmental goods are characterised as either consumption goods or production inputs: I am ignoring, therefore, other direct uses of environmental goods, for example as inputs into consumer durables (housing, fencing) or as

[7] Given by $(dx_1/dt = r_1x_1 - \alpha x_1x_2,\ dx_2/dt = -r_2x_2 + \beta x_1x_2)$.

[8] Given by $(dx_i/dt = F(x_i, r_i, N_i) + \alpha_i x_i x_j,\ i \neq j,\ j = 1,2)$.

[9] Although all environmental resources are collected using household labour, for some resources households can use labour-augmenting technologies. For example, in the case of wood collection some households transport the wood using scotch carts (ngoro) rather than headloading, and cut the wood using an axe rather than picking up dead wood or breaking off branches with their bare hands. For thatching grass also, transportation can be done by cart rather than by head. These collection technologies can make a considerable difference to unit collection costs, especially when the resources are heavy, as in the case of tree trunks used for hut floors, walls, fencing and as slow-burning fuel when baking bricks. For analytical convenience I ignore these technology effects here, but they are addressed later when it comes to the econometric estimation.

inputs into asset formation (livestock browse and graze), and any indirect uses of environmental goods, for example soil erosion protection, watershed protection, micro-climatic regulation, shade and so on. Second, q_w and q_z are defined in (3) as scalars, whereas in reality they are vectors of goods. These simplifications are made both for analytical convenience and to fit environmental goods into a static framework. For example, the value of indirect uses of environmental resources is almost always related to the stock of the resource, since these indirect uses are generally non-consumptive. Including these uses, then, would require some assumption about the evolution of the stock, precisely the assumption we are trying to avoid.

Justification
Given all the caveats listed above, it may be felt that the static formulation of environmental goods production in (3), whereby resource use is divorced from the dynamics of the resource stock, is so unrealistic as to be at best meaningless and at worst misleading. However, in fact there are three justifications for this formulation that go beyond the question of sheer tractability, although this is as we have seen a non-trivial issue. The first is that there are some resources which are sufficiently abundant that human use, although in principle damaging to the resource stock, in practice has a negligible impact, so that the chief determinants of the harvest level are the returns to resource use and the labour costs of collection, with zero impact of use via stock effects on collection costs. There are a number of cases of this type amongst the resource utilizations listed in section 2. For example, although potters can use only specific soil types in making their various pots, namely wettish clay soils which are found in around vleis and riverine areas, these are sufficiently abundant that pottery does not in practice reduce the level of resource stocks. Likewise, use of termitaria for fertiliser has little impact on resource availability, not just because the number of termite mounds is large, but also because, once used, termite mounds are rebuilt in a couple of years.

The second justification is that there are some environmental utilisations which by their nature have either little or no impact on resource stocks. Canonical here would be the consumption of wild fruits and wild fruit produce. Human consumption/use of wild fruits has few deleterious impacts on the tree species concerned,[10] and indeed may be mildly beneficial by acting as a seed dispersal agent. So in this case the supply of resources is limited only by the extent of production, or nature's bounty. Demand pressures may exhaust the resource supply, but they will not affect the resource stock. In such a case, (3) will be an adequate representation. Other examples where harvesting by its nature does not affect the resource stock are thatching grass, the use of leaf litter for fertiliser, the use of barks (where practised moderately), and the collection of firewood when the wood is collected dead (the overwhelming majority of cases in Shindi).

The third, more general justification is that the bulk of the environmental goods in Shindi are supplied under conditions of effective open access. Certainly, some rules exist at the species level which moderate demands on commons resources, and some environmental goods (for example, some wild vegetables and some thatching grass) are collected from fields which are effectively privately-managed. However, in general households are free to collect resources from wherever they wish. The implications of open access for the behaviour of resource harvesters is well-known: individual harvesters will act as if they had an infinite discount rate, thereby ignoring the stock effect of their harvesting decisions. At the aggregate level a stock externality exists, which is the source of the economic inefficiency of open access, but at the household level agents take decisions as if they were facing a purely static resource allocation problem. The consequence is that resource harvesting becomes solely a function of harvesting costs and (static) resource abundance, and this is precisely the formulation adopted in (3). Thus,

[10] The only deleterious impacts come from children harvesting fruits early by hurling sticks and stones at the trees to induce premature fruit fall, and adults tearing branches off favoured fruit trees for consumption while walking around the area. However, the damage to any particular tree from these activities is small.

although the environmental production function is indeed a simplification, it is not without justification for those cases either where resources are super-abundant, where resource use does not affect the resource stock, or where resources are open access. These conditions characterise a large number of the environmental resource utilisations under review.[11]

Environmental markets

As is the case for agricultural goods, production of environmental goods (q_w, q_z) does not necessarily equal consumption (x_w) or use (v_z) of those goods: in other words, markets exist in which households can buy and sell both the environmental consumption good and the environmental production input. These are traded at market-clearing prices p_w and p_z, so that net demands/supplies of these goods are $p_w(q_w - x_w)$ and $p_z(q_z - v_z)$ respectively. Thus, to consume or use a good, the household does not necessarily have to collect it: if the household's marginal product of labour in non-collection activities is sufficiently high to make collection unprofitable, the household can simply buy in the environmental goods in desires. Similarly, the fact that a household collects a good does not mandate its use: the household can sell all its collected quantity at prevailing market prices. Indeed, this is exactly what gold panning households do. Finally, as for agricultural goods, the fact that households both collect and consume environmental goods is not necessarily a sign of market failure, meremy a consequence of the joint production/consumption nature of the rural household.

Is the assumption of environmental markets tenable? As we will see, one reason for assuming complete and clearing environmental goods markets is analytic convenience: the price vector remains parametric thus making both theoretical derivation generally, and econometric implementation of commodity demands in particular, much simpler. However, also pertinent here is the finding in Cavendish (1997: 62-68) concerning the valuation of environmental goods. There it was noted that for a large number of environmental goods, either local trading was reasonably common, sufficiently so that they effectively had a local market, or local trading was thin but Shindi-wide prices for environmental goods were recognised and quoted. So the assumption of environmental markets does not severely violate the reality of the economic system in the research area.

The full model of peasant households' environmental resource use

Having defined and justified the environmental production function, it remains to make certain other minor adjustment to the model in (1). First, the utility function now includes an argument in the consumption of environmental goods, x_w. Second, the agricultural production function is expanded to include two variable inputs, one purchased, v_m, and one collected free from environmental resources, v_z. No restriction is placed on the substitutability or complementarity of these inputs, since in principle any pattern of cross-price elasticities is possible. For example, if v_m were seed and v_z natural fertiliser, we would expect a pattern of complementarity, while if v_m were commercial fertiliser we would expect a pattern of substitutability instead. Finally, the time constraint is adjusted to reflect the fact that the household can now allocate labour to leisure (l_l), agriculture (l_a) and collection of environmental goods (l_w).

The final model, then, is:

[11] We can also justify the static formulation of the environmental production function on the practical grounds that the empirical analysis of section 4 is based on a cross-sectional data set only. Even if feedback effects from resource use $\{q_w, q_z\}$ to resource abundance D were incorporated in the theoretical model, in practice we would expect such feedbacks to have little impact on household choices over a period as short as a year. Thus, not only will the household's actions have little impact on aggregate resource change - the open access problem - but also the changes in resource abundance during the data collection period were also limited, implying very modest effects on household choices (such as environmental demand functions) conditioned on D.

$$
\begin{aligned}
&\max \quad U = U(x_a, l_l, x_m, x_w) \\
&\text{w.r.t.} \quad \{x_a, l_l, x_m, x_w, q_a, L, v_m, v_z, q_w, q_z, l_w\} \\
&\text{s.t.} \quad p_m x_m = p_a(q_a - x_a) + E + p_w(q_w - x_w) + p_l(L - l_a) - p_v v_m + p_z(q_z - v_z) \\
&T = l_l + l_a + l_w \\
&G = G(q_a, L, v_m, v_z, K) \\
&W = W(q_w, q_z, l_w, D)
\end{aligned}
\tag{4}
$$

This model can be solved in the same way as the standard agricultural household model (Strauss 1986). We can substitute the time constraint into the budget constraint to obtain the full income constraint, and form the Lagrangean accordingly with respect to the multipliers $\{\lambda_1, \lambda_2, \lambda_3\}$. First-order conditions for this maximisation problem are then:

$$
\begin{aligned}
&U_i - \lambda_1 p_i = 0, \quad i = \{a, l, m, w\} \\
&p_l T + (p_a q_a + p_w q_w + p_z q_z - p_l L - p_v v_m - p_z v_z - p_l l_w) + E = p_a x_a + p_w x_w + p_l l_l + p_m x_m \\
&p_j + \mu G_j = 0, \quad j = \{a, l, v, z\} \\
&G(q_a, L, v_m, v_z, K) = 0 \\
&p_h + \rho W_h = 0, \quad h = \{w, z, l\} \\
&W(q_w, q_z, l_w, D) = 0
\end{aligned}
\tag{5}
$$

where $\mu = \lambda_2/\lambda_1$ and $\rho = \lambda_3/\lambda_1$. Total differentiation of this system of equations gives:

$$
\begin{bmatrix} U & 0 & 0 \\ 0 & G & 0 \\ 0 & 0 & W \end{bmatrix} . \tilde{d} = \tilde{b}
\tag{6}
$$

where

$$
U = \begin{bmatrix} U_{aa} & U_{al} & U_{am} & U_{aw} & -p_a \\ U_{la} & U_{ll} & U_{lm} & U_{lw} & -p_l \\ U_{ma} & U_{ml} & U_{mm} & U_{mw} & -p_m \\ U_{wa} & U_{wl} & U_{lm} & U_{lw} & -p_w \\ -p_a & -p_l & -p_m & -p_w & 0 \end{bmatrix}, \quad
G = \begin{bmatrix} \mu G_{aa} & \mu G_{aL} & \mu G_{av} & \mu G_{az} & G_a \\ \mu G_{La} & \mu G_{ll} & \mu G_{Lv} & \mu G_{Lz} & G_L \\ \mu G_{va} & \mu G_{vL} & \mu G_{vv} & \mu G_{vz} & G_v \\ \mu G_{za} & \mu G_{zL} & \mu G_{zv} & \mu G_{zz} & G_z \\ G_a & G_L & G_v & G_z & 0 \end{bmatrix}, \quad
W = \begin{bmatrix} \rho W_{ww} & \rho W_{wz} & \rho W_{wl} & W_w \\ \rho W_{zw} & \rho W_{zz} & \rho W_{zl} & W_z \\ \rho W_{lw} & \rho W_{lz} & \rho W_{ll} & W_l \\ W_w & W_z & W_l & 0 \end{bmatrix}
$$

and

$$\tilde{d}^{\prime} = \left[dx_a, dl_l, dx_m, dx_w, d\lambda_1, dq_a, dL, dv_m, dv_z, d\mu, dq_w, dq_z, dl_w, d\rho \right]$$

$$\tilde{b}^{\prime} = \left[\lambda_1 dp_a, \lambda_1 dp_l, \lambda_1 dp_m, \lambda_1 dp_w, \Phi, -dp_a, -dp_l, -dp_v, -dp_z, 0, -dp_w, -dp_z, -dp_l, 0 \right]$$

$$\text{where} \quad \Phi = -\left(T - L - l_l - l_w\right)dp_l + x_m dp_m - \sum_i \left(q_i - x_i\right)dp_i - dE - v_m dp_v + p_l dT$$

$$- \mu G_K dK - \rho W_D dD, \quad i = \{a, w, z\}$$

In general, we can use the implicit function theorem to solve this system of equations. However, as in the standard agricultural household model the matrix of second-order derivatives in (6) is block diagonal, implying that we can solve the system recursively. In other words, we can treat the household as first solving its allocation decisions with respect to agricultural and environmental production, then deciding on consumption conditional on its (exogenously) maximised profits. The fact that this recursiveness property is retained in the environmentally-augmented agricultural household model is a consequence both of the specification of the environmental production function used here, and also of the assumption of complete and clearing markets. So in the first stage we derive optimal supplies (q_a, q_w, q_z), labour inputs (L, l_w) and variable inputs (v_m, v_z) as functions of prices in the production section of the model and fixed factors of production:

$$\begin{aligned}
q_a &= q_a(p_a, p_l, p_v, p_z, K) \\
q_w &= q_w(p_w, p_l, p_z, D) \\
q_z &= q_z(p_w, p_l, p_z, D) \\
L &= L(p_a, p_l, p_v, p_z, K) \\
l_w &= l_w(p_w, p_l, p_z, D) \\
v_m &= v_m(p_a, p_l, p_v, p_z, K) \\
v_z &= v_z(p_a, p_l, p_v, p_z, K)
\end{aligned} \tag{7}$$

These then define a profit function $\pi = \pi(p_a, p_l, p_v, p_w, p_z, K, D)$, and after substitution of this profit function into the full income constraint we can derive standard uncompensated demands:

$$\begin{aligned}
x_a &= x_a(p_a, p_l, p_m, p_w, p_l T + \pi(p_a, p_l, p_v, p_w, p_z, K, D) + E) \\
l_l &= l_l(p_a, p_l, p_m, p_w, p_l T + \pi(p_a, p_l, p_v, p_w, p_z, K, D) + E) \\
x_m &= x_m(p_a, p_l, p_m, p_w, p_l T + \pi(p_a, p_l, p_v, p_w, p_z, K, D) + E) \\
x_w &= x_w(p_a, p_l, p_m, p_w, p_l T + \pi(p_a, p_l, p_v, p_w, p_z, K, D) + E)
\end{aligned} \tag{8}$$

These demands are, as expected, functions of the full vector of prices in the model and maximised full income.[12]

3.3 The Complexity of the Commons at a Theoretical Level

What light does this general model of peasant households' environmental resource use shed on the question we are concerned with, namely the relationship between poverty and environmental sustainability in the context of a multiple resource use system? This modelling framework reveals two key points, which we discuss in turn. The first is that *a multiplicity of determinants of resource use* emerge when environmental goods are considered as part of the household's consumption and production system. This is the case whether one examines the determinants of the household's resource supply (q_w and q_z), resource use (v_z) or resource demand (x_w). In other words, the focus on income as a primary determinant of resource use is dangerously narrow. For example, examination of the relevant functions in (7) suggest that the household's collection of environmental resources will be influenced by the relative price of environmental goods, by the opportunity cost of labour, and by the household's spatial location, while the household's use of environmental production inputs will be determined by the household's level of productive assets and the price of agricultural outputs, as well as the relative price of inputs. We have already noted one such relationship above between different types of fertiliser, commercial and environmental, and we would expect these *a priori* to have a relatively high elasticity of substitution. And indeed it has been noted that following the liberalisation of the fertiliser price under the Structural Programme in Zimbabwe, rural farmers have gone "leaf mad"[13] as they attempt to maintain soil nutrient levels: exactly the reaction one might expect given the analysis above.

Similarly, the environmental demand function $x_w(.)$ allows for a range of determinants other than income. The presence of the price vector alongside the full income term in this function means that we must pay attention to the potential pattern of consumption substitutes and complements between the environmental good (x_w), the purchased commodity (x_m), household production (x_a) and leisure (l_l) if we are to fully characterise the household's consumption of environmental goods. And of course there are no restrictions on this pattern other than those imposed by the symmetry and negative semi-definiteness of the Slutsky matrix. In principle, any pattern of cross-price elasticities is possible, and this is the case in spades if we think of $\{x_w, x_m, x_a\}$ as vectors - as they indeed are - rather than scalars as in the model above. In this case, there could easily be a pattern of substitutes and complements amongst

[12] It is in the fact that commodity demand functions can be expressed in conventional form that the importance of the assumption of complete and clearing markets can be most fully appreciated, since it allows conventional demand estimation to ensue. Consider if environmental goods markets were no longer assumed to be complete. It would follow that the household faced an extra constraint in the programme (4.4), in that $q_w = x_w$ and/or $q_z = v_z$, so that the (virtual) price of the missing-market good would now be determined endogenously for each household, as a function of the entire set of exogenous variables in the model (see McKay and Taffesse 1994 for a derivation). As a result, the household model would no longer be recursive - or "separable" as it is sometimes known - since (virtual) environmental prices now depend on both the consumption and production decisions of the household. Demand functions for all goods could no longer be expressed as functions of maximised full income and parametric prices, but instead would need to be jointly identified from both the production and consumption sides of the model. The fact that "production side" variables such as labour availability, resource distances, and other determinants of collection costs would then affect demands through their impact on virtual prices forms a test of recursiveness: such a test is implemented in Benjamin (1992) on data from Java, for which no strong evidence of non-separability in found. Such a test could potentially be carried out on our data set, possibly through the regression of the imputed unit value data reported in chapter 2 on a vector of exogenous characteristics. However, the concern of this chapter is not to test recursiveness, but rather to examine differentiation in the economic characteristics of environmental goods. Since it seems highly unlikely that the differentiation we observe in income elasticities would collapse into a uniform elasticity under estimation of a non-recursive system, we leave this possibility for future work.

[13] Personal communication from Dr. I. Scoones, IDS, Sussex.

environmental goods as well as between these and other goods. For example, we will present evidence later that suggests that contemporaneously-fruiting wild fruits are substitutes while asynchronously-fruiting wild fruits are not, a pattern that appears also to be replicated between wild fruits and exotics.

The second key point is that there are *no prior restrictions on the signs of income elasticities*, and of course therefore there is additionally no guarantee that the income elasticities of different environmental goods are identical. Indeed, any set of preferences is possible, so that environmental goods could conceivably, in the absence of any empirical verification, span the range of income elasticities from inferior goods via normal goods to luxuries. If we are thinking of the poverty-environment relationship primarily as one between income levels and environmental resource use, then, not only is the sign of the relationship indeterminate, but there may be multiple poverty-environment relationships, each corresponding to a different type of environmental good.

Consideration of these two key points warrants a further inference, namely that we can expect environmental demands to be affected in a multiplicity of ways by changes in exogenous parameters. This inference this has crucial ramifications for the sustainability debate. For example, it may be that some environmental resource utilisations - such as wild foods - have fairly direct consumption substitutes whether other wild species or other, more conventional foods, such that any increase in species scarcity leading to an increase in price also results in a "spillover" of demand pressures onto other species and purchased substitutes. Where these types of consumption substitutes do not exist, so the resource is more likely to be exhausted or driven to extinction.[14] The importance of species substitutions and the existence and costs of other substitutes ("backstops") as a determinant of environmental resource utilizations has gone largely unremarked as an organizing principle in the literature on peasant resource use. However, these factors play a strong role in determining how changes in resource demands or changes in collection costs affect a given resource by determining the degree to which rising demands or rising supply costs can be absorbed by or spill over into other species or economic activities. A different problem may be posed by the acquisition of technology, where the pattern of response may be quite diffuse. Consider, for example, the acquisition of a scotch cart (an important asset for the households studied). This, by lowering the costs of crop marketing, may be expected to increase agricultural surplus and crop production, and hence labour allocated to agriculture as against wild goods collection. However, this

[14] We can carry out the same analysis for environmental production inputs, where the substitute is more usually termed the backstop technology, but can equally well be different species. The point can be illustrated by comparing firewood versus construction wood use. For firewood, desired characteristics (of being a good, smoke-free burn) imply that in any given region, there are preferred species: however, there are many species substitutes that offer an acceptable alternative (du Toit *et al* 1984) . Furthermore, in response to initial reductions in firewood availability there is a range of low-cost ways in which household can react, including technical efficiency improvements, greater recycling within the household of wood used elsewhere (cattle kraals, fencing, old buildings), greater use of smaller branches and twigs, abandonment of wood stores, and greater use of cut wood. As Brouwer *et al* (1997) show in Malawi, households can also switch collection locations, trading off lower woodland quality for shorter distances and hence lower collection costs. For this reason, genuine firewood scarcities only emerge after considerable woodland clearance has occurred. Furthermore, there is a range of backstop technologies for the provision of household energy needs, such as the use of dung, crop residues, kerosene and solar power, each of which has a different unit cost of energy provision, and each of which will therefore be adopted by households at differing levels of income and firewood scarcity. It is this combination of species substitutes and backstops that explains the patterns of household energy provision with respect to income and deforestation observed by du Toit et al (1984) and Campbell and Mangono (1994). However, while for these reasons firewood can be described as a "flexible" resource use, very different conditions hold for construction wood. Here, the necessity for poles to be strong, straight, and insect resistant results in a much narrower range of usable species (Grundy *et al* 1993), so that species substitution possibilities are circumscribed. At the same time, the only backstop is a shift to purchased inputs, and the cost of these is often high. Thus, it is the lack of flexibility of resource use that explains the common observation that it is construction wood scarcities which emerge a long time before firewood scarcities (Dewees 1992), despite the lower overall volumes of wood needed per household for construction purposes: households desire only a limited range of species, and they will keep searching further for these until collection costs rise high enough to make adoption of the backstop economically rational.

may also be expected to increase the value of environmental production inputs. Furthermore, ownership of a scotch cart also dramatically decreases the unit labour costs of collecting certain wild resources, particularly firewood and construction wood. The ultimate impact on resource supply is therefore unclear.

Notice that we have derived this plethora of possibilities by analysing solely a static formulation of the problem of determining the household's consumption and use of environmental resources. We have ignored the issue of variability in resource supplies implicit in (2), and yet we noted earlier that species and resources can differ dramatically in their autoecological characteristics. Integrating this environmental variability with the economic model to provide a genuinely ecological-economic, encompassing framework for the analysis is beyond the scope of this paper: however, consideration of this task and of the points made above lead one inexorably to the conclusion that sustainability is a complex matter.

4. Econometric Analysis of Environmental Demands

The theoretical model above suggested, potentially a much more complex pattern of connections between rural households' economic choices and environment resources than is found in the literature. However, the crucial word here is potentially. As we noted at the opening of the paper, a recurrent problem in the poverty-environment literature has been the absence of rigorous empirical verification of various hypothesised relationships. So it is important to answer the question - is it the case in reality that environmental goods differ widely in their economic characteristics, or can we treat them as homogenous goods? It is to this issue of empirical verification that we now turn. To do this, in this section we present econometric evidence on the determinants of environmental demands, focussing in particular on estimates of income elasticities across types of goods and species, and then on demand function estimation for certain species in more detail. However, since the data that we have on environmental resource use are only cross-sectional, there is a limit to econometric possibilities. So in section five, we suggest how other, mostly non-economic, studies of Zimbabwean rural households' resource use can be interpreted in the framework of our theoretical analysis, and hence how they can be used to support the claims of this paper.

4.1 Data and Econometric Specification

A generic problem in the environmental economics literature is poor or absent data with which to test theoretical priors. Often, this is due to a lack of accurate physical data on environmental impacts or environmental change - witness, for example, the debates over Amazonian deforestation, Sahelian desertification or global warming. However, in the poverty-environment literature, the problem is even more basic in that there are simply no public access data sets which systematically relate environmental resource utilisations to other economic data at the household level. This is not to say that a literature does not exist on the use of environmental resources by the poor, indeed quite the opposite: there is a huge amount published on the subject (for specific reviews, see Lampietti and Dixon 1994, Townson 1994 and Scoones et al 1992). However, the vast bulk of this is focussed on the use or valuation of particular species rather than environmental resources as a whole, and furthermore little attention is paid to the relationship between environmental resource use and agents' other economic choices (see Godoy and Bawa 1993).

In response to this problem, a data set was collected by the author over a one year period in 1993/94 from 213 households in Shindi Ward, rural Zimbabwe, using a set of questionnaires which purposively integrated economic and environmental variables at the household level. To do this, the standard quarterly Income-Consumption-Expenditure survey, as used in national household budget surveys and in the LSMS, was expanded to include questions on the range of environmental utilisations listed in section 2. Amongst other things, these questions included data on the income from, consumption of and expenditure on environmental goods, as well as information on quantities, prices and sources of all reported natural resource utilisations. (Further specifics of this data set are given in Appendix I). In consequence, it is possible to use this data set to integrate environmental goods into standard economic analyses of rural households. One result of this work was shown in section 2, where we demonstrated the quantitative importance that environmental resources have Shindi households. However, we can also use this data set to explore in a unique way the determinants of rural households' resource use.

We can classify the environmental resource utilisations of Shindi households by their economic function, as in table 4.1. (Note that this table omits completely non-consumptive environmental resource uses, and ignores some consumptive resource uses, such as bark use, wild soaps and shampoos, tooth-cleaning twigs and so on, on which it was impossible to obtain reliable consumption data). In principle, we can use the data set to estimate all the relevant economic functions for environmental goods contained in this table, namely supply functions, input demand functions and commodity demand functions. In this paper, though, we focus on the last of these functions: this is in order to provide estimates of the income elasticity of demand for the environmental goods in our sample and hence shed some quantitative light on the debate about peasants and the environment.

Table 4.1 - A Classification of Environmental Resource Utilisations by Economic Function

Consumption Goods	Inputs	Output Goods	Durables and Stocks
1. Wild fruits	1. Firewood (beer brewing)	1. Wild fruit sales	1. Furniture
2. Wild vegetables	2. Firewood (brick burning)	2. Wild vegetable sales	2. Large hh utensils (wood)
3. Large wild animals	3. Leaf litter	3. Wild animal sales	3. Firewood store (bakwa)
4. Small wild animals	4. Termitaria	4. Wine sales	4. Construction wood
5. Wine	5. Livestock browse & graze	5. Firewood sales	5. Fencing (wood)
6. Other wild foods	6. Thatching grass	6. Construction wood sales	
7. Firewood (cooking/heating)		7. Thatching grass sales	
8. Agricultural tools (wood)		8. Other wild good sales	
9. Small hh utensils (wood)		9. Carpentry sales	
10. Mats (reeds)		10. Woven goods sales	
11. Woven baskets		11. Pottery sales	
12. Pottery		12. NHU labour sales	
13. Wild medicines		13. Gold sales	

Specification of environmental demands

The general form for environmental demands was derived in the set of equations (8) and discussed subsequently. For econometric purposes, however, this equation must be modified in three significant ways. The first is that, as a consequence of the cross-sectional data set, own- and cross-price elasticities cannot be estimated directly. Households face identical price vectors, so there is no variation with which to identify price effects. This leaves income as the chief explanatory variable. The second is that we must make some assumption about the form of the demand function which accords with theoretical priors and empirical practice. However, given that we are estimating cross-sectional demands, there is a multitude of possibilities. The only theoretical restriction on cross-sectional demands is that of adding up: since this is a property of the data, it does not suggest any particular functional form. Likewise, the empirical literature has used a wide range of functions of income and transforms of income, whether estimating demand functions for quantities (x_i) or Engel budget shares (w_i). While some of these can be ruled out as imposing unlikely restrictions on the cost function (see Deaton and Muellbauer 1980), many possible forms remain to choose from. Some commonly-used forms for Engel curve estimation with their corresponding cost functions are summarized in table 4.2. Of this set, we have chosen for a variety of reasons to use the Working-Leser form. First, it is a simple and convenient form which is consistent with broader demand systems which have appealing properties, namely the AIDS and Translog specifications. Second, although simple it has been found to perform extremely well on cross-sectional data, in that the linear-in-logs specification for Engel curves has been found to characterise parsimoniously a variety of commodity demands across a range of countries (see Deaton 1996, Hausman *et al* 1991).[15] Finally, in the Shindi data set transforms of income are highly correlated, so that use of these transforms in demand estimation introduces severe collinearity problems.[16]

Table 4.2 - Common Functional Forms for Engel Curves and Their Economic Implications

Engel Curve		Demand Function	Conditional Cost Function		Engel Curve Rank	Income Elasticity
Name	Form		Name	Form		
Working-Leser	$w_i = \alpha_i + \beta_i \ln x$	AIDS, Translog	PIGLOG	$\ln c(u,p) = u \ln a(p) + (1-u) \ln b(p)$	2	$\eta_{D,Y} = 1 + \beta_i/w_i$
Generalized Working-Leser	$w_i = \alpha_i + \beta_i x^{-\varepsilon}$		PIGL	$c(u,p) = [u\, a(p)^{\varepsilon} + (1-u)\, b(p)^{\varepsilon}]^{1/\varepsilon}$	2	$\eta_{D,Y} = 1 - (\beta_i/w_i)\, \varepsilon\, x^{-\varepsilon}$
Augmented Working-Leser	$w_i = \alpha_i + \beta_i \ln x + \delta_i (\ln x)^2$			$\ln c(u,p) = a(p) - b(p)/[u + d(p)]$	3	$\eta_{D,Y} = 1 - \beta_i/w_i + (\delta_i/w_i)\, 2 \ln x$
?	$w_i = \alpha_i + \beta_i x$	Linear Expend. System (LES)			2	$\eta_{D,Y} = 1 + (\beta_i/w_i)\, x$
?	$w_i = \alpha_i + \beta_i x^{-1} + \delta_i x$	Quadratic ES		$c(u,p) = a(p) - b(p)/[u + d(p)]$	2	$\eta_{D,Y} = 1 - (\beta_i/w_i)\, x^{-1} + (\delta_i/w_i)\, x$
?	$w_i = \alpha_i + \beta_i x^{-1} + \gamma_i x^{-2} + \delta_i x + \theta_i x^2$	Augmented QES			4	
Logistic	$w_i = \alpha_i [1 - 1/(1 + \beta_i \exp(- \delta_i \ln x))]$					

The third adjustment needed is to introduce differences in household structure into the demand system. These were implicitly ignored in the theoretical model, largely for notational convenience but also because the derivation is straightforward. For example, if we reparameterise the utility function in (4) so that $U = U(x_a, l_l, x_m, x_w; S)$ where S is a vector of household characteristics, then the resulting environmental demands would simply be of the form $x_w = x_w(p_a, p_l, p_m, p_w, Y^*; S)$ where Y^* is maximised full income. One of the major differences in structure across households is, of course, demographic. However, introduction of demographic differences into demand systems is an area of controversy (see the review by Browning 1992), since any particular procedure involves restrictions on the form of the cost function, and these may be more or less defensible. Rather than go into detail in this area, we have chosen to use a demographically-augmented form of the Working-Leser function which allows convenient interpretation of the parameters to be estimated. So household demands are assumed to take the form

[15] In the case of non-parametric Engel curve estimation, it is a common result to generate a rank 2, linear-in-logs specification for trimmed data, with some evidence of non-linearities at both extremes of the income distribution (see Lewbel 1991).

[16] There is a suggestion from cross-plots that some of the environmental demands would be best described by a nonlinear specification. As the correlation coefficient between total income (y) and y^2 is 0.933, between ln(y) and $\ln(y)^2$ is 0.997, and between y and y^{-1} is -0.501, the most natural method of testing for these is not available.

$$w_i = b_0 + b_1 \ln\left(\frac{Y_i}{N_i}\right) + b_2 \ln N_i + \sum_{j=1}^{J} b_{3j} \frac{n_{ij}}{N_i} + d_{ik} D + u_i \qquad (9)$$

where w_i = the budget share of a good for the *i*th household;
Y_i = the *i*th household's total income;
N_i = the *i*th household's total size;
n_{ij} = number of people of the *j*th demographic type in the *i*th household;
D = a vector of household-specific and/or goods-specific dummies.

With this formulation, b_1 can be used to calculate the per capita income elasticity of demand, b_2 measures the pure economies of scale effect and the b_{3j}'s measure the effect of differences in household demographic composition on commodity demands. Other differences across households are summarised in the vector *D*, for example the type of household head, measures of the household's age and education level, and a village dummy. The list of the variables used in all the demand regressions with summary statistics for each variable is found in table 4.3. Note that for household demographic composition, household members were divided up by sex and by four age ranges (0 to 4, 5 to 14, 15 to 54 and 55 and over), and demographic shares calculated accordingly. The vector *D* also contains any goods-specific dummies: data on these dummies are also presented in table 4.3, but the definition and use of these will be discussed later when we present results for individual demand functions.

Finally, our estimation of environmental demands is carried out at a highly disaggregated level, sometimes at the level of individual species. This is in contrast to much demand analysis, which usually estimates broad commodity aggregates on the basis of some (often implicit) separability assumption. We have chosen to estimate such disaggregated demands for two reasons. First, environmental demands of this type have not been estimated anywhere else, so there are no prior results concerning commodity aggregation on which we can rely. Second, part of the purpose of the enquiry is to examine whether or not environmental goods are differentiated by economic determinants, hence the need to estimate demand functions at as disaggregated a level as is possible. This introduces a slight complication into the estimation, in that it means that a proportion (and sometimes a majority) of households have zero budget shares for most of the environmental goods.[17] Under these conditions, it is well-known that OLS is a biased estimator, so the standard response to censoring of this kind is to use Tobit estimation. However, the unbiasedness of the Tobit procedure depends heavily on the normality and homoscedasticity of the residuals, a condition frequently violated in cross-section data in general, and with monotonous regularity in our data in particular. As there are no clear results on the comparative bias of OLS versus Tobit under these conditions (see Deaton 1996), and as they tend to be biased in different directions, we report results for both.[18]

[17] In some cross-sectional demand work, zero observations are treated as cases of selection bias rather than of genuine non-consumption, on the assumption that they arise either where households have misreported consumption, or where the questionnaire recall period does not match the typical consumption period, as is often the case with durables. However, in the Shindi questionnaire households were asked to report the consumption of an extensive list of environmental goods on a quarterly basis (ie. three month recall) over the period of an entire year. In these circumstances it is much more likely that zero budget shares do indeed represent non-consumption.

[18] In future work, more robust estimators such as Powell's Least Absolute Deviations estimator will be used.

Table 4.3 - Variables Used in the Demand Regressions

Variable	Description	Mean	Std. Dev.
1. Variables in all demand regressions			
LGX_N	Log of household total income per hh member (1)	-0.702	0.550
LGN	Log of number of household members (2)	1.736	0.611
M05_14SH	Share of males aged 5 to 14 in total hh members	0.151	0.150
F05_14SH	Share of females aged 5 to 14 in total hh members	0.152	0.148
M15_54SH	Share of males aged 15 to 54 in total hh members	0.205	0.151
F15_54SH	Share of females aged 15 to 54 in total hh members	0.263	0.157
M55PLSH	Share of males aged 55 plus in total hh members	0.026	0.088
F55PLSH	Share of females aged 55 plus in total hh members	0.061	0.163
AGEHHHD	Age of the household head	44.780	13.892
HHHDFLDF	De facto female-headed household	0.202	0.402
HHHDFLDJ	De jure female-headed household	0.160	0.367
HHHDMMDV	Divorced/widowed male-headed household	0.023	0.152
EDYRMAX	Maximum no. of years education, any hh member	6.920	2.920
EDHHHD4Y	Hh head has four years of schooling dummy	0.146	0.354
EDHHHDPL	Hh head has primary leaver's certificate dummy	0.132	0.339
EDHHHDJC	Hh head has junior certificate dummy	0.023	0.152
[Plus 28 Village Dummies Not Listed]			
2. Wild fruit demand dummies			
TRHHMANG	Number of mango trees at homestead	0.714	1.456
TRHHGUAV	Number of guava trees at homestead	0.258	0.892
TRHHMULB	Number of mulberry trees at homestead	0.188	0.560
TRFDMUPF	Number of female <u>mupfura</u> trees in hh's fields (3)	1.296	1.735
TRFDNYII	Number of <u>munyii</u> trees in hh's fields (3)	0.099	0.314
TRFDKWAK	Number of <u>mukwakwa</u> trees in hh's fields (3)	0.521	0.861
TRFDTAMB	Number of <u>mutamba</u> trees in hh's fields (3)	0.136	0.395
TRHHMUPF	Number of female <u>mupfura</u> trees at homestead (3)	0.380	0.765
TRHHNYII	Number of <u>munyii</u> trees at homestead (3)	0.038	0.214
TRHHKWAK	Number of <u>mukwakwa</u> trees at homestead (3)	0.258	0.742
3. Wild vegetable demand dummies			
GARDENUS	Number of gardens used by hh in 1993/94	0.216	0.424
4. Firewood demand dummies			
Q2FWUSE	Nov to Jan firewood use	0.250	0.430
Q3FWUSE	Feb to Apr firewood use	0.250	0.430
Q4FWUSE	May to Jun firewood use	0.250	0.430
CARTCOLL	Collection and transportation by scotch cart	0.025	0.155
DEADCUT	Collected by cutting dead trees	0.036	0.187
DEADFELL	Collected by felling dead trees	0.097	0.297
COLLMALE	Male hh members usually collect firewood	0.042	0.201
FWCLFAIR	Firewood collection relatively easy	0.582	0.494
FWCLHARD	Firewood collection hard	0.516	0.500
FWCLVHRD	Firewood collection very hard	0.174	0.379
FWSRCFLD	Firewood collected from a field	0.019	0.136
FWSRCRIV	Firewood collected from a riverine woodland	0.061	0.240
FWSRCVLE	Firewood collected from a vlei	0.007	0.084
FWSRCPLN	Firewood collected from a plains woodland	0.211	0.408
FWSRCRST	Firewood collected from resettlement area	0.088	0.284

Notes

1. Household total income here means crude or unadjusted household total income. Total income has been rescaled by 10^{-3}.
2. Each household member is weighted by the proportion of the year in 1993/94 that s/he spent at the household.
3. Botanical names are as follows: *Berchemia discolor* (<u>munyii</u>); *Sclerocarya birrea* (<u>mupfura</u>); *Strychnos madagascariensis* (<u>mukwakwa</u>); *Strychnos cocculoides* (<u>mutamba</u>). Note that only female <u>mipfura</u> produce fruit.

4.2 Estimates of Income Elasticities

In tables 4.4 and 4.5, OLS and Tobit results are presented for a range of environmental resource demands based on (9), with income elasticities calculated accordingly. A variety of diagnostic statistics is also reported for each regression. Examining these diagnostics first, there is substantial evidence of regression mis-specification. In the case of OLS, this is to be expected given the cross-sectional nature of the data and the censored distribution: the diagnostics here suggest universal heteroscedasticity and non-normality of the residuals, and very substantial regression mis-specification. For the Tobit regressions, the two tests for residual heteroscedasticity likewise suggest very considerable problems in 16 of the 22 regressions. As mentioned before, this heteroscedasticity is a serious difficulty for Tobit estimation, since the Maximum Likelihood estimator will be inconsistent in the presence of non-constant variance.[19] For these reasons, then, we regard the results in tables 4.4 and 4.5 as indicative estimates of the elasticities involved rather than as definitive figures.[20]

With this caveat in mind, inspection of the income elasticity results suggests two broad conclusions. The first is that *many of the income elasticities for environmental goods are fairly low*. This is particularly the case if one examines the income elasticities for aggregated commodities, such as all wild fruits (Tobit elasticity [η_T] = 0.44, OLS elasticity [η_O] = 0.33), all wild vegetables (η_O = 0.63), firewood (η_O = 0.42) and all wild goods (η_T = 0.46, η_O = 0.36). The implication of these relatively low aggregate elasticities is that, as incomes rise, so the budget shares of these various environmental goods will decrease in significance. These aggregate elasticities are non-negative, though, so that total demand still rises as income rises, albeit relatively gently. Thus the implication of these figures would be that an increase in per capita income would *ceteris paribus* lead to a rise in environmental resource demands, but that this would occur at a relatively slow pace.

However, the second broad conclusion - which contradicts the first to a degree - is that there appears to be reasonably strong evidence of *economic differentiation across environmental goods*. One needs to be more tentative in drawing this conclusion since OLS and Tobit estimates differ more widely at the individual species level. Nonetheless, the pattern of elasticities differs in a manner consistent with casual empirical evidence, and at times the point estimates can be quite distinct. Take for example individual species of wild vegetables. From interviews with Shindi women, it was clear that the two least regarded wild vegetables were munyemba, on account of its soapy taste, and the category "other", which comprises a large number of species which either grow irregularly or scantily, or whose taste is poor.[21] By contrast species such as muboora and derere are sufficiently well regarded that in some cases they are almost domesticated (see also McGregor 1995 for more evidence on household preferences for wild vegetables). The estimated income elasticities reflect this differentiation. The income elasticity for other wild vegetables is very low (η_T = 0.20, η_O = 0.00): indeed, the OLS estimate almost categorises these as inferior goods, while that for munyemba is consistently below 0.5 (η_T = 0.40, η_O = 0.49). The elasticities

[19] Even more severe problems are posed if the distribution is non-normal. Although we have not calculated a specific test for non-normality, given the results for the heteroscedasticity tests and the fundamental non-normality of the distribution of the budget shares, it seems likely that the assumption of normality will be violated, so that once again the Tobit estimator is mis-specified (Pudney 1989).

[20] The Tobit income elasticities are usually higher than the OLS income elasticities. This is consistent with the predicted sign of the estimation bias.

[21] Indeed, some of these species are known only by older women, so that use of them is generally dying out. But this knowledge proved to be highly useful in the 1991/92 drought, when it was precisely these obscure - and sometimes vile-tasting - relishes that were eaten following the failure of all other foods and crops. For example, in that year some households relied on leaves from the trees *Adansonia digitata* (muuyu) and *Afzelia quanzensis* (mukamba) as well as the bush muzunguma, which even those who consumed it admit tastes horrible.

for muboora and derere by contrast are much higher (η_T = 0.76, η_O = 0.75 and η_T = 1.00, η_O = 0.71 respectively). So although in aggregate the elasticity for wild vegetables is moderate, disaggregation by species reveals considerable differentiation around this mean.

This point also holds for the demand for wild animals. In aggregate, both OLS and Tobit suggest a unit elasticity for all wild animals, but closer inspection suggests that individual species differ substantially. For example, the estimates for mice consumption point to a fairly low elasticity (η_T = 0.41, η_O = 0.28), and this is very much in accordance with expectation. Mice consumption is usually associated with poorer households, some of whom rely on mice sales for income, and small children. Indeed, households can be embarrassed about reporting mice consumption, in part because some of the local evangelical churches ban their consumption, and in part because they are regarded as poor quality food.[22] By contrast, both wild fish and game meats have higher elasticities (η_T = 1.31, η_O = 1.53 and η_T = 1.00, η_O = 0.50 respectively): indeed, over the (very low) income range of Shindi households, wild fish are luxury goods. One reason for these comparatively high elasticities is that these foods tend to be sold by specialist, itinerant fishers and hunters, so that the only households which can purchase these foods are those which have sufficient cash to hand on a regular basis. However, these higher elasticities also reflect genuine preferences: game meat and fish are prized as relishes in Shindi.[23]

The situation with other aggregates is less clear. It appears likely that many wild fruits have similar, and fairly low elasticities, but some of the Tobit and OLS estimates vary quite a bit for the same species (eg. nyii and the fruit wine mukumbi). Further, three of the fruits that local interviews suggested were most preferred, namely *Sclerocarya birrea* (mupfura), *Strychnos madagascariensis* (mukwakwa) and *S. spinosa* (mutamba), had insufficient observations at the species level to run demand regressions. So the likely differentiation that exists with respect to wild fruits is difficult to observe.[24] Similarly, elasticity estimates for individual wild goods differ across estimators in a confusing manner, although some of the point estimates do accord with one's priors. Thus the OLS elasticity for environmental resource-derived household utensils is -0.06, which seems likely given that these goods have better-quality purchased substitutes (metal plates, spoons etc.) that are widely available. By contrast, pottery elasticities are higher, reflecting the unique uses that some pots have, and the high price of purchased substitutes for others, namely those associated with the bulk storage of liquids.

[22] The only time that mice are considered a delicacy is when they are sold at beer-brewing parties as the traditional complement to local beer (goga).

[23] High values for wild meat are reported elsewhere in Africa (Asibey 1974, Martin 1983, Eltringham 1984, Anadu *et al* 1988). In West Africa the consumption of wild meats has been so intensive that prices have risen above those of domesticated species and fears have been expressed for the survival of the wild species concerned.

[24] This situation is implicitly repeated in the case of firewood demands. Our estimate here is for all species used as firewood, but this disguises the fact that different species have very different firewood properties, and that these are reflected in households' species preferences. Since firewood use was not collected on a species basis, it is not possible to estimate different elasticities for firewood species: however, for evidence on household rankings of different species see McGregor (1991). The same points also apply to thatching grass.

Table 4.4 - OLS Estimates of Per Capita Income Elasticities for Environmental Goods

Type of Environmental Good	No. of Non-Zero Cases	Mean Budget Share	Coeff.	t-stat. (1)	Income Elast. (2)	Adj. R^2	F-stat.	B-P LM (3)	J-B Wald (4)	White χ^2 (5)
1. All Wild Fruits	206	0.00541	-0.00363	3.281 **	0.33	0.09	1.42 *	109.82 **	108.20 **	14.02 **
Diospyros mespiliformis (suma)	180	0.00094	-0.00048	2.142 **	0.49	0.33	2.88 **	899.11 **	203.76 **	0.89
Sclerocarya birrea nut (shomwe)	87	0.00166	-0.00119	2.173 **	0.28	0.15	1.71 **	121.55 **	71.99 **	21.94 **
Sclerocarya birrea wine (mukumbi)	68	0.00206	-0.00166	1.844 *	0.19	0.04	1.18	225.29 **	137.27 **	15.78 **
Berchemia discolor (nyii)	93	0.00040	-0.00025	2.287 **	0.41	0.14	1.63 **	135.99 **	91.84 **	11.66 **
2. All Wild Vegetables	213	0.04970	-0.0183	3.280 **	0.63	0.44	4.63 **	152.43 **	69.30 **	25.85 **
Phaseolus vulgaris? (munyemba)	182	0.01332	-0.00680	2.641 **	0.49	0.31	3.05 **	130.94 **	82.77 **	24.18 **
Cucurbita pepa? (muboora)	211	0.02088	-0.00530	2.007 **	0.75	0.38	3.74 **	131.19 **	69.38 **	14.93 **
Cucumis metuliferis? (muchacha)	189	0.00593	-0.00320	3.576 **	0.46	0.28	2.77 **	230.25 **	131.45 **	12.10 **
Corcorus olitorius? (derere)	168	0.00354	-0.00103	1.477	0.71	0.10	1.53 **	197.89 **	138.36 **	3.30
Gynandropsis gynandra? (rudhe)	140	0.00435	*-0.00031*	*0.272*	*1.00*	0.09	1.46 **	188.82 **	131.05 **	3.44
Other wild vegetables	93	0.00171	-0.00171	2.233 **	0.00	0.07	1.36 *	275.48 **	184.15 **	10.94 **
3. All Wild Animals	180	0.00793	*-0.00053*	*0.272*	*1.00*	0.29	2.87 **	356.24 **	162.09 **	11.29 **
Mice	120	0.00257	-0.00185	2.540 **	0.28	0.10	1.51 **	534.85 **	361.69 **	2.52
Game meats	74	0.00114	-0.00057	1.408	0.50	0.54	6.45 **	490.21 **	82.59 **	33.15 **
Wild fish	96	0.00394	0.00207	1.330	1.53	0.19	2.08 **	627.59 **	231.06 **	1.79
4. All Wild Foods	213	0.06580	-0.0301	5.243 **	0.54	0.44	4.79 **	121.72 **	61.49 **	31.43 **
5. Firewood	213	0.06110	-0.0356	11.272 **	0.42	0.57	6.93 **	71.31 **	43.61 **	20.33 **
6. All Wild Goods	188	0.00480	-0.00308	2.990 **	0.36	0.19	2.11 **	95.70 **	60.84 **	26.75 **
Agricultural tools (wood)	99	0.00097	-0.00067	2.180 **	0.31	0.05	1.25	332.04 **	282.46 **	2.89
Small household utensils (wood)	84	0.00030	-0.00004	2.727 **	-0.06	0.03	1.15	284.17 **	226.21 **	17.74 **
Woven goods	125	0.00330	-0.00215	2.428 **	0.35	0.14	1.79 **	95.71 **	68.83 **	27.63 **
o/w - mats (reeds)	84	0.00250	-0.00188	2.166 **	0.25	0.20	2.20 **	109.12 **	75.86 **	29.64 **
Pottery	141	0.00110	-0.00056	2.314 **	0.50	0.07	1.39 *	175.03 **	78.83 **	6.30 **
7. Thatching Grass	91	0.00898	-0.00674	1.826 *	0.25	0.23	2.37 **	343.24 **	252.56 **	17.03 **

Table 4.5 - Tobit Estimates of Per Capita Income Elasticities for Environmental Goods

Type of Environmental Good	No. of Non-Zero Cases (6)	Mean Budget Share	Marg. Coeff. (7)	t-stat.	Income Elast. (2)	Log Like-lihood	Pagan-Vella (8)	
							LM	LR
1. All Wild Fruits	206	0.00541	-0.00303	3.344 **	0.44	794.8	4.0	4.2
Diospyros mespiliformis (suma)	180	0.00094	-0.00033	1.455	0.64	899.5	0.8	0.9
Sclerocarya birrea nut (shomwe)	87	0.00166	-0.00118	2.687 **	0.28	299.1	63.8 **	57.4 **
Sclerocarya birrea wine (mukumbi)	68	0.00206	*-0.00006*	*0.238*	*1.00*	190.6	89.1 **	78.6 **
Berchemia discolor (nyii)	93	0.00040	*-0.00008*	*0.995*	*1.00*	253.6	46.8 **	42.5 **
2. All Wild Vegetables	213	0.04970			0.63			
Phaseolus vulgaris? (munyemba)	182	0.01332	-0.00801	3.213 **	0.40	516.8	0.6	0.7
Cucurbita pepa? (muboora)	211	0.02088	-0.00491	1.828 *	0.76	616.5	5.4 *	5.7 *
Cucumis metuliferis? (muchacha)	189	0.00593	-0.00309	2.839 **	0.48	691.4	1.1	1.1
Corcorus olitorius? (derere)	168	0.00354	*-0.00082*	*1.011*	*1.00*	630.2	0.4	0.4
Gynandropsis gynandra? (rudhe)	140	0.00435	*0.00033*	*0.301*	*1.00*	435.1	8.9 **	8.5 **
Other wild vegetables	93	0.00171	-0.00136	2.868 **	0.20	303.5	38.5 **	35.1 **
3. All Wild Animals	180	0.00793	*0.00013*	*0.073*	*1.00*	535.2	0.1	0.1
Mice	120	0.00257	-0.00151	2.019 **	0.41	397.9	18.5 **	17.3 **
Game meats	74	0.00114	*0.00012*	*0.434*	*1.00*	243.9	98.7 **	87.5 **
Wild fish	96	0.00394	0.00122	1.614 *	1.31	241.4	34.6 **	31.9 **
4. All Wild Foods	213	0.06580			0.54			
5. Firewood	213	0.06110			0.42			
6. All Wild Goods	188	0.00480	-0.00261	3.411 **	0.46	736.3	0.2	0.2
Agricultural tools (wood)	99	0.00097	-0.00049	1.748 *	0.49	391.4	38.8 **	35.5 **
Small household utensils (wood)	84	0.00030	-0.00017	2.621 **	0.50	14.3	65.9 **	59.2 **
Woven goods	125	0.00330	-0.00106	1.511	0.68	420.9	24.1 **	22.5 **
o/w - mats (reeds)	84	0.00250	*-0.00070*	*1.286*	*1.00*	247.6	99.4 **	95.9 **
Pottery	141	0.00110	-0.00039	1.588	0.65	646.1	10.9 **	10.3 **
7. Thatching Grass	91	0.00898	*-0.00093*	*0.515*	*1.00*	162.5	47.6 **	43.5 **

Notes on tables 4.4 and 4.5

1. All t-statistics calculated using White's heteroscedastic-consistent standard errors.
2. Per capita income elasticities are calculated according to the Working-Leser formula $\eta_I = (b_i/w_i) + 1$, using the mean budget share for w_i. Figures in italics are cases where the estimated coefficient is not significantly different from zero at the 15 percent level, implying a unit elasticity.
3. Breusch-Pagan LM test for residual heteroscedasticity, $\sim \chi^2(K)$.
4. Jarque-Bera Wald test for residual non-normality, $\sim \chi^2(2)$.
5. White test for general mis-specification (run on a restricted set of regressors), $\sim \chi^2(5)$.
6. There are 213 households in the sample, so that if the number of non-zero cases is 213, Tobit estimation is unnecessary. For these cases, the elasticities reported in table 4.5 are the OLS calculations.
7. Coefficient of marginal effects calculated at the mean of the regressors.
8. Pagan-Vella LM test for residual heteroscedasticity, $\sim \chi^2(2)$, and Pagan-Vella LR test for residual heteroscedasticity, $\sim \chi^2(K)$.
9. For all tests: * = significant at the 10 percent level; ** = significant at the 5 percent level.

4.3 Other Determinants of Environmental Demands

These estimates of income elasticities provides reasonably strong evidence that the set of environmental goods under review are heterogenous rather than homogenous. In other words, the notion of a single demand elasticity for environmental goods, or alternatively a single poverty-environment relationship, does not appear to be supported by the data. Recall, though, that income was merely one argument in the environmental demand function (8) and in the empirical specification (9). In the theoretical discussion it was also stressed that patterns of complements and substitutes could exist within environmental goods, as well as between these and other consumption goods, while in the empirical specification attention was drawn to the likely role of demographics and other household socio-economic variables as additional determinants of demand .

In order to demonstrate the impact that these different variables have on demands, in this section we present results for some of the individual demand regressions from which the income elasticities above were calculated. We illustrate these broader determinants of environmental demands using four particular regressions: those for the wild fruit *Diospyros mespiliformis* (suma), the wild vegetable *Cucumis metuliferis* (muchacha), firewood (huni) and wild fish (hove). The coefficients for the household-specific factors follow straightforwardly from the procedure described in section 4.1. More problematic is the attempt to estimate coefficients which might reveal patterns of substitutes and complements within and between environmental and non-environmental goods. As we noted above, it is difficult to estimate cross-price effects on cross-sectional data, due to the uniformity of the price vector across households. Nonetheless, we wish to find a method through which the pattern of interrelationships amongst goods might be established. The essential problem is the need for exogeneity in the relevant regressors if identification is to be valid. Prices, being parametric to the household, fulfill this requirement, but contemporaneous measures of other goods' consumption do not, as this consumption is endogenous to the household's joint maximisation problem. We have attempted to solve this difficulty by including in the regressions, where definable, capital stock-type proxies for the availability of likely complements and substitutes which are exogenous to the household's current allocation decisions. The argument underlying this that cross-sectional environmental demands will be conditioned on the availability of other goods, whether environmental or non-environmental, and that given the exogeneity condition, the signs of the coefficients on these variables will be indicative of the demand relationship between them and the environmental resource in question. We will explain and justify our choice of individual capital stock variables in the discussion of each environmental goods' regressions.

The wild fruit Diospyros mespiliformis *(suma)*
Table 4.6 contains the results of the full OLS and Tobit regressions for suma. Examining these regressions, several points stand out. First, there is no evidence of any economies of scale effect (lgN) in suma consumption: this is as one would expect as suma are eaten raw rather than being prepared in any way. Second, examination of the demographic share variables suggests that there is quite a strong and significant increase in suma consumption associated with a higher share of young males in the household (OLS and Tobit), and hints of greater consumption associated with young females (f05_14sh) and adult males (m15_54sh). The Tobit regression also points to a statistically significant reduction in suma consumption as the age of the household head increases, but the coefficient is small. Both these results fit in with the pattern described in chapter 2 of fruit consumption generally being more strongly associated with younger individuals. There is little evidence of any significant effect on suma consumption of education levels (edyrmax, edhhhd4y, edhhhdpl, edhhhdjc) or of the type of household head (hhhfldf, hhhdfldj, hhhdmmdv).

Most interestingly, though, these regressions do provide evidence on complements and substitutes for suma. In order to uncover these, we have included in the regressions variables measuring the number of trees of different fruit species at the household's homestead (trhh----) and in the household's fields (trfd---). The species included are exotic fruits such as mangoes, guavas and mulberries, and indigenous fruits such as female mipfura, minyii, mikwakwa and mitamba. These, then, are our capital stock proxies for likely complements and substitutes for suma. The number of trees of the different species are a proxy for the availability of these other fruits, but the tree stock numbers are exogenous to the household's current decisions.[25] Examination of the regressions reveal that two species have significant, negative coefficients, namely mulberries and mitamba, while the remainder generally have significant, positive coefficients, particularly when they are at the homestead (which is a stronger proxy variable than trees in fields). Interestingly, the two species which have negative coefficients fruit contemporaneously with suma, and hence could be expected to be consumption substitutes, whereas the others fruit at different times of the year. Consumption of suma, then, will not be unrelated to changes in the availability and prices of other fruits. Thus we have statistical evidence that one wild fruit at least has a pattern of consumption substitutes and complements of the sort suggested in our theoretical model.

The wild vegetable Cucumis metuliferis (*muchacha*)
Table 4.7 contains the results of the full OLS and Tobit regressions for muchacha. (Note that for this Tobit regression there is no evidence of heteroscedasticity in the residuals, suggesting that this may be a well-specified regression). Once again, there is an important role played by structural differences across households in determining resource demands. First, in both regressions there is a highly significant economies of scale effect, which we would expect as muchacha is a prepared food. Second, as for a number of other wild foods, both boys and girls appear to have a positive impact on the budget share of muchacha. Third, a higher education level of the household head is associated with a significant reduction in muchacha consumption. The incremental reduction in muchacha demand is particularly strong for household heads with at least the Primary School Leavers' Certificate ie. at least seven years of education (edhhhdpl). Given the connection between human capital and permanent income, the significance of these education variables may be related to wealth effects independent of the income variable: equally, though, they may reflect the impact of education in shifting preferences away from wild foods. Finally, the type of household head also affects demands: de facto female-headed households (hhhdfldf) consume more, while male divorcee-headed households (hhhdmmdv) consume less. This last result may be due to the fact that weeding and wild vegetable collection is considered women's work in Shindi: it would be embarrassing for a man to be found collecting these types of goods so that male divorcees, in the absence of female labour in the household, consume less.

The natural consumption substitute for wild vegetables is domesticated vegetables, and these are overwhelmingly grown in "gardens" - small patches of land that have to be near to a good source of water. Thus, we include a variable (gardenus) which measures the amount of garden area owned by a household at the beginning of the year, ie. the amount of land available to a household to grow domesticated vegetables should it choose to. Since clearing and fencing of these areas involves time and effort, we can treat this as an exogenous to current consumption but at the same time a proxy for the availability of domesticated vegetables. The significant, negative coefficient on this variable suggests that domestic and wild vegetables are indeed consumption substitutes.

Firewood
One of the most interesting individual environmental demand we discuss in details is that for firewood: OLS regression results for both annual and quarterly firewood demands are reported in table 4.8. Once again socio-economic variables play an important role in determining firewood demands. For example, there is a strong economies of scale effect for firewood that almost matches the size of the income elasticity. These economies of scale seem logical: it takes hardly any more firewood to cook for or heat a hut for one person

[25] Tree species numbers were derived from specific questionnaire modules on trees at the homestead and trees in fields implemented half way through the research period. These modules revealed that exotic fruit trees had in all cases been planted by the household, whereas indigenous trees never were. However, all indigenous fruit trees had been selected for preservation by households in the fact of competing demands for labour and land. So while tree species numbers all reflected household preferences, decisions concerning tree stock levels were taken by households well before the data accounting period.

than it does for more than one.[26] While household composition seems to have little consistent effect on firewood demands, there seem to be a quite strong impact of household headship type, but the reasons for this are unclear. More straightforward are the seasonal dummies, by which firewood consumption in the cold, winter period (q4fwuse) is significantly higher than in other parts of the year. During the winter (chando), households sometimes keep fires burning all through the night in order to ward off the cold, and in general will let fires burn longer in the evenings after cooking so that people at least go to sleep warm. This reason for higher consumption is strongly confirmed in our data.

In the case of firewood, there is no possibility of introducing substitutes and complements as all the sample households use firewood for cooking and heating all of the time. But we have included in the quarterly regression a range of variables which measure different aspects of firewood scarcity. And indeed the empirical results demonstrate the impact of these various indicators of scarcity on firewood demand. For example, households were asked whether firewood collection in their area was easy, fairly easy (fwclfair), hard (fwclhard) or very hard (fwclvhrd). In the latter case, household firewood use is significantly reduced. Households were also asked every quarter how their firewood had been collected, whether by picking up dead wood, cutting dead branches (deadcut) or felling dead trees (deadfell).[27] Households only resort to felling dead trees if firewood is relatively scarce, hence the significant negative coefficient on this dummy variable. Finally, households were also asked every quarter from whence their firewood had been collected: mountain woodlands, riverine woodlands (fwsrcriv), plains woodlands (fwsrcpln), the adjacent resettlement area (fwsrcrst), vleis (fwsrcvle) or fields (fwsrcfld). The last two of these again are associated with firewood scarcities, and once more these variables have significant, negative coefficients. All these results, then, suggest a negative own price effect in response to rising scarcities. In line with other studies, we can hypothesise that it is these types of processes which eventually lead to technological substitutions away from firewood use as the price of firewood rises.[28]

Wild fish

The final environmental demand we discuss in detail is that for wild fish (table 4.9). In this case, we were unable to define any capital stock proxies to explore the pattern of substitutes and complements, however this regression demonstrates again the importance of demographic and socio-economic influences on consumption. In the Tobit regression, we observe that as for other prepared foods, there is a strong economies of scale effect (lgN). There also appears to be a strong link between wild fish consumption and sex. For example, both OLS and Tobit regressions suggest that wild fish consumption is significantly reduced when there is a greater proportion of women in the household. The coefficients on young women (f05_14sh) and old women (f55plsh) are significant and negative for both OLS and Tobit regressions, while the coefficient on adult women (f15_54sh) is always negative and hints at significance in the Tobit regression. Associated with this is the positive and significant coefficient in the Tobit regression for divorced or widowed male-headed households which tend to have more men in the household. Finally, in both OLS

[26] This effect will be more muted in polygamous households if each wife cooks in her own kitchen. But although it was the traditional arrangement for each wife to have her own kitchen, at which she would provide for her own children only, nowadays some wives share the responsibility for cooking.

[27] Under the chief's rules it is illegal in Shindi to collect live wood for use as firewood. While people do still do this, they would be unlikely to report this in response to a questionnaire.

[28] Amacher *et al* (1993) used household-based data from rural Nepal to conduct an econometric analysis of firewood supplies and demands. They find marginally positive income elasticities of demand for firewood for low income households, and negative income elasticities for higher income households; a very low, negative own price elasticity (proxied for by collection distances); a substitution elasticity between firewood and crop residues of less then one; and a significant reduction in firewood demands consequent on the adoption of improved stoves. These findings provide further empirical confirmation of the points made in section 2 and above in this chapter, namely the importance of income, prices, backstops/substitutes and technology in jointly determining resource use.

and Tobit regressions, the more educated is the household (as measured by the variable edyrmax), the less wild fish it consumes.

4.4 Conclusion: The Complexity of the Commons at an Empirical Level

Naturally, we could continue this examination of the multiple determinants of environmental demands for each of environmental good in turn, demonstrating how different goods are affected in different ways by different variables. But the general point is clear, namely that the analysis of environmental resource demands reveals environmental goods to be a markedly heterogenous group. Recall that the theoretical analysis suggested that environmental resource demands can broadly be written as functions of income, prices and household structure. For each of these arguments in the demand function, empirical demand estimation suggests that environmental goods differ considerably. This evidence of resource differentiation was strongest with regard to income elasticities, as these are relatively easy to estimate on cross-section data. However, examination of individual resource demands in section 4.3 has suggested that differentiation is just as marked with regard to price effects (where these can be proxied) and household structure as well. Environmental goods are likely to have patterns of substitutes and complements which differ across goods, just as resource demands will be affected in different ways by changes in socio-economic conditions at the household level.

Thus environmental demand estimation supports the contention that it is difficult to make broad generalisations about the relationship between income and environmental change, in part because this relationship is varied and in part because there are many other determinants of environmental demands. Ultimately, the fact that natural environments offer a vector of environmental resource utilizations which differ in their economic characteristics implies that the commons is a complex place: as we noted earlier, any change in an exogenous parameter will affect environmental demands in a multiplicity of ways.

5. Evidence on Resource Differentiation From Other Studies

There is a substantial case study literature on rural households' environmental resource use in Zimbabwe, particularly relating to the use of woodland resources (for example Bradley and McNamara 1993 and various chapters in Campbell 1996), and this literature is much richer than that for many other African countries. While none of this is economic in orientation, so that there are no estimations of demand determinants of the type contained above, nonetheless it provides valuable further information on aspects of resource differentiation, especially concerning the determinants of supply and input demand functions that are not estimated in this paper.

5.1 Evidence on Socio-Economic Differentiation and Resource Use

Though other sources do not examine resource use within the context of the total household economy, there are narrower studies of environmental resource utilizations which support the points made above, that socio-economic differentiation can lead to significant differences in resource use and value. First, studies have documented differential resource use by certain groups. For example, studies of children in miombo areas have demonstrated how wild fruits, rodents, insects and birds can form a crucial source of foods for children from poorer households while at school (those from better off households being sent to school with food or money) or while herding (Campbell *et al* 1991, McGregor 1995). It is partly for this reason that children can display remarkable knowledge of the local woodland resource, with mental fruit tree maps and nicknames for the sweetest fruit trees (Wilson 1987). Similarly, a significant difference across gender has been found in the evaluation of shrinking woodland access, on account of the different resource demands of men as against women (Fortmann and Nabane 1992). In an echo of this point, it has also been found that widows and widowers, though both resource dependent, utilize quite different products, the former utilising fruits and grass, while the latter rely on hunting and fishing. Second, a number of studies have documented how the

Table 4.6 - OLS and Tobit Regressions for the Wild Fruit *Diospyros mespiliformis* (<u>suma</u>)

1. OLS

Variable	Coefficient	Standard Error	t-ratio	P[|T|=t]	Mean of X	Diagnostics	
Constant	0.11396E-02	0.73430E-03	1.552	0.12268			
LGX_N	-0.47489E-03	0.22171E-03	-2.142	0.03375	-0.7018	Adj. R^2	0.332
LGN	-0.26040E-03	0.30544E-03	-0.853	0.39522	1.736	d.w.	2.178
M05_14SH	0.19607E-02	0.81854E-03	2.395	0.01779	0.1509	F-stat (56, 156)	2.88
F05_14SH	0.14437E-02	0.96400E-03	1.498	0.13624	0.1520	B-P LM (56)	899.1
M15_54SH	0.14311E-02	0.91272E-03	1.568	0.11891	0.2052	J-B Wald (2)	203.8
F15_54SH	0.65218E-03	0.87421E-03	0.746	0.45677	0.2630	White (5)	0.89
M55PLSH	0.23510E-02	0.16101E-02	1.460	0.14625	0.2556E-01		
F55PLSH	0.18610E-02	0.13555E-02	1.373	0.17175	0.6107E-01	<u>Standardised Resid:</u>	
AGEHHHD	-0.23244E-04	0.14887E-04	-1.561	0.12047	44.78	Mean	-0.02
HHHDFLDF	-0.17192E-03	0.23708E-03	-0.725	0.46945	0.2019	St. Dev.	0.026
HHHDFLDJ	-0.57893E-03	0.30696E-03	-1.886	0.06115	0.1596	Skewness	-14.5
HHHDMMDV	-0.39500E-03	0.50951E-03	-0.775	0.43936	0.2347E-01	Kurtosis	210.0
EDYRMAX	-0.72355E-04	0.49271E-04	-1.469	0.14398	6.920		
EDHHHD4Y	-0.17980E-03	0.25264E-03	-0.712	0.47773	0.1455	No. of obs.	213
EDHHHDPL	-0.15000E-03	0.28466E-03	-0.527	0.59897	0.1315	No. of regressors	56
EDHHHDJC	-0.31074E-04	0.51337E-03	-0.061	0.95181	0.2347E-01		
TRHHMANG	0.93687E-04	0.55069E-04	1.701	0.09088	0.7136		
TRHHGUAV	0.21507E-03	0.10405E-03	2.067	0.04038	0.2582		
TRHHMULB	-0.27848E-03	0.16850E-03	-1.653	0.10040	0.1878		
TRFDMUPF	0.13009E-03	0.84860E-04	1.533	0.12732	1.296		
TRFDNYII	0.11586E-04	0.24789E-03	0.047	0.96278	0.9859E-01		
TRFDKWAK	0.73090E-05	0.83229E-04	0.088	0.93013	0.5211		
TRFDTAMB	-0.50438E-03	0.17978E-03	-2.806	0.00566	0.1362		
TRHHMUPF	0.89296E-03	0.35889E-03	2.488	0.01389	0.3803		
TRHHNYII	0.15205E-02	0.39385E-03	3.861	0.00017	0.3756E-01		
TRHHKWAK	0.97481E-03	0.50536E-03	1.929	0.05555	0.258	+ 28 village dummies	

2. Tobit (estimated, not marginal, coefficients)

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|=z]	Mean of X	Diagnostics	
Constant	0.70715E-03	0.92997E-03	0.760	0.44702			
LGX_N	-0.47576E-03	0.32708E-03	-1.455	0.14579	-0.7018	Log like.	899.5
LGN	-0.13607E-03	0.38166E-03	-0.357	0.72146	1.736	P-V LM (2)	0.8
M05_14SH	0.25688E-02	0.10739E-02	2.392	0.01676	0.1509	P-V LR (57)	0.9
F05_14SH	0.17405E-02	0.11274E-02	1.544	0.12263	0.1520		
M15_54SH	0.16659E-02	0.11033E-02	1.510	0.13107	0.2052		
F15_54SH	0.98390E-03	0.12405E-02	0.793	0.42771	0.2630		
M55PLSH	0.30051E-02	0.22119E-02	1.359	0.17427	0.2556E-01		
F55PLSH	0.14989E-02	0.14657E-02	1.023	0.30647	0.6107E-01		
AGEHHHD	-0.28160E-04	0.15103E-04	-1.865	0.06225	44.78		
HHHDFLDF	-0.21944E-03	0.34693E-03	-0.633	0.52706	0.2019		
HHHDFLDJ	-0.32042E-03	0.42205E-03	-0.759	0.44773	0.1596		
HHHDMMDV	-0.47997E-03	0.92867E-03	-0.517	0.60527	0.2347E-01		
EDYRMAX	-0.75094E-04	0.53029E-04	-1.416	0.15675	6.920		
EDHHHD4Y	-0.14808E-03	0.35546E-03	-0.417	0.67699	0.1455		
EDHHHDPL	-0.10605E-03	0.37546E-03	-0.282	0.77759	0.1315		
EDHHHDJC	0.71787E-04	0.76950E-03	0.093	0.92567	0.2347E-01		
TRHHMANG	0.11775E-03	0.84899E-04	1.387	0.16546	0.7136		
TRHHGUAV	0.31651E-03	0.14607E-03	2.167	0.03025	0.2582		
TRHHMULB	-0.30287E-03	0.24190E-03	-1.252	0.21056	0.1878		
TRFDMUPF	0.13703E-03	0.71655E-04	1.912	0.05584	1.296		
TRFDNYII	-0.42891E-04	0.36701E-03	-0.117	0.90697	0.9859E-01		
TRFDKWAK	-0.34910E-04	0.14312E-03	-0.244	0.80729	0.5211		
TRFDTAMB	-0.54958E-03	0.30849E-03	-1.781	0.07483	0.1362		
TRHHMUPF	0.92126E-03	0.15489E-03	5.948	0.00000	0.3803		
TRHHNYII	0.15870E-02	0.51027E-03	3.110	0.00187	0.3756E-01		
TRHHKWAK	0.95144E-03	0.16466E-03	5.778	0.00000	0.2582		
σ	0.14229E-02	0.76390E-04	18.627	0.00000		+ 28 village dummies not shown	

Table 4.7 - OLS and Tobit Regressions for the Wild Vegetable *Cucumis metuliferis* (muchacha)

1. OLS

Variable	Coefficient	Standard Error	t-ratio	P[|T|=t]	Mean of X	Daignostics	
Constant	0.75135E-02	0.33631E-02	2.234	0.02682			
LGX_N	-0.32034E-02	0.89570E-03	-3.576	0.00046	-0.7018	Adj. R^2	0.28
LGN	-0.51933E-02	0.15865E-02	-3.274	0.00129	1.736	d.w.	2.269
M05_14SH	0.78426E-02	0.37154E-02	2.111	0.03629	0.1509	F-stat (47, 165)	2.77
F05_14SH	0.11496E-01	0.47528E-02	2.419	0.01666	0.1520	B-P LM (47)	230.3
M15_54SH	0.11518E-02	0.36945E-02	0.312	0.75562	0.2052	J-B Wald (2)	131.5
F15_54SH	-0.33494E-02	0.45481E-02	-0.736	0.46251	0.2630	White (5)	12.10
M55PLSH	-0.72635E-03	0.57090E-02	-0.127	0.89891	0.2556E-01		
F55PLSH	-0.27323E-02	0.41727E-02	-0.655	0.51351	0.6107E-01	Standardised Resid.	
AGEHHHD	0.17410E-04	0.56645E-04	0.307	0.75896	44.78	Mean	0.00
HHHDFLDF	0.28706E-02	0.10877E-02	2.639	0.00911	0.2019	St.Dev.	0.00
HHHDFLDJ	-0.70610E-03	0.11400E-02	-0.619	0.53652	0.1596	Skewness	1.6
HHHDMMDV	-0.50559E-02	0.15780E-02	-3.204	0.00163	0.2347E-01	Kurtosis	8.1
EDYRMAX	0.29144E-03	0.20393E-03	1.429	0.15485	6.920		
EDHHHD4Y	-0.24299E-02	0.12866E-02	-1.889	0.06069	0.1455	No. of cases	213
EDHHHDPL	-0.42211E-02	0.11203E-02	-3.768	0.00023	0.1315	No. of regressors	47
EDHHHDJC	0.73247E-03	0.30852E-02	0.237	0.81263	0.2347E-01		
GARDENUS	-0.32990E-02	0.97368E-03	-3.388	0.00088	0.2160	+ 28 village dummies	

2. Tobit (estimated, not marginal, coefficients)

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|=z]	Mean of X	Diagnostics	
Constant	0.66206E-02	0.37849E-02	1.749	0.08025			
LGX_N	-0.37274E-02	0.13129E-02	-2.839	0.00452	-0.7018	Log like.	691.4
LGN	-0.58696E-02	0.16543E-02	-3.548	0.00039	1.736	P-V LM	1.1
M05_14SH	0.72062E-02	0.42065E-02	1.713	0.08669	0.1509	P-V LR	1.1
F05_14SH	0.12439E-01	0.43909E-02	2.833	0.00461	0.1520		
M15_54SH	0.20198E-02	0.43685E-02	0.462	0.64383	0.2052		
F15_54SH	-0.47268E-02	0.47961E-02	-0.986	0.32436	0.2630		
M55PLSH	-0.22487E-02	0.94911E-02	-0.237	0.81271	0.2556E-01		
F55PLSH	-0.43720E-02	0.56466E-02	-0.774	0.43877	0.6107E-01		
AGEHHHD	0.38061E-04	0.60868E-04	0.625	0.53178	44.78		
HHHDFLDF	0.33986E-02	0.13396E-02	2.537	0.01118	0.2019		
HHHDFLDJ	-0.10109E-02	0.16866E-02	-0.599	0.54891	0.1596		
HHHDMMDV	-0.80751E-02	0.39824E-02	-2.028	0.04259	0.2347E-01		
EDYRMAX	0.27168E-03	0.20048E-03	1.355	0.17537	6.920		
EDHHHD4Y	-0.22730E-02	0.13666E-02	-1.663	0.09627	0.1455		
EDHHHDPL	-0.47908E-02	0.15090E-02	-3.175	0.00150	0.1315		
EDHHHDJC	0.17661E-02	0.29938E-02	0.590	0.55524	0.2347E-01		
GARDENUS	-0.36818E-02	0.12266E-02	-3.002	0.00268	0.2160		
σ	0.57061E-02	0.29652E-03	19.243	0.00000		+ 28 village dummies not shown	

Table 4.8 - OLS Regressions for Annual and Quarterly Firewood Use

1. Annual Demands

Variable	Coefficient	Standard Error	t-ratio	P[|T|=t]	Mean of X	Diagnostics	
Constant	0.10327	0.91948E-02	11.231	0.00000			
LGX_N	-0.35576E-01	0.31561E-02	-11.272	0.00000	-0.7018	Adj. R^2	0.57
LGN	-0.31063E-01	0.36822E-02	-8.436	0.00000	1.736	d.w.	2.226
M05_14SH	-0.39871E-02	0.10267E-01	-0.388	0.69828	0.1509	F-stat (48, 164)	6.93
F05_14SH	0.10409E-02	0.10691E-01	0.097	0.92256	0.1520	B-P LM (48)	71.3
M15_54SH	-0.11365E-01	0.10149E-01	-1.120	0.26442	0.2052	J-B Wald (2)	43.6
F15_54SH	-0.44500E-02	0.11935E-01	-0.373	0.70974	0.2630	White (5)	20.33
M55PLSH	0.38041E-01	0.19007E-01	2.001	0.04700	0.2556E-01		
F55PLSH	-0.17520E-01	0.15175E-01	-1.155	0.24997	0.6107E-01	<u>Standardised Resid.</u>	
AGEHHHD	0.59246E-04	0.13393E-03	0.442	0.65880	44.78	Mean	0.00
HHHDFLDF	-0.76918E-02	0.31652E-02	-2.430	0.01617	0.2019	St. Dev.	0.88
HHHDFLDJ	0.97128E-02	0.44620E-02	2.177	0.03093	0.1596	Skewness	0.4
HHHDMMDV	-0.13221E-01	0.73917E-02	-1.789	0.07552	0.2347E-01	Kurtosis	3.4
EDYRMAX	-0.47514E-03	0.46791E-03	-1.015	0.31139	6.920		
EDHHHD4Y	-0.86983E-03	0.38361E-02	-0.227	0.82090	0.1455	No. of cases	213
EDHHHDPL	-0.81254E-03	0.32449E-02	-0.250	0.80259	0.1315	No. of regressors	49
EDHHHDJC	-0.30798E-02	0.99894E-02	-0.308	0.75824	0.2347E-01		
COLLMALE	-0.30960E-02	0.53335E-02	-0.580	0.56239	0.4225E-01		
FWCLFAIR	0.80553E-02	0.53406E-02	1.508	0.13340	0.5822		
FWCLHARD	-0.79748E-02	0.53823E-02	-1.482	0.14035	0.5164		
FWCLVHRD	-0.86112E-02	0.37749E-02	-2.281	0.02383	0.1737	+ 28 village dummies	

2. Quarterly Demands

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|=z]	Mean of X	Diagnostics	
Constant	0.24189E-01	0.27440E-02	8.815	0.00000			
LGX_N	-0.89607E-02	0.77797E-03	-11.518	0.00000	-0.7018	Adj. R^2	0.36
LGN	-0.78324E-02	0.93343E-03	-8.391	0.00000	1.736	d.w.	1.851
M05_14SH	-0.10579E-02	0.26428E-02	-0.400	0.68893	0.1509	F-stat (59, 792)	9.22
F05_14SH	0.53911E-03	0.28070E-02	0.192	0.84770	0.1520	B-P LM (59)	391.7
M15_54SH	-0.29945E-02	0.27148E-02	-1.103	0.27001	0.2052	J-B Wald (2)	509.6
F15_54SH	-0.10596E-02	0.29855E-02	-0.355	0.72266	0.2630	White (5)	26.93
M55PLSH	0.93435E-02	0.67139E-02	1.392	0.16402	0.2556E-01		
F55PLSH	-0.44309E-02	0.38690E-02	-1.145	0.25211	0.6107E-01	<u>Standardised Resid.</u>	
AGEHHHD	0.13878E-04	0.34964E-04	0.397	0.69142	44.78	Mean	1.99
HHHDFLDF	-0.19122E-02	0.73618E-03	-2.597	0.00939	0.2019	St. Dev.	1.25
HHHDFLDJ	0.23591E-02	0.11961E-02	1.972	0.04858	0.1596	Skewness	1.7
HHHDMMDV	-0.32383E-02	0.20314E-02	-1.594	0.11091	0.2347E-01	Kurtosis	7.7
EDYRMAX	-0.13911E-03	0.13637E-03	-1.020	0.30771	6.920		
EDHHHD4Y	-0.25874E-03	0.88511E-03	-0.292	0.77004	0.1455		
EDHHHDPL	-0.23420E-03	0.82672E-03	-0.283	0.77696	0.1315		
EDHHHDJC	-0.64207E-03	0.18883E-02	-0.340	0.73383	0.2347E-01		
Q2FWUSE	-0.50304E-03	0.60747E-03	-0.828	0.40761	0.2500		
Q3FWUSE	0.44329E-03	0.64292E-03	0.689	0.49051	0.2500		
Q4FWUSE	0.67159E-02	0.88068E-03	7.626	0.00000	0.2500		
CARTCOLL	0.26489E-02	0.19488E-02	1.359	0.17407	0.2465E-01		
DEADCUT	0.12802E-02	0.15068E-02	0.850	0.39554	0.3638E-01		
DEADFELL	-0.17820E-02	0.85762E-03	-2.078	0.03772	0.9742E-01		
COLLMALE	-0.10052E-02	0.13820E-02	-0.727	0.46700	0.4225E-01		
FWCLFAIR	0.16692E-02	0.15649E-02	1.067	0.28612	0.5822		
FWCLHARD	-0.15590E-02	0.16051E-02	-0.971	0.33140	0.5164		
FWCLVHRD	-0.20371E-02	0.96783E-03	-2.105	0.03530	0.1737		
FWSRCFLD	-0.39910E-02	0.21202E-02	-1.882	0.05979	0.1878E-01		
FWSRCRIV	0.12842E-03	0.16250E-02	0.079	0.93701	0.6103E-01		
FWSRCVLE	-0.33902E-02	0.16644E-02	-2.037	0.04167	0.7042E-02		
FWSRCPLN	0.73853E-04	0.81607E-03	0.090	0.92789	0.2113		
FWSRCRST	0.18799E-03	0.10787E-02	0.174	0.86165	0.8803E-01	+ 28 village dummies	

Table 4.9 - OLS and Tobit Regressions for Wild Fish

1. OLS

Variable	Coefficient	Standard Error	t-ratio	P[|T|=t]	Mean of X	Diagnostics	
Constant	0.12495E-01	0.53803E-02	2.322	0.02142			
LGX_N	0.20660E-02	0.15531E-02	1.330	0.18528	-0.7018	Adj. R^2	0.189
LGN	0.16854E-02	0.18813E-02	0.896	0.37163	1.736	d.w.	1.856
M05_14SH	-0.28579E-02	0.47857E-02	-0.597	0.55121	0.1509	F-stat (46, 166)	2.08
F05_14SH	-0.11597E-01	0.59431E-02	-1.951	0.05270	0.1520	B-P LM (46)	627.6
M15_54SH	0.24515E-02	0.59186E-02	0.414	0.67926	0.2052	J-B Wald (2)	231.1
F15_54SH	-0.49769E-02	0.49828E-02	-0.999	0.31934	0.2630	White (5)	1.79
M55PLSH	-0.12399E-01	0.20820E-01	-0.596	0.55230	0.2556E-01		
F55PLSH	-0.12557E-01	0.64873E-02	-1.936	0.05461	0.6107E-01	Standardised Resid:	
AGEHHHD	-0.82460E-06	0.84124E-04	-0.010	0.99219	44.78	Mean	0.02
HHHDFLDF	0.63643E-03	0.17229E-02	0.369	0.71231	0.2019	St. Dev.	0.86
HHHDFLDJ	0.73475E-03	0.19893E-02	0.369	0.71234	0.1596	Skewness	2.6
HHHDMMDV	0.24607E-01	0.16269E-01	1.513	0.13229	0.2347E-01	Kurtosis	17.4
EDYRMAX	-0.76322E-03	0.27384E-03	-2.787	0.00594	6.920		
EDHHHD4Y	-0.53812E-03	0.19084E-02	-0.282	0.77831	0.1455		
EDHHHDPL	-0.18581E-02	0.14955E-02	-1.242	0.21582	0.1315		
EDHHHDJC	-0.53326E-02	0.37739E-02	-1.413	0.15953	0.2347E-01	+ 28 village dummies	

2. Tobit (estimated, not marginal, coefficients)

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|=z]	Mean of X	Diagnostics	
Constant	0.15887E-01	0.97677E-02	1.626	0.10385			
LGX_N	0.51236E-02	0.31736E-02	1.614	0.10643	-0.7018	Log like.	241.4
LGN	0.66477E-02	0.40133E-02	1.656	0.09764	1.736	P-V LM (2)	34.6
M05_14SH	-0.11990E-01	0.11454E-01	-1.047	0.29518	0.1509	P-V LR (47)	31.9
F05_14SH	-0.23070E-01	0.11396E-01	-2.024	0.04294	0.1520		
M15_54SH	-0.50873E-02	0.11321E-01	-0.449	0.65317	0.2052		
F15_54SH	-0.16986E-01	0.11905E-01	-1.427	0.15365	0.2630		
M55PLSH	-0.80709E-02	0.20327E-01	-0.397	0.69133	0.2556E-01		
F55PLSH	-0.21385E-01	0.14993E-01	-1.426	0.15378	0.6107E-01		
AGEHHHD	-0.14179E-03	0.14959E-03	-0.948	0.34318	44.78		
HHHDFLDF	-0.30356E-02	0.34945E-02	-0.869	0.38501	0.2019		
HHHDFLDJ	0.32103E-02	0.40738E-02	0.788	0.43067	0.1596		
HHHDMMDV	0.30677E-01	0.77927E-02	3.937	0.00008	0.2347E-01		
EDYRMAX	-0.13363E-02	0.49761E-03	-2.685	0.00724	6.920		
EDHHHD4Y	0.12387E-02	0.33832E-02	0.366	0.71428	0.1455		
EDHHHDPL	-0.57017E-02	0.41865E-02	-1.362	0.17322	0.1315		
EDHHHDJC	-0.67696E-01	0.87372	-0.077	0.93824	0.2347E-01		
Õ	0.12179E-01	0.92625E-03	13.149	0.00000		+ 28 village dummies not shown	

same resource is used differently by different groups. In the case of firewood, while McGregor (1991) found that, at all times of the year, wealthier households use more firewood than poorer households, Campbell and Mangono (1994) found that this result is area-dependent: in deforested areas near cities, wealthier households are more likely to shift to purchased substitutes such as kerosene. Similarly, wealthier households usually use less construction wood than poorer households, as they can afford to shift to non-wood replacements. However, manure use - representing a transfer of nutrients from woodland to field - is positively correlated with income (Dewees 1992), as is the use of termitaria as a soil amendment (McGregor 1991).

5.2 Categorizing the Determinants of Resource Use

We saw theoretically in section 3 and empirically in section 4 that there are multiple determinants of resource use. This is reflected in the case study literature under review. For example, studies have found that variations in leaf litter use are not explained simply by wealth. Campbell and Nyathi (1993) established a positive correlation between leaf litter use and wealth in Masvingo, a finding replicated by Wilson (1990) in Mazvihwa. However Musvoto and Campbell (1995) found no correlation of this type in Mangwende, while in Shurugwi, poorer households were found to use leaf litter more (McGregor 1995). Explanation of these differences lies not just in socio-economic variation, but also in other factors. In Masvingo, where leaf litter is largely cured in cattle pens before use, and in Mazvihwa, where large volumes of leaf litter must be transported by cattle-drawn cart, quantities deployed will be positively correlated with cattle ownership and, in turn, wealth. In Mangwende, by contrast, leaf litter is mostly applied as a leaf mulch on gardens, an activity in which almost all households were involved. Finally, in Shurugwi, high levels of deforestation make leaf litter harder to find, with the result that wealthier households prefer other sources of fertiliser to leaf litter.

These examples support the theme of this paper concerning the importance of understanding resource differentiation in explaining systematically the determinants of resource use. In practice, though, few case studies cover the full range of these determinants, so that in the review that follows we use different case studies to illustrate different points. The focus is what these case studies have to say on three critical determinants of households' resource utilizations, namely income, wealth and household preferences; the costs of collection; and species substitutions and the existence of backstops. While each of these points is illustrated with reference to case studies from the environmental resource use literature, it should be remembered that these determinants interact in explaining any particular observation.

Wealth/income effects and household preferences
Section 4.2 dealt at length with the issue of the relationship between income and resource utilizations, and there is further evidence from case studies on this these. With regard to household composition, as households get richer they tend to get larger, both as a consequence of a man marrying more wives, each wife having more children, and wealthier households looking after dependents from other parts of the extended family. It is not surprising, then, to find the volume of firewood used increasing as household income rises (McGregor 1991), as more food must be prepared for richer households. Likewise, as rural households grow richer, so they enter riskier or higher-return activities and abandon others: such shifts in production activities will lead to a host of shifts in woodland resource uses, which are connected in different ways to different activities. For example, it is poor households which depend more on the sale of various gathered products than the rich (McGregor 1995). Of course, one of the most important assets in rural areas is cattle: as wealth rises, so too will demands for woodland-derived goods that are necessary for cattle maintenance and use (such as livestock graze and browse, wooden cart frames, poles for cattle kraals, yokes and skeys etc.) or complements to such uses, such as leaf litter to compost with manure (Campbell and Nyathi 1993).

Evidence on shifts in household preferences is anecdotal but suggestive. The importance of education in wild food demands regressions suggests that “modernity” reduces wild food demands. This is particularly true for those resources - such as the majority of edible insects, wild soda, roots and bulbs and certain wild leaf vegetables - which are frequently regarded as children's foods, or suitable only for the poor (Wilson 1990). Incidentally, wild food demands also differ inter-seasonally: during the late dry and early rainy seasons, when other sources of nutrients are scarce, wild fruit consumption is at its highest (Campbell 1987, Gumbo *et al* 1990, McGregor 1995). But there are other reasons for shifts in household preferences: some evangelical Christian sects ban the consumption of certain wild goods (such as insects, mice, fruit-based wines and traditional medicines) as "heathen" practices: the spread of these groups in rural areas is bound to have an impact on resource demands.

Environmental supplies and the costs of collection

The focus of the empirical work in this paper has been on the determinants of environmental demands. However, the case study literature also provides evidence on the determinants of environmental supplies, and how variations in these across households also lead to variations in resource use. Essentially, a chief concern for the rural household is how to allocate its labour time between a range of possible activities in order to get the highest returns. A major factor in deciding these returns will be the costs of undertaking each activity. Thus, an important determinant of the household's use of environmental resources will be the costs of collection: *ceteris paribus*, the higher these are, the less will be used, until at some point the household may withdraw from an activity altogether. However, the costs of collection are themselves related to a variety of factors, which we discuss in turn. These factors relate clearly to the theoretical model in section 3.

<u>Labour availability</u>

As most environmental resources are collected and processed predominantly using household labour, the availability (and opportunity cost) of such labour is one determinant of the cost to the household of collecting and using resources. Though the environmental literature has not in general been concerned with the connection between labour allocation and resource use, the point has been implicitly well-established by studies of seasonality in labour-intensive woodland resource use. Thus, the construction of housing, granaries, livestock pens, wood fencing etc. and (re)thatching overwhelmingly occurs in the dry season, when agricultural labour demands are at a minimum (Grundy *et al* 1993), as do other labour-intensive activities such as fishing and hunting. Similarly, as Wilson (1987) shows, the characteristics of firewood demands differ between seasons in response to changing (mostly female) labour scarcities. In the cold season, when agricultural labour demands are low, more time is spent searching for firewood, larger firewood pieces are collected, and the species desired are those which burn slowly and smokelessly, to warm people safely through the cold nights. By contrast, in the rainy season when agricultural labour demands are intense, firewood is collected opportunistically (for example while walking home from the fields), more twigs and small branches are collected, and the species desired are those which spark when wet and burn more intensively, as there is less time for cooking available.

<u>Harvesting and processing technologies</u>

A second determinant of the costs of collecting and using resources are the harvesting and processing technologies available to resource users: acquisition of these technologies can play an important role in explaining differentiation in resource use. The classic instance of this, which we mentioned previously, is the shift from headloading in firewood collection to transport by scotch cart (Campbell and Mangono 1994). Use of scotch carts allows greater volumes of firewood to be collected per visit than headloading, and allows greater distances to be travelled in the search for firewood, thereby expanding the potential woodland resource base economically available to a household. However, scotch cart acquisition can also have an impact on other resource utilizations. As noted above, Wilson (1990) relates variations in leaf litter use in Mazvihwa to scotch cart ownership, and a similar suggestion has been made by McGregor (1991) in explaining the lesser use of termitaria by poorer households. On another front, Arnold and Easton (1993) analyse forest-based enterprises in rural Zimbabwe, and demonstrate that the chief constraint to these enterprises' activities is not an adequate supply of woodland supplies, but rather access to tools, hardware and management skills. Acquisition of these production inputs can significantly alter production activities and woodland resource demands. A spectacular example of this point is given in Campbell *et al* (1995), concerning a truck-owning firewood trader in Jinga. Finally, there is anecdotal evidence that the absence of technologies for processing wild fruits is a cause of their decline in consumption relative to exotic fruits: Wilson (1987) records that the absence of nut-cracking technologies is responsible for a decline in the consumption of the fruits of *Sclerocarya birrea*, and the same factor may well explain the reduction in the frequency of wild fruit porridge meals observed by McGregor (1995).

Distances and spatial variation

Collection costs are also related systematically to distances to woodlands and spatial variation in woodland resource availability (though as we saw in the previous section, distance costs will be conditional on the type of technology available for transportation). Several studies have demonstrated the impact these factors have both on the pattern of woodland resource use and on the woodland itself. Grundy *et al* (1993) examined the spatial effects of fuel and construction wood use for 6 villages in Mutanda Resettlement Area, and showed how the number of live trees per hectare is positively correlated with the distance moved away from the village, suggesting that increased distance to woodland resources raises collection costs and thus mediates resource use. Likewise, Wilson (1987) working in Mazvihwa demonstrated that the existence and composition of households' firewood stocks is systematically related to the location of the household within the rural geography, so that the probability of a household establishing a firewood stock increased as the distance from a good quality woodland increased. Fortmann and Nabane (1992) found a clear relationship between spatial factors, gender and woodland resource use: thus, for the same type of product, women were significantly more likely to use homestead- and field-sourced resources, reflecting their work primarily as agricultural producers and domestic workers and hence the lower distance costs of collecting from these areas. Finally, studies of woodland change over long periods (Wilson 1987, Scoones 1990) have shown the importance of national government interventions through reorganization of the settlement pattern of villages across ecological zones for the distribution of Communal Area woodlands, resulting in localised patterns of scarcity and surplus as a consequence of changing distance costs of collection and hence of resource utilizations.

Resource scarcity

A final determinant of collection costs is changing resource availability. As resources become more scarce, so collection costs rise and, in response, households may alter their patterns of resource use in a variety of ways. The most extensive documentation of this effect comes from the substantial literature on firewood use and deforestation: a summary of the various ways in which households have been found to change practices in response to rising scarcity and costs is contained in Bradley and McNamara (19??). Some of these involve species substitutions and the transition to backstops, which we discuss below. However, others involve changed practices (lowering grates, extinguishing embers, building windbreaks) which can bring improvements in the technical efficiency of resource use of up to 50 percent: actions that were not economical beforehand become so as firewood becomes more scarce. As a result, as Hancock (1990) shows, household firewood consumption can be reduced by 40 percent. Rising scarcities as the cause of changing resource use practices have been found elsewhere as well. McGregor (1995) explains the shift in household consumption of wild vegetables from vlei-based species to field-based in Shurugwi as a consequence of a dramatic reduction in the latter's availability. The same study suggests that decreased per capita availability of wild fruits has led to more thorough harvesting and the creation of secret holes for burying and ripening fruit.

Species substitutions and the existence of backstops

In section 3.3, the theoretical importance of species substitutions and the existence and costs of backstops as potential determinants of environmental demands was discussed, and examples there were given of wild foods and of firewood versus construction wood. Econometric evidence was also presented on these effects when discussing the individual demand regressions for suma and muchacha in section 4.3. However, the point is quite general. For example, there are a variety of durable goods that many rural households make from wood, including carts, doors, furniture, mortars and pestles, yokes, agricultural implements and so. The smaller of these can usually be made from a wide range of species, while the larger durables use a more restricted set. However, given the generally high costs of purchased backstops (equivalent durables sold in stores), it is the resource demands for larger durables that may result in greater stress on certain species.[29]

There are some cases where the introduction of an preferred backstop which is a substitute in consumption has considerably affected resource demands: a case in point is McGregor's (1995) observation that the spread of exotic leaf vegetables has reduced demand for wild vegetables. Of course, the extreme case of this is where the provision of a cheap backstop completely replaces an older woodland resource use. This seems to have happened with the use of bark from *Adansonia digitata* to make clothing, the use of tree-based glues, the use of wild soda (from *Sclerocarya birrea* and *Tabernaemontana elegans)* and the use of bark to make fishing lines, all of which have declined in the face of cheap, preferred, purchased substitutes.[30] But the reverse can also occur: that is to say, when a consumption-substitute becomes harder to acquire, the demand for wild resources can rise in consequence. This is essentially what happens during a drought or during seasonal scarcities: the price of purchased foods rises, and in response people increase their demands for wild resources (Wilson 1990, Zinyama *et al* 1990). A similar framework can be used to explain Scoones' (1989) observations of inter-seasonal rangeland patch grazing by cattle: herders switch cattle between woodland browsing, grassland grazing, crop residue consumption and vlei feeding according to the relative availabilities (or "prices") of these resources.

It is possible that a final case of species substitutions and backstop utilizations is the widely-observed planting of exotic fruits and the preservation of wild fruit trees. There is a considerable literature on this in Zimbabwe (see *inter alia* du Toit *et al* 1984, Campbell 1987, Wilson 1989, Gumbo *et al* 1990, Fortmann and Nhira 1992, Campbell *et al* 1993), of which the findings are well-known: that extensive planting of exotic fruit trees and less extensive planting of eucalypts (both investments in backstops) has occurred in rural Zimbabwe, and that preservation of favoured indigenous fruit trees has maintained species numbers in the face of continuous deforestation. However, there is insufficient evidence on the economics either of tree planting or of low-cost tree preservation to say more on this issue (Dewees 1992).

6. Conclusion: Rural Households and Multiple Environmental Resources

In the introduction, we asserted that much of the poverty-environment literature is mistaken as it ignores two vital characteristics of natural habitats in rural Africa, namely that natural resources offer rural households multiple environmental goods, and that these goods are significantly differentiated in economic terms. Taking these characteristics seriously at a theoretical level, and providing econometric and case study support for them, has been the purpose of the paper. In theoretical terms, then, we concluded that it is important to recognise that there is a multiplicity of determinants of environmental resource utilisations: it is not just the fact that income elasticities for environmental goods may vary substantially across goods, but also that

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[29] The impact of wood demands to make large durables on certain specific tree species is made more intense due to two other factors. The first is that the preferred woods for making many large durables are frequently the same species. Of the large durables (wooden beds, wardrobes, tables, chairs, scotch cart, drawers and wooden trolleys) owned by Shindi households in 1993/94, all were made from just two species, namely *Afzelia quanzensis* (<u>mukamba</u>) and *Pterocarpus angolensis* (<u>mukwa</u>). Second, on account of the volume of wood that constitutes these large durables, whole trees were required to be cut down to make them. By contrast, smaller items were made from a much wider variety of species - for example, yokes were made from ten species, skeys from twelve, hoe handles from twenty one, stools from seventeen and so on - and these species are not all the same as each other. Also, many of these smaller items can be made from single branches so that a whole tree does not need to be cut down to satisfy these resource demands.

[30] For a comprehensive description of the range of pre-colonial artefacts made in Zimbabwe, many of them from miombo woodland resources and most of which have disappeared, see Ellert (1984).

different goods will have different patterns of substitutes and complements both amongst environmental goods and between environmental goods and other, more “normal” goods. Econometric results from environmental demand regressions supported these conclusions. Estimated income elasticities differ across goods and species, and there is clear evidence that other demand determinants such as species substitute and backstops, scarcity and household structure also affect different goods in different ways. We also examined the case study literature on rural households’ resource use in Zimbabwe, and suggested that the range of findings in this literature also demonstrated that both environmental demands and environmental supplies are affected by a number of different factors. In conclusion, we suggest that the commons is a complex place: environmental resource use and hence also environmental change will be driven by a multiplicity of factors, and these factors can differ quite considerably across different species and resources. In consequence, simplistic conceptions of the link between rural households and the environment will be quite wrong.

Discussion

We believe these findings to be important and new. However, we end by asking the question - what can we conclude from the work of this paper about the full causes of environmental change? Perhaps it is useful here to conduct a (somewhat limited) thought experiment concerning the impact of development on the environment. In a very narrow sense, we can characterise the process of development as one of rising personal incomes. What impact might this have on environmental resources? The fact that income elasticities differ across environmental demands implies that some resource demands will intensify while others - such as inferior foods - will tend to zero. So if resource change was driven solely by the level of resource demands, we could highlight the resources under threat and put in place economic mechanisms aimed at conservation. However, as we have seen at various stages of our analysis, the dynamics of resource change are not driven by demand factors alone. Rather, if a full understanding of resource change is desired, such demand factors would need to be integrated with at least four other factors which together will jointly determine the relationship between resource use and resource change. And crucially, environmental resources are as equally differentiated in terms of these other factors as they are in income elasticity terms.

The first was discussed in section 5, namely the household supply of environmental goods. Changes in overall economic conditions and in resource demands will affect the determinants of environmental goods supplies, such as costs, technologies and spatial choices, in ways that will differ across environmental goods. Second, there is the response of local communities to changes in the size of the open access externality consequent on levels of environmental goods' household demands and supplies. As we suggested when discussing the static environmental production function, the demand function estimates are all conditional on a given level of the open access externality:[31] but as this changes we can expect communities to change the institutions governing access to the different resources they use. There is no reason to expect that these institutions will all change in the same way given that environmental demands and supplies are so economically differentiated, implying quantitatively differentiated changes in aggregate use for each resource type. Third, there is the fact that resource uses have different impacts on resource stocks for different environmental resources. Some resource utilizations are benign; some have a neutral impact on resource stocks; and some resource utilizations have a destructive impact. (Recall that these differentiated resource impacts were also discussed in section 3.1 when examining the difficulties of incorporating feedback effects into the environmentally-augmented household model). So in moving from resource use to resource impact, we would need to be incorporate these differentiated feedback effects for different resource utilizations. Finally, species differ in their autoecology, in other words they differ in their response to resource impact, and ecosystems as a whole differ in dynamic characteristics such as their stability and interconnectedness. So the overall change in the availability of environmental resources in response to a given resource impact will vary both across species and across ecosystems.

[31] I am grateful to Tim Besley for drawing my attention to this point.

In conclusion, then, a full understanding of resource change would require theoretical and empirical modelling using a joint economic-ecological approach. On the one hand this would need to integrate household environmental demands, household environmental supplies and community management responses to generate an understanding of resource use (the economic side); this resource use would then need to be related to resource change through integrating the link between resource use and resource impact, and the response of both species and the ecosystem to disturbance, so as to generate an understanding of resource change (the ecological side). This is why earlier we suggested that the commons is a complex place: environmental resource use and hence also environmental change will be driven by a multiplicity of factors, and these factors can differ quite considerably across different species and resources. In this paper, we have made important inroads into this problem through an investigation of the economic side of environmental change. However, if a full understanding of environmental change is desired in areas where rural households use multiple, differentiated resources, much work remains to be done.

Bibliography

Amacher,G.S., Hyde,W.F. and Joshee,B.R. (1993) Joint production and consumption in traditional households: fuelwood and crop residues in two districts in Nepal. *Journal of Development Studies* 30(1), 206-25.

Arnold,J.E.M. (1992) *Community forestry: ten years in review*. FAO, Rome.

Arnold,M. and Easton,J. (1993) Forestry industry development and supply of industrial wood. In Bradley,P.N. and McNamara,K. (eds.) *Living with trees: policies for forestry management in Zimbabwe.* World Bank Technical Paper No.210, World Bank, Washington DC. pp.243-304.

Benjamin,D. (1992) Household composition, labor markets and labor demand: testing for separation in agricultural household models. *Econometrica* 60(2), 287-322.

Bradley,P.N. and McNamara,K. (eds.) (1993) *Living with trees: policies for forestry management in Zimbabwe*. World Bank Technical Paper No.210, World Bank, Washington DC.

Brouwer,I.D., Hoorweg,J.C. and Van-Liere,M.J. (1997) When households run out of fuel: responses of rural households to decreasing fuelwood availability, Ntcheu District, Malawi. *World Development* 25(2), 255-66.

Bojö,J. (1993) Economic valuation of indigenous woodlands. In Bradley,P.N. and McNamara,K. (eds.) *Living with trees: policies for forestry management in Zimbabwe*. World Bank Technical Paper No.210, World Bank, Washington DC. pp.227-241.

Campbell,B.M. (1987) The use of wild fruit in Zimbabwe. *Economic Botany* 41, 375-385.

Campbell,B.M., Vermeulen,S.J. and Lynam,T. (1991a) *The role and value of trees in the small-scale farming sector of Zimbabwe*. Mimeo, University of Zimbabwe, Harare. pp.41.

Campbell,B.M., Vermeulen,S.J. and Lynam,T. (1991b) *Value of trees in the small-scale farming sector of Zimbabwe*. IDRC-MR302e, International Development Research Centre, Ottawa.

Campbell,B.M., Grundy,I. and Matose,F. (1993) Tree and woodland resources - the technical practices of small-scale farmers. In Bradley,P.N. and McNamara,K. (eds.) *Living with trees: policies for forestry management in Zimbabwe*. World Bank Technical Paper No.210, World Bank, Washington DC. pp.29-62.

Campbell,B.M. and Mangono,J.J. (1994) *Working towards a biomass energy strategy for Zimbabwe*. University of Harare. 93pp.

Campbell,B.M., Clarke,J., Luckert,M., Matose,F., Musvoto,C. and Scoones,I. (1994) *Local level economic valuation of savanna woodland resources: village cases from Zimbabwe*. Mimeo, University of Zimbabwe. 118pp.

Campbell,B.M (ed.) (1996) *The miombo in transition: woodland and welfare in Africa*. CIFOR, Bogor, Indonesia.

Cavendish,W.P. (1997) *The economics of natural resource utilisation by Communal Area farmers of Zimbabwe*. Submitted D.Phil., University of Oxford.

Chidumayo,E.N. (1993) *Responses of miombo to harvesting: ecology and management*. Energy, Environment and Development Series No.24, Stockholm Environment Institute, Stockholm.

Clark,C.W. (1990) *Mathematical bioeconomics*. John Wiley, New York. 2nd edition.

Dasgupta,P. (1993) *An enquiry into well-being and destitution*. Clarendon Press, Oxford.

Davies,A.G. and Richards,P. (1991) *Rainforest in Mende life*. ODA, London.

Deaton,A. (1991) Savings and liquidity constraints. *Econometrica* 59(5), 1221-48.

Deaton,A. (1996) *Microeconometric analysis for development policy: approach to analyzing household surveys*. Johns Hopkins University Press, Baltimore.

Deaton,A. and Muellbauer,J. (1980) *Economics and consumer behaviour*. Cambridge University Press, Cambridge.

Dewees,P.A. (1992) *Household economy, trees and woodland resources in Communal Areas of Zimbabwe*. Mimeo, Oxford Forestry Institute, University of Oxford, Oxford. 85pp.

Duraiappah,A. (1996) *Poverty and environmental degradation: a literature review and analysis.* CREED Working Paper Series No.8, IIED, London.

du Toit,R.F., Campbell,B.M., Haney,R.A. and Dore,D. (1984) *Wood usage and tree planting in Zimbabwe's Communal Lands*. Forestry Commission of Zimbabwe, Harare.

Ellert,H. (1984) *The material culture of Zimbabwe*. Longman Zimbabwe, Harare. 133pp.

Falconer,J, and Arnold,J.E.M. (1991) *Household food security and forestry: an analysis of socio-economic issues*. FAO, Rome.

FAO (1985) *Tree growing by rural people*. FAO, Rome.

Fortmann,L. and Nabane,N. (1992) *The fruits of their labours: gender, property and trees in Mhondoro District*. Centre for Applied Social Studies, University of Zimbabwe. 47pp.

Fortmann,L. and Nhira,C. (1992) *Local management of trees and woodland resources in Zimbabwe: a tenurial niche approach*. OFI Occasional Working Paper, Oxford Forestry Institute, University of Oxford. 34pp.

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

Grundy,I.M., Campbell,B.M., Balebereho,S., Cunliffe,R., Tafangenyasha,C., Fergusson,R. and Parry,D. (1993) Availability and use of trees in Mutanda Resettlement Area, Zimbabwe. *Forest Ecology and Management* 56, 243-266.

Gumbo,D.J., Mukamuri,B.B., Muzondo,M.I. and Scoones,I.C. (1990) Indigenous and exotic fruit trees: why do people want to grow them? In Prinsely,R.T. (ed.) *Agroforestry for sustainable production: economic implications*. Commonwealth Science Council, London. pp.185-214.

Hancock,D. (1990) *Stoves, trees and how people manage and use energy supplies*. Mimeo, ZERO, Harare.

Hausman,J.A., Newey,W.K. and Powell,J.L (1991) Nonlinear errors in variables: estimation of some Engel curves. *Journal of Econometrics* 65, 205-233.

Iqbal,F. (1986) The demand and supply of funds among agricultural households in India. In Singh,I., Squire,L. and Strauss,J. (ed.) *Agricultural household models: extensions, applications and policy.* Johns Hopkins University Press, Baltimore. Ch.6, 183-205.

Lampietti,J.A. and Dixon,J.A. (1994) *A guide to non-timber forest benefits*. Mimeo, Environment Department, World Bank, Washington DC.

Lewbel,A. (1991) The rank of demand systems: theory and non-parametric estimation. *Econometrica* 59(3), 711-730.

McGregor,J. (1991) *Woodland resources: ecology, policy and ideology*. Unpublished Ph.D. thesis, Loughborough University of Technology, Loughborough.

McGregor,J. (1995) Gathered produce in Zimbabwe's Communal Areas: changing resource availability and use. *Ecology of Food and Nutrition* 33, 163-193.

McKay,A. and Taffesse,A.S. (1994) *Rationing and peasant househood behaviour*. CSAE Working Paper Series WPS/94.9, CSAE, Oxford.

Musvoto,C. and Campbell,B.M. (1995) Mango trees as components of agroforestry systems in Mangwende, Zimbabwe. *Agroforestry Systems* 32, 247-60.

Nyathi,P. and Campbell,B.M. (1993) The acquisition and use of miombo litter by small-scale farmers in Masvingo, Zimbabwe. *Agroforestry Systems* 22, 43-48.

Parkin,D. and Croll,E. (eds.) (1992) *Bush base, forest farm: culture, environment and development.* Routledge, London.

Pudney,S. (1989) *Modelling individual choice: the econometrics of corners, kinks and holes.* Basil Blackwell, Oxford.

Scoones,I. (1989) Patch use by cattle in a dryland environment: farmer knowledge and ecological theory. In Cousins,B. (ed.) *People, land and livestock*. Centre for Applied Social Studies, University of Zimbabwe, Harare. pp.277-309.

Scoones,I. (1990) *Livestock populations and the household economy: a case study from southern Zimbabwe*. Ph.D. Thesis, University of London.

Scoones,I., Pretty,J.N. and Melnyk,M. (1992) *The hidden harvest harvest: wild foods in agricultural systems. A bibliography and literature review*. IIED, London.

Townson,I.M. (1994) *Forest products and household incomes: a review and annotated bibliography*. Oxford Forestry Institute, Oxford.

Wilen,J.E. (1985) Bioeconomics of renewable resource use. In Kneese,A.V. and Sweeney,J.L. (eds.) *Handbook of natural resource and energy economics, Vol. I*. Elsevier, Amsterdam.

Wilson,K.B. (1987) *Research on trees in the Mazvihwa and surrounding areas*. Report prepared for ENDA, Zimbabwe. 69pp.

Wilson,K.B. (1989) Trees in fields in southern Zimbabwe. *Journal of Southern African Studies* 15(2), 369-383.

Wilson,K.B. (1990) *Ecological dynamics and human welfare: a case study of population, health and nutrition in southern Zimbabwe*. Ph.D. Thesis, University College, London.

Zinyama,L.M., Matiza,T. and Campbell,D.J. (1990) The use of wild foods during periods of food shortage in rural Zimbabwe. *Ecology of Food and Nutrition* 24, 251-265.

Appendix I - A Description of the Research Area and of Data Collection Procedures

The data underlying this study were collected by the author during a 13 month period of fieldwork (August 1993 to September 1994) in Shindi Ward, Chivi Communal Area, Zimbabwe. Shindi Ward is located in the South East of Zimbabwe in NR IV, and is an area of some 200 km^2 comprised of 30 villages under the chieftainship of Chief Shindi. To the north and west, Shindi is border by Gororo and Madzivire Wards, also in Chivi CA. To the east, Shindi is bordered by a well-wooded resettlement area: though acquisition of environmental resources is illegal from the resettlement area, breaches of this ban are common. Shindi has an irredentist land claim over this area. The southern border of Shindi follows the Runde River, a major watercourse which serves as a source of gold and fish, though once again both these activities are illegal. Directly south of the Runde is a set of large, commercial, white-owned farms, on which some Shindi people are legally employed and on which some Shindi people illegally hunt game animals.

In terms of its economic status, Shindi is typical of the Communal Areas delineated in the accompanying chapter: that is to say, it is poor, lacks basic infrastructure (no tarred roads, water supply or electricity), its agricultural system is agro-pastoral (or hoe-based where people have no large livestock), and remittances from non-Shindi sources play an important role in supporting the local economy. In terms of its physical and resource characteristics, it is important to stress given the concerns of this study that Shindi is not an untouched, resource-abundant area. Rather, it has been settled for a long period of time and since the 1950s there has been substantial growth in the settled population both from natural increase and due to the resettlement in Shindi of whole villages from other parts of Zimbabwe. In consequence, the environmental resource base has been much reduced in the last 40 years: for example, although some plains woodlands (<u>dondo</u>) exist, the bulk of remaining woodlands are refuge woodlands on mountains, on kopjes and along riverine areas. In floristic terms, Shindi is in the miombo zone, so that the dominant species in natural woodlands are *Brachystegia spiciformis* (<u>musasa</u>), *B. glaucescens* (<u>muuzhe</u>) and *Julbernadia globiflora* (<u>mutondo</u>): however, it is on the edge of this zone, and hence mopane woodland species such as *Colophospermum mopane* (<u>mupani</u>) and *Adansonia digitata* (<u>muuyu</u>) are also found. In terms of its soils, Shindi is characterised by predominantly sandy soils (<u>jecha</u>), but these are interlaced with smaller patches of more fertile black soils (<u>dema</u>) and red soils (<u>chiumbwa</u>): soil patterning occurs at the scale of the individual field.

The quantitative data were collected using household-based questionnaires, administered in chiKaranga (the local variant of Shona) by a team of six local enumerators trained and supervised by the author. In the absence of an official census, in order to generate a sample of households a household roster was compiled by asking each village headman to name all the household heads under their authority: this information was rechecked and updated at the end of the fieldwork period.[32] 1,092 households were listed by this procedure under 29 villages, and a 1-in-5 random selection was made of these to generate a 218 household sample. Of these 218 households, a mere 5 dropped out over the course of the year, all due to household dissolution or migration, leaving 213 households for which a full set of data is available. The questionnaire used was of the Income, Consumption and Expenditure (ICE) type: however, a number of modifications were made to fit the particular requirements of this research. First, income, expenditure and agricultural categories were matched directly to the restricted set of possibilities available to Shindi households elicited by a pre-questionnaire local listing of these items (for an example of a typical questionnaire, see Appendix I). Second, the four quarterly surveys were augmented by beginning- and end-of-period surveys on demographics and household assets, including livestock. Third, the standard ICE framework was expanded to include special sections on the quantitative use of environmental resources. Fourth, best recall periods for each questionnaire item were investigated locally, and the questionnaires designed accordingly. Fifth, a range of special questionnaire modules were added focusing on specific environmental utilizations, for example fuelwood collection and storage, housing and construction, tree planting, fields and environmental improvements, fencing, agricultural risk etc. Thus, in all eight questionnaire rounds were completed during the fieldwork period.

Comprehensive cross-checking was built into the research programme. Within-questionnaire cross-checks were included to show up respondent inconsistency and enumerator error, whether in questioning or recording the data. Across-questionnaire cross-checks were included again to reduce respondent inconsistency and also to control for the inability to interview the same household member at each visit. Random follow-ups were undertaken in each questionnaire round to check the translation of questions into the vernacular and to monitor the enumerators. Perhaps most valuably, an extensive range of qualitative information was collected as a supplement to the questionnaires. This took the form of interviews with groups of resource users,[33] with local authorities, whether traditional (chiefs and headmen) or modern, and with local historians and elders; life history work; collection of aerial photographs; resource walks; work in the National Archives in Harare; and a species listing and species questionnaire sheet on ecology, use and distribution for roughly 200 different local trees and grasses.

[32] Relying on village headmen had the unfortunate drawback of missing out one small village, Makokwe, whose headman had been absent for many years but who had not yet chosen a replacement.

[33] Carpenters, weavers, potters, gold panners, herders, traditional healers and children.

Appendix II - Long List of Environmental Resource Utilizations in Shindi

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
1. Food and Drink				
Wild fruits	Mabaribari	Mubaribari	*Margaritaria discoidia*	
		Mubhubhunu	*Grewia spp*	
	Mabikasadza	Mubikasadza	*Rhus chirindensis*	
	Chakata	Muchakata	*Parinari curatellifolia*	
	Checheni	Muchecheni	*Ziziphus mucronata*	
	Chechete	Muchechete	*Mimusops zeyheri*	
	Gan'acha	Mugan'acha	*Lannea discolor*	
	Humbakumba	Muhumbakumba	*Bridelia mollis*	
	Hute	Muhute	*Syzygium guineense subsp. guineense*	
		Mukashu	*Tabernaemontana elegans*	Toad-fruit. Eat flesh surrouding the seeds.
	Kosvo	Mukosvo	*Artabotrys brachypetalus*	
	Kudende	Mukudende	*Syzygium guineense subsp. afromontanum*	
	Makwakwa	Mukwakwa	*Strychnos madagascariensis*	
	Mbambara	Mumbambara	*Carissa edulis*	
	Nhengeni	Munhengeni	*Ximenia caffra*	
	Nhunguru	Munhunguru	*Flacourtia indica*	
		Munyambo	*Manilkara mochisia*	
	Nyani	Munyani	*Friesodielsia obovata*	Yoghurt taste
	Nyii	Munyii	*Berchemia discolor*	Used to be stored
	Nzviru	Munzviru	*Vangueria infausta*	
		Munzvirubota	*Vangueria randii*	
		Munzvirupesu	*Lagynias dryadum*	
	Maonde	Muonde	*Ficus spp.*	
		Muondepasi	*Ficus sur*	
		Mupawa, mutove	*Ficus thonningii*	
	Bvura (mapf-)	Mupfura	*Sclerocarya birrea*	
		Mupimbi	*Garcinia livingstonei*	
	Maroro	Muroro	*Annona senegalensis*	Very rare in Shindi
	Masakama	Musakama	*Hexaglobus monopetalus*	
	Sambarahwahwa	Musambarahwahwa	*Antidesma venosum*	
	Sekesa (ma-)	Musekesa	*Bauhinia thonningii*	
		Mushangura	*Euclea natalensis*	
	Shavhi	Mushavhi	*Ficus spp.*	
		Musiyaseu	*Bridelia cathartica*	
	Sosoti	Musosoti	*Securinega virosa*	
	Suma	Musuma	*Diospyros mespiliformis*	
		Musvimwa	*Lannea schweinfurthii*	
	Svita	Musvita	*Ficus spp.*	
	Damba (mat-)	Mutamba	*Strychnos cocculoides*	
	Dohwe (mat-)	Mutohwe	*Azanza garckeana*	
	Tsubvu	Mutsubvu	*Vitex mombassae*	
	Tsvanzva	Mutsvanzva	*Bequaertiodendron megalismontanum*	
	Mauyu	Muuyu	*Adansonia digitata*	
		Muvambangwena	*Combretum paniculatum*	Eaten especially by herdboys
		Muyambukira	*Rhoicissus revoilii*	Fruit not very nice
		Muzambiringa	*Ampelocissus africana*	Only eaten by children
		Muzumi	*Strychnos sp.?*	Tree very rare in Shindi
Insects		Chidhongoti		Available Jan-Feb
		Chikugwemuroi		Black cricket. Eaten in drought
		Dhumbudya (ma-)	*Ruspolia differens?*	Green grasshopper. Available Jan-Dec
		Dora (ma-)		General term for edible caterpillar
		Gandari (ma-)	*Coimbrasia belina?*	Edible caterpillar on mupani, musasa. Jan-Feb
		Gugwe (mak-)	*Bracytrypes membranaceus*	Large sand cricket. Available Feb-Mar
		Harati	*Cirina forda?*	Edible caterpillar on mukarati. Dec-Jan.
		Harungwa		
		Ishwa		Flying stage of the termite

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
		Juru (ma-)	*Macrotermes spp.?*	Soldier termites. Aug-Nov
		Mhashu	*Cystocanthoseris?*	Grasshopper, locust
		Mise		Available Mar-May
		Nyenze, nyezhe		Cicada. Oct-Nov. Lives on mugaranyenze
		Sambarafuta	*Carebara videa?*	Large, edible flying ant. Nov-Dec
		Shwarara		Available Nov-Dec
Fish	Hove	Hunga		Eel
		Makwaya	*Oreochromis spp.?*	Bream
		Maruru		Red-spotted mudsucker
		Mhatye/muramba		Barbel
		Mhumbu		Mud-sucker
		Shawi		
		Sinde		Minnow
Game meat		Gudo		Baboon, very rarely eaten
		Jachacha		Civet cat
		Mbira		Dassie (=rock rabbit)
		Mbizi		Zebra
		Mhara		Impala
		Mhembwe		Duiker
		Mhofu		Eland
		Ngururu		Klipspringer
		Nhoro		Kudu
		Njiri		Warthog
		Shindi		Squirrel. Much eaten in the past, but now rare
		Shoko		Monkey. Few people eat this
		Simba		V. rarely eaten, though you still see skins
		Siriri		Larger than mbira, long tail with white end
		Soma		V. rarely eaten
		Tsuro		Hare
Mice	Mbeva			General name for edible mouse or rat
Honey	Uchi			
Nuts	Hwakwa	Mukwakwa	*Strychnos madagascariensis*	
	Mahuhu	Muchakata	*Parinari curatellifolia*	Edible seed in nut
	Shomwe	Mupfura	*Sclerocarya birrea*	Edible seed in nut, sold for 50c per cup
Vegetables	Chidoverere			
	Chikumbo chenjiva			
	Chikwemechembudzi			
	Chinungu			Variety of wild spinach
	Dambatamba		*Commelia africana*	Eaten in drought
	Derere, gusha		*Corchorus olitorius*	Bush okra. Eaten in drought, not planted
	Dumburedhongi, mudhongi			"Stomach of the donkey"
	Dzvengetsvenge		*Sonchus oleraceus?*	Eaten in drought
	Jayarefu/mujayamurefu			
	Mhapayavagororo			Has almost disappeared
	Mowa		*Amarynthus thunbergii*	
	Mowagomo			Eaten in drought
	Mowashiri			Eaten in drought
	Mubogobogo			Eaten in drought
	Muboora		*Cucurbita pepa*	When dried is called mukata
	Muchacha		*Cucumis metuliferus*	
	Muchongwe			Eaten in drought
	Mudhuvura			Eaten in drought
	Mudyamvuu, mubooragwizi		*Alternanthera sessilis*	"Food of the hippo"
	Mudyavanguvo			
	Mukake			
	Munda, mundanda			Eaten in drought, found at rivers
	Munhangavave			Eaten in drought
	Munhenzva		*Asclepias densiflora*	
	Munhori			Eaten in drought
	Munyemba, mundumba		*Phaseolus vulgaris*	

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
	Munyembahude			Found in fields & mountains
	Mupombera			
	Mupundepunde			Eaten in drought
	Musemwasemwa		*Cleome monophylla*	Eaten in drought
	Mushamba		*Citrullus lanatus*	Grows naturally
	Musungusungu		*Solanum nigrum*	Nightshade. Eaten in drought
	Mutsvangandima			Eaten in drought
	Mutyavanguvo			Eaten in drought
	Muvhunzandadya		*Chenopodium album*	Eaten in drought
	Nyovhi, rudhe		*Gynandropsis gynandra?*	
	Rujongwe		*Wormskoldia longepedunculata*	
	Ruvendekete			
	Soso		*Dicerocaryum zanguebarium*	Ground creeper. Eaten in drought
	Zunguma/muvhunguma			Leaves eaten in drought, but v. bad smell
Mushrooms	Howa	Chambwe		Mushrooms available in wet season
		Chidyavashe		
		Dindindi	*Boletus edulis*	
		Firifiti	*Canthorellus longisporus*	
		Howachuru		
		Howamusasa		
		Nhedzi	*Amanita zambiana*	
		Nzeve, zheve	*Cantharellus densifolius*	
		Rimiren'ombe		
		Shapfugwi		
		Zongororo		
		Zvukwezvukwe	*Cantherallus spp?*	Found on termitaria
Birds		Chidhidhii		Quelea?
		Chigogodza		Woodpecker?
		Chikwari		Francolin?
		Gwenhure (ma-)		Black-eyed bulbul?
		Hanga		Helmeted guinea-fowl?
		Husvu		Red-shouldered glossy starling?
		Nhengure		Fork-tailed drongo?
		Njiva		Dove
Liquids	Matigonde	Bongamusero	*Combretum microphyllum*	Drink sweet liquid in flower (tiigonde)
		Mumveva	*Kigelia africana*	Drink liquid from flower
		Renja	*Cissus integrifolia*	Drink liquid from this creeper
Wine	Mukumbi	Mupfura	*Sclerocarya birrea*	Drunk and sold
Roasted fruit	Hwakwa	Mukwakwa	*Strychnos madagasariensis*	
Porridge		Muchakata	*Parinari curatellifolia*	
		Gwangwata	*Typha latifolia*	Roots dried and pounded into upfu.
		Musekesa	*Bauhinia thonningii*	In drought, seed from pod pounded into upfu
	Gomba	Mushavhi	*Ficus spp.*	
	Mutanda	Mutamba	*Strychnos cocculoides*	Rarely made, not enough fruit
Butter and oil	Mahanya	Muchakata	*Parinari curatellifolia*	Made by pounding chakata fruit
	Dovi reshomwe	Mupfura	*Sclerocarya birrea*	Made from shomwe nut
Roots, bulbs, leaves and flowers	Chidhoro	Mudhoro	*Opuntia spp.*	Cactus, flower eaten
	Rundumba	Gayekaye	*Aloe spp.*	Flowers of aloe, eaten in drought only
		Hodo		Grass root tuber eaten by children
		Mujumbura	*Manihot esculenta*	Cassava. Root eaten like potato
		Mukamba	*Afzelia quanzensis*	Leaves eaten in drought only
		Ndungira		Bulbous root, mostly found near mupani
		Muteva		Plant looking like munyemba, root eaten
	Derere remuuyu	Muuyu	*Adansonia digitata*	Leaves eaten during drought only
Soda	Mukume	Dumburedhongi		Made from stems of plant
- for baking bread		Guri (ma-)		Made from cornless maize cob
- for making snuff		Mukashu	*Tabernaemontana elegans*	Made from fruit shells
		Mupfura	*Sclerocarya birrea*	Made from shomwe shells
Jam	Jam remupfura	Mupfura	*Sclerocarya birrea*	Made from shomwe nut shells

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
Salt (wild)				No longer made
2. Non-Food Direct Uses				
Medicines	Mushanga	Chavurayamhepo		
		Mudzungu	*Xeroderris stuhlmannii*	Against dizziness (dzungu)
		Mufute	*Ricinus communalis*	N'anga extract oil and use in gona. V. valuable
		Gayekaye	*Aloe spp.*	Curing diarrhoea, eye infections in chickens
		Gomarara	*Loranthus spp.*	Parasitic grass. Used by n'anga for many cures
		(Gum	*Eucalyptus spp.*	Flu)
		Jekacheka	*Scleria foliosa*	Used by n'anga to cure period pains
		Mukamba	*Afzelia quanzensis*	Against stomach ache
		Mukashu	*Tabernaemontana elegans*	Against toothache, stomach ache
		Mukombegwa	*Crossopteryx febrifugia*	Against mhepo, stomach ache
		Mukwa	*Pterocarpus angolensis*	Against cataracts
		Mumharagunguvo	*Ozoroa paniculosa*	Against mhepo
		Mumveva	*Kigelia africana*	
		Munhuhwanuhwe	*Paederia bojeriana*	Leaves, for children affected by evil spirits
		Mupanda	*Lonchocarpus capassa*	Against chibereko, head problems
		Mupawa	*Ficus thonningii*	Fruits used against mouth ulcers
		Mupfura	*Sclerocarya birrea*	Stomach ache, diarrhoea, mhepo, coughing
		Chipwamhango	*Ansellia gigantea*	Rumoured to be used by n'anga
		Renja	*Cissus integrifolia*	Eye problems, stimulating lactation
		Rimiremombe	*Vernonia colorata*	Leaves chewed against stomach problems
		Muroro	*Annona senegalensis*	Roots, cure for STDs
		Chirovadunguru	*Catunaregum spinosa*	Roots, for tooth ache
		Murumanyama	*Cassia abreviata*	
		Murungu	*Ozoroa paniculosa*	Mhepo
		Murunjurunju	*Cissus quadrangularis*	Liquid, kill maggots in cattle's wounds
		Rupwanyimo	*Pogornarthia squarrosa*	Grass used to cure stomach aches
		Ruvavashuro	*Indigofera delagoaensii*	Stomach problems
		Musakaradza	*Rhus lancea*	Leaves, cure for hangover
		Mushangura	*Euclea natalensis*	Tooth ache
		Shanje	*Cynodon dactylon*	Stomach ache
		Mushozhowa	*Pseudolachnostylis maprounelifolia*	
		Soso	*Dicerocaryum zanguebarium*	Stomach ache, measles, tooth ache, head ache
		Musunhunguravanhu		N'anga, to induce mother to expel afterbirth
		Mususu	*Terminalia sericea*	Stomach ache, diarrhoea
		Musvayanyoka	*Cassia singueana*	N'anga use for stomach ache
		Chisvosve	*Synadenium spp.*	Curing cataracts in cattle
		Mutohwe	*Diplorynchus condylocarpon*	Ear ache, stomach ache, STDs
		(Tomato plant		For painful eyes)
		Torani	*Elephantorrhiza goetzei*	Mhepo, musana, stomach ache, STDs.
		Mutondo	*Julbernadia globiflora*	Mhepo, ngubhani
		Mutondoshungu	*Schotia brachypetala*	Stomach pain
		Mutovhoti	*Spirostachys africana*	Treating small wounds
		Muvavira		Root infusion against snakebite
		Muvengahonye	*Psydrax livida*	Leaves, kill maggots in cattle's wounds
		Zimbani	*Lippia javonica*	Flu
		Muzeze	*Peltophorum africanum*	Tooth ache, coughing
		Muzumi	*Strychnos ?*	Roots, cure for STDs
Wild soap		Mufufu	*Securidaca longependunculata*	
		Soso	*Dicerocaryum zanguebarium*	Ground creeper
Wild shampoo		Soso	*Dicerocaryum zanguebarium*	
Wild soap powder		Gwisamusenga	*Albizia versicolor*	Barks pounded to powder. No longer used
Glue/lime		Muhedge	*Euphorbia tirucalli*	Glue from latex
		Mukarati	*Burkea africana*	Glue exudes from bark
		Chikonde	*Euphorbia spp*	Makes sticky latex to catch birds

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
		Munamirabhuku	*Cordia monoica*	Used by children to glue school books
		Muora	*Albizia amara sericocephala*	Used by children
		Mupfura	*Sclerocarya birrea*	Milk comes from the tree stem
		Musiringa	*Melia azedarach*	Gum comes from the tree stem
		Mutondo	*Julbernardia globiflora*	Glue exudes from bark
Tooth-cleaning twigs		Muchakata	*Parinari curatellifolia*	Agritex promoted tooth-sticks in the 1940s
		Mukonachando	*Dodonea viscosa*	
		Musambarahwahwa	*Antidesma venosum*	Very rarely used
		Mushangura	*Euclea natalensis*	
		Mushozhowa	*Pseudolachnostylis maprounelifolia*	
		Musuma	*Vangueria infausta*	
		Musumadombo	*Diospyros lycioides*	
		Mususu	*Terminalia sericea*	
Insect repellant		Zimbani	*Lippia javonica*	Leaves burnt againt mosquitoes
Floor polish	"Cobra"	Mufute	*Ricinus communis*	Excellent cobra
		Mushamba		
		Musiringa	*Melia azedarach*	Leaves for green cobra
		Muzunguma	*Senna occidentalis*	Leaves for cobra
Torch		Chikonde	*Euphorbia spp.*	A light for hunting insects at night
School cane		Mushenjere	*Oxytenanthera abyssinica*	Bamboo
Liquid strainer		Musumadombo	*Diospyros lycioides*	Used for straining mukumbi
Fish poisons (usually banned but rumoured to be used)		Mudyahudo	*Strychnos potatorum*	Crushed barks
		Gwisamusenga	*Albizia versicolor*	Barks used
		Muhedge	*Euphorbia tirucalli*	Milky latex used
		Mukonde	*Euphorbia spp.*	Milky latex used
		Mupakamabwe	*Mundulea sericea*	Fruit and leaves used
		Mutsure	*Synaptolepsis kirkii*	Pounded roots used
		Muuzhe	*Brachystegia glaucescens*	Barks used
Paint/decoration		Mutsviri	*Combretum imberbe*	Ashes used to paint huts white. Rare now
3. Wood Uses				
3.1 Firewood	Huni			
Daily cooking and heating		Innumerable		
Beer brewing		Many		Species with a long and slow burn
Brick kiln firing		Many		Ditto
Stock	Bakwa	Many		Species which are resistant to insects
3.2 Construction Wood				
Kitchen hut	Imba yekubikira	Walls - mubaribari, mubvumira, mukarati, mukashu, mukwakwa, muora, mupani, mushozhowa, musimbiti, musuma, mususu, mutondo, mutovhoti, muvhiyambudzi, muwayawaya		
Main sleeping hut	Imba yekurara	Nhungo - mubaribari, muchakata, gum, mukashu, mukonashanu, mukwakwa, munyii, muora, mupangara, mupani, musasa, mushozhowa, musimbiti, musuma, mususu, mutovhoti, muuzhe		
Dormitory hut - boys	Gota	Mbariro - mubasinga, mubhubhunu, muburoburo, mukosvo, munyani, mupimbi, muvambangwena		
Dormitory hut - girls	Nhanga			
Crop granary	Dura	Walls - mukashu, mupangara, mushozhowa, musungavadzimba, mususu, muuzhe, muwayawaya		
		Floor - mudyahudo, mugwiti, muhumbakumba, mukarati, mukashu, munanga, mupangara, mupani, mupfura, mushozhowa, musimbiti, musuma, mususu, mutohwe, mutondo, muuzhe, muwayawaya		
		Nhungo - muhumakumba, gum, mupani, mushozhowa, musimbiti, mususu		
		Mbariro - mukosvo, munyani		
Crop storage hut	Tsapi	Walls - mukashu, muora, mupangara, mupfura, musimbiti, mususu, mutondo		
		Floor - munanga, mususu, mutondo		
		Nhungo - mukosva, mukwakwa, mupani, musimbiti, musuma, mususu		
		Mbariro - mukosvo, munyani		
Crop guard hut	Chirindo			
Kraals	Danga	Mudyahudo, mugwiti, muhumbakumba, mukarati, mukashu, mukwa, muora, mupangara, mupani, musimbiti, musiringa, musuma, mususu, mutondo, muuzhe		
Goat huts		Nhungo - mususu; mbariro - mukosvo		

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
Chicken, dove pens	Chirugu	Walls - musimbiti, mususu; nhungo - mukashu, munanga, musimbiti, mutehwa		
Stover store	Mutanho	Muhumbakumba, mususu		
Drying rack	Dara	Mupangara		
Shade	"Shade"	Mususu		
Brushwood fencing		Muburoburo, muchecheni, mudyahudo, mugwiti, mujerenga, mukashu, mukwakwa, munanga, munhunguru, munzvirupesu, muora, mupangara, chirovadunguru, musekesa, musimbiti, musosoti, sosovori, mususu, mutondo, muuzhe		
Fencing poles		Mugwiti, muhumbakumba, muhute, mukarati, mukashu, mukwakwa, munyambo, muonde, mupangara, mupani, mupfura, musasa, musimbiti, mususu, mutondo, muuzhe		
Live fencing		Muruva, sava(rechirungu)		
Tree protectors				
Doors	Madoor	Mubvumira, mugaranyenze, gum, mukamba, mukarati, chikondekonde, mukwa, mumveva, muonde, mupfura, musuma, mususu, mutovhoti		
Door frames	Madoorframe	Mubvumira, mugaranyenze, mugwismusenga, mukamba, mukarati, mukwa, mususu, mutovhoti		
3.3 Agricultural implements and tools				
Scotch cart frame	Ngoro	Mukamba, mukwa, mususu		
Plough wheel				
Yokes	Majoko	Muhumbakumba, mukombegwa, musekesa, musimbiti, musuma, musungavadzimba, mususu, mutehwa, mutiti, mutovhoti, muvhiyambudzi		
Skeys	Zvikeyi	Mudyahudo, mugwiti, muhumbakumba, mukombegwa, mukwakwa, muora, musekesa, musimbiti, musuma, mususu, mutehwa, muvhiyambudzi, muwayawaya		
Adze, hoe handles	Mipinyi	Mubaribari, mubhondo, mubhubhunu, mudyahudo, mugwiti, muhumbakumba, mukamba, mukarati, mukashu, mukombegwa, mukwakwa, muora, mupangara, mupfura, musasa, musimbiti, musuma, mususu, mutehwa, mutohwe, mutondo, muuzhe, muvhiyambudzi, muwayawaya, muzeze		
Threshing sticks	Mipuro			
3.4 Household furniture				
Tables	Tebhuru	Mukamba, mukwa		
Chairs	Zvigaro	Mukamba, mukwa		
Wooden beds		Mukamba, mukwa		
Wardrobe		Mukamba, mukwa		
Chest of drawers	Madrawers	Mukamba		
Sideboards		Mukamba, mukwa		
Trolley	Tray	Mubvumira, mugaranyenze, mukamba, mukwa, mukwakwa		
Stools	Zvituro	Mubvumira, gum, mugwiti, muhumbakumba, mukamba, mukarati, mukashu, mukashu root, mukombegwa, mukwa, mukwakwa, munyani, mupfura, musasa, mususu, mutiti, mutondo		
Bench				
Shelving - books and hh items		Mukamba, mukwa, mupfura		
Radio stand				
3.5 Household implements and utensils				
Sacking needle	Bumho	Jepfuchepfu	*Commiphora mollis*	Used to make handle (runzvi) of bumho
Clothes hangers		Gum, mukamba, mukombegwa, mukwa, musimbiti		
Drying rack (food)	Mutariko			
Plates	Ndiro	Muchechete, mukombegwa, mupfura, mupfuti, mutiti		
Sugar basins				
Teapots				
Cutting boards				
Bowls/basins				
Cook sticks	Misika	Mubaribari, mubhubhunu, mubikasadza, mudyahudo, mugwiti, muhumbakumba, mukamba, mukashu, mukombegwa, mukosvo, mukwakwa, munyani, muora, mupwezha, musimbiti, musuma, mususu, mutamba, mutehwa, mutiti, mutohwe, mutondo, muvhiyambudzi		
Sadza-stirring spoon	Migoti	Mubhondo, mubhubhunu, mubikasadza, mudyahudo, mugwiti, muhumbahumba, mukakata, mukashu, mukombegwa, mukwakwa, munyani, mupwezha, murumanyama, musambarahwahwa, musimbiti, mususu, mutehwa, muvhiyambudzi		
Sadza-ladling spoon	Migwaku	Mubhubhunu, mukamba, mukashu, mukombegwa, mukwa, mukwakwa, munyani, mupfura, musuma, mususu		

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
Sadza-smoothing	Zvibhako	Mubhubhunu, mubikasadza, mudyahudo, mugwiti, mukamba, mukombegwa, mukwa, mukwakwa,		
spoon		muora, mupangara, musimbiti, mususu, mutohwe		
Mortar	Duri	Muhute, mukamba, mukwa, mupfura, mususu, mutiti		
Pestles	Mihwi	Mugwiti, mukamba, mukwakwa, munanga, munyii, muonde, mupani, mupfura, musuma, musimbiti, mususu, mutiti, mutohwe, mutsviri, muvhiyambudzi		
(Pillow/headrest	Mutsago			No longer used in Shindi)
3.6 Cultural, musical and hunting items				
Staffs/knobkerries	Svimbo	Mugwiti, mukamba, mutehwa, mutiti, mutovhoti		
Carvings		Mukamba, mukwa, mupfura		
Divining piece	Hakata			Can be made from ivory or wood
"Tsoro" game	Tsoro			Played on wooden board or on ground
Drum - general	Ngoma	Mugwisamusenga, mukamba, mupepe, mupfura, mutiti		
Tambourine	Gandira			Very rare nowadays
Stringed instruments	Chipendani			Very rare nowadays
Hand rattle	Hosho	Mutamba	*Strychnos cocculoides*	Used as the shell
		Munhitii	*Abrus precatorius*	Seeds used as rattling things
Guitar				
Wood flute				
(Xylophone	Marimba)			
(Thumb piano	Mbira)			
Fishing rods		Mutehwa		
4. Other Tree Uses				
Leaf litter	Murakani	Innumerable		
Livestock fodder and browse		Innumerable		
Shade	Mumvuri	Innumerable		
Windbreak	Kuvhara mhepo			
Rain-making locations,		Mubvumira	*Kirkia acuminata*	Talking to ancestors
spiritual locations		Muchakata	*Parinari curatellifolia*	Rain-making
		Mukamba	*Afzelia quanzensis*	Rain-making, talking to ancestors
		Mupfura	*Sclerocarya birrea*	Large tree used for rain-making in resettlement
		Chitarara		Shade on graves
Seasonal indicators	Bongamusero - when flowers turn red, the ploughing season is coming and crocodiles will be particularly dangerous Mubvumira - when leaves go yellow and flowers drop, groundnuts are ready to be dug up and harvest time is over Mukamba - when udochi falls, the first rains are coming and people should dry-plant mhunga. If udochi dries without the rains coming, drought will ensue Mumveva - leaf flush occurs close to the first rains Musasa - leaf flush means rains are coming			
Children's play		Mumveva	*Kigelia africana*	Add wheels to large fruit to make a toy car
		Munanzva	*Pouzolzia mixta*	Making leaf hats, bowls, cups, slides, sledges
		Muonde	*Ficus spp.*	Fruit used to make toy car wheels
		Mupepe	*Albizia tanganyicensis*	Root used to make toy car wheel
		Renja	*Cissus integrifolia*	Rope swing
		Muroro	*Annona senegalensis*	Pound leaves and soak to make green paint
		Sisi	*Cocculus hirsutus*	Black fruit juice used for paint
		Mushamba	*Citrullus lanatus?*	Fruits used
		Musumadombo		Chew leaves to turn tongue yellow
		Mutamba	*Strychnos cocculoides*	Make motor cars from the fruit
5. Items Made From Tree Bark (Dota)				
Bark canoes	Gwazvo	Mutondo	*Julbernadia globiflora*	Large piece, used for crossing rivers
(Blankets	Gudza	Muuyu	*Adansonia digitata*	No longer made)
Ropes, fibres and	Makavi	Mubasinga	*Sterculia rogersii*	One of the best strings
string		Mubhubhunu	*Grewia spp.*	Not the best, used due to scarcity
- for tieing vegetables		Mubvumira	*Kirkia acuminata*	
- for use in making mats		Mufufu	*Securidaca longipendunculata*	
- for use in making baskets		Mugan'acha	*Lannea discolor*	Not very strong

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
- for thatching		Mujerenga	*Acacia nilotica*	Remove thorns first
- for making herding whips (tyava)		Munyani	*Friesodielsia obovata*	Not common
- for tieing firewood bundles		Mupani	*Colophospermum mopane*	Used to make tyava
- for tieing thatching grass		Mupfuti	*Brachystegia boehmii*	Esp. hunting whips
		Mupumbu	*Acacia polyacantha*	
		Musasa	*Brachystegia spiciformis*	Harvesting causing problems for regrowth
		Sava(remudondo)	*Sansevaria spp.*	Only for tieing firewood
		Musekesa	*Bauhinia thoningii*	Used to make tyava
		Mushavhi	*Ficus spp.*	Used to make tyava
		Musungavadzimba	*Pteleopsis mytilifolia*	Esp. for hunters to tie up hunted animals
		Mutohwe	*Azanza garckeana*	
		Mutondo	*Julberniada globiflora*	Used to make tyava
		Mutsure	*Synaptolepsis kirkii*	Not very strong so not often used
		Muuyu	*Adansonia digitata*	Excellent, sustainably harvestable
		Muuzhe	*Brachystegia glaucescens*	Used to make tyava
		Muvazve	*Obetia tenax*	V. strong for mumbure, mats
Hunting nets	Mumbure	Sava(rechirungu)	*Agave americana*	A string, not a bark
		Muuyu	*Adansonia digitata*	
"African" snuff	Mukume	Mukwakwa	*Strychnos madascariensis*	
Dyes		Muchakata	*Parinari curatellifolia*	
		Mukwakwa	*Strychnos madascariensis*	Green
		Munhunguru	*Flacourtia indica*	Reddish
		Munyii	*Berchemia discolor*	Brown
		Mupfura	*Sclerocarya birrea*	Brown
		Murungu	*Ozoroa paniculosa*	Brown
		Musekesa	*Bauhinia thonningii*	Russet/orange
		Musvimwa	*Lannea stuhlmannii*	Dark brown
Pot-firing barks		Mubvumira, mupfura, musasa, mususu, mutondo, muuzhe		
(Washing soap		Mugwisamusenga	*Albizia versicolor*	No longer used)
6. Direct Uses of Grass, Reeds, Rushes and Cane				
Thatching grass	Uswa	Chiraramhene	*Schizachyrium spp.?*	Only found in resettlement
		Gwangwata	*Typha latifolia*	Used as under-thatch
		Mararasoma		Excellent for base or top
		Mbavani	*Bracharia ?*	Poor; used a lot when good grasses are scarce
		Mbumi		Very good; collected in resettlement
		Mhodyo		
		(Mhunga stalks		Used as under-thatch)
		Mwisewebhiza		Good but scarce
		Pfumvuto		
		Rupwanyimo		Thatch of chicken pens, small structures only
		Shengezhu	*Hyparrhenia spp.*	Used as base thatch. Rare in Shindi
		Sine	*Heteropogon contortus*	
		Sin'izani		Poor; used a lot when good grasses are scarce
Brooms (house)	Mutsvairo	Murara	*Phoenix reclinata*	
		Sin'izani		
Brooms (yard)	Mavovo	Mavovo emugomo		
		Mufandichimuka	*Myrothamnus flabellifolius*	
		Ruvavashuro		
Mouse-traps	Miteva	Mhodyo		Strong so mice can't break it
Head-load cushion	Hata	Gondya		For comfortable carrying of heavy items
Liquid strainers		Mbuvi (grass)		
7. Items Used in Weaving				
Hats	Nguwani	Muchigwi		Not found in Shindi
Sleeping mats	Rupasa	Furi	*Coleochloa setifera*	Sedge for doormats, baskets, hats
Door mats	Madoormat	Gondya		Soft grass for making dendere
Table mats		Gwangwata	*Typha latifolia*	Soft reed for mhasa
Storage basket	Dengu	Jekacheka	*Scleria foliosa*	Grass used to make dendere
N'anga's basket	Fineko	Mumveva	*Kigelia africana*	Esp. for making rusero

Description	ChiKaranga name	Name of species used: ChiKaranga	Botanical	Notes
Cooking baskets	Tswanda	Nharauta	*Ficus capreifolia*	Split twigs used to make rusero
	Gwindi	Nhokwe, mizi	*Cyperus digitatus*	Esp. mats and baskets
Winnowing basket	Rusero	Mupangara root	*Dichrostachys cinerea*	
Shopping basket	"Basket"	Mupingamusasa		
Chicken-hatching b.	Dendere	Murara	*Phoenix reclinata*	Palm tree
(Fishing baskets	Duwo)	Murarahomba	*Alchornea laxiflora*	
		Ruka		
		Sava(rechiringu)	*Agave americana*	Door and table mats, joining mhasa
		Sava(remudondo)	*Sansevaria spp.*	Occ. used for door mats and table mats
		Shanga	*Phragmites mauritianus*	Multiple uses
		Shengezhu	*Hyparrhenia spp.*	
		Mushenjere	*Oxytenanthera abyssinica*	Wild bamboo
		Sisi	*Cocculus hirsutus*	Creeper
		Muuyu	*Adansonia digitata*	Bark used to make fibre, gudza for clothing
		Muuzhe	*Brachystegia glaucescens*	Very rare now
		Muvavira		
		Muvazve	*Oberia tenax*	Very strong
Bangles	Shambo	Nhandira		Tall part used of this creeper
8. Specialist Earth Or Mud Uses				
Termitaria - soil nutrient input				
Termitaria - brick-making				
Pottery	Hadyana	Wettish clays from vleis		Small pot for cooking relish
	Gate/muvambiro	Mukura - red clay, not available in Shindi		Large pot for storing beer
	Mbiya	Chidzuro - special black clay		Rimmed plate for eating relish or drinking
	Nyengero			Big pot for brewing and storing beer
	Pfuko			Large pot for storing beer, maheu, water
	Shambakodzi			Medium pot for cooking sadza
Pot decoration		Munhitii	*Abrus precatorius*	Red/black seeds used to decorate pfuko neck
Hut decoration		Ivhujena - white soil, found when digging deep in termitaria eg. when excavating for a toilet		
		Ivhudzuku - red soil		
		Ivhudema - black soil		
		Ivhureyellow - only found in a few places, and you have to dig deep for it.		
9. Miscellaneous				
Gourds	Mukombe	Deteni		For pouring beer from container into cup
Water-carrier	Dende	Gavhu (=squash)	*Laganeria siceraria*	
Grinder	Gagada	Gavhu (=squash)	*Laganeria siceraria*	For grinding groundnuts into paste
Gold	"Mari"			From Runde river - scarce now