Local Knowledge of Agriculture / Environment Symbioses:

Farmers and Natural Resource Management in Shinyanga District, Tanzania



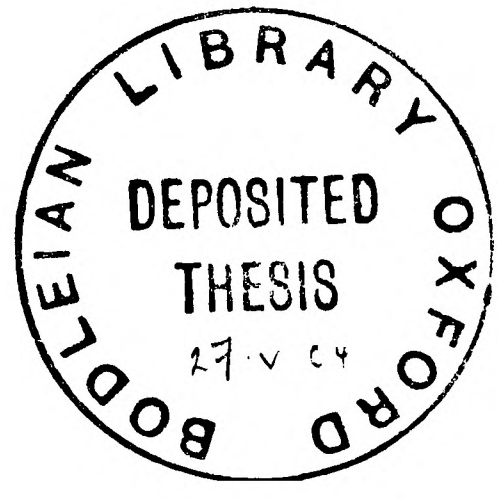


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Abstract

In rural districts of Sub-Saharan Africa, livelihoods typically centre around peasant agriculture and herding. While historically effective, changing resource constraints associated with rapid population growth and resource degradation have put these livelihoods under strain. Dramatic shifts over recent years in agricultural policy and the prices of agricultural inputs and outputs have not helped. Together, such changes arguably amount to a set of destabilising influences and a relative paucity of advantageous opportunities. The question is whether local people successfully adapt their land-use strategies to these changing circumstances.

'Sustainable agriculture' technologies such as agroforestry practices represent an obvious means of adaptation to change in low-potential areas, which largely lack access to purchased agricultural inputs. Yet despite the promise these technologies have shown in farm trials, their adoption by farmers has generally been hesitant and limited. This has been widely interpreted as evidence that these technologies do not respond effectively to the needs of target beneficiaries.

Based on a household survey from Shinyanga District, Tanzania, the study revisits the issues of adaptation to changing circumstances and technology adoption. It highlights the possibility that some households adapt to change more effectively than others, with some adopting advantageous available technologies while others do not. Its focus is on the differing knowledge and perceptions informing decisions vis-à-vis tree management, with a view to identifying distinct knowledge types within the wider body of local knowledge.

The study posits then tests a theoretical model problematising local knowledge. It finds that integrating local knowledge variables into regressions of tree management practice greatly increases their explanatory power, suggesting that these variables do not simply reflect incentives, as suggested by contemporary theory. The implication is that problematic local knowledge may critically constrain rural livelihoods in areas facing unprecedented challenges and opportunities. Finally, diverse associations with observed knowledge patterns are considered, suggesting promising ways to build on this work.

Acknowledgements

Although immensely rewarding, this task has also been difficult for me. Doubtless there are some individuals who skate through their doctorates without much ado, without late-nights and weekends at the computer, without floundering, inertia and angst. Be that as it may, I am not one of them. Instead, I am one of that larger group who have to overcome diverse personal demons and bad habits in their journey to this point.

If anything, such trials and tribulations make the journey all the more rewarding. One analogy often heard among graduate students is to 'giving birth'. For those of us who had a difficult time – and perhaps also for the others, those lucky, uncomplicated or hopelessly clever types – this metaphor refers not just to the obvious, i.e., giving birth to a piece of work. More fundamentally, it suggests giving birth to oneself. Thus, via the vehicle of 'saying my piece' and externalising my Big Idea, I've made large strides to becoming the person I believe myself to be.

In different ways, various people have made critical contributions to my life and work over these past five years.

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Chapter 1

Peasant Agriculture, Natural Resource Management and Local Knowledge

1.1 Introduction

1.1.1 Poverty as rural and agricultural

Vast rural areas containing hundreds of millions of people remain mired in poverty, while the rate of poverty reduction is far below that needed to meet the international poverty reduction targets. Specifically, every second person in South Asia and Sub-Saharan Africa lives in absolute poverty, with the situation expected to worsen given current trends, particularly in Sub-Saharan Africa. The extreme poor live mainly from farming, notably growing staple foods for home consumption and working as farm labourers (IFAD 2001; Pinstrup-Anderson & Pandya-Lorch 2001).

Despite these realities, the real value of aid has fallen over recent years, particularly aid to rural areas and agriculture (IFAD 2001). This fall in aid can be traced to a loss of confidence in the rural development 'project', given its poor past performance (Ashley & Maxwell 2001). This situation is best viewed as a challenge to find ways to provide effective assistance. Towards this end, the present study examines a neglected potential constraint on smallholder agricultural production.

Despite diverse efforts over many years to address Tanzania's economic and social problems, over one-half of all Tanzanians today are considered poor, while approximately one-third live in abject poverty. Based on the 1992 Household Budget Survey, approximately one-quarter of Tanzanians lived in households unable to meet their nutritional requirements, while about half were unable to meet their combined food and non-food basic requirements. Updated estimates for the year 2000 suggest that poverty levels may have increased since then. Notable characteristics of contemporary Tanzanian poverty include that it is largely rural and that the poor are concentrated in subsistence agriculture on low-potential lands[1] (PRSP 2000). The present study examines one such area of Tanzania.

The agricultural problems currently facing African communities are serious. Although agriculture is the prime occupation of a large majority of the population in most African countries, food production per capita has been

[1] These lands occupy approximately one-third of the country and support one-quarter of Tanzania's population.

falling in Tanzania (World Bank 1994:5) and Africa generally (Pinstrup-Anderson 1997) in recent years, leaving forty-three percent of the region's population malnourished (Human Development Report 1998:50). Specifically, cereal yields per hectare in Tanzania have fallen by 8 percent over the period 1990-2001, while meat production per capita has fallen by 12 percent[2] (World Resources 2002). Moreover, many African smallholder farmers cannot buy food to offset production shortfalls due to cash constraints (Pinstrup-Anderson 1997). Given this situation, these farmers urgently need to find ways to enhance their land's productivity (IFPRI 1996:14). More generally, agriculture is the obvious lead sector in most low income countries, given its diverse forward and backward linkages (Pinstrup-Anderson & Pandya-Lorch 2001). While non-farm opportunities are increasingly significant and a broader process of de-agrarianisation may be observed, in poorer areas where such opportunities are minimal large numbers of people remain stuck in subsistence production (Bryceson 2003).

One cause of poor agricultural performance in Africa that has received great attention in recent years is government policies that discriminate against agriculture. Such policies were virtually universal within developing country agriculture until the 1980s, and had the effect of suppressing output prices received by farmers. This anti-agriculture bias within government policy has been largely addressed, notably via structural adjustment programmes (e.g., Krueger 1992). More recently, the poor performance of agriculture is increasingly attributed to environmental degradation[3] (e.g., World Bank 1996; Lutz 2000; Scherr & Yadav 2002).

1.1.2 Study focus on farmer knowledge

Within contemporary theory knowledge is generally assumed to be good, including both its 'scientific' and 'local' varieties. Modern scientific knowledge (MSK) derived via the scientific method is seen as a key resource that is often 'missing' in poor communities. "Poor countries – and poor people – differ from rich ones not only because they have less capital, but because they have less knowledge" (WDR, 1999). 'Indigenous' or local knowledge (LK) derived from years of observation and trial and error experience is seen as both sound and well-adapted to local conditions. "LK is the basis for local-level decision making... and the main asset [of the poor] to invest in the struggle for survival. It is developed and adapted continuously to gradually changing environments" (World Bank 2002).

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[2] Because this trend correponds with the final phasing out of agricultural subsidies, these falls in productivity are likely to reflect decreased use of purchased farm inputs such as hybrid seeds and chemical fertilisers and pesticides.
[3] For discussion of this term, see section 1.2.1.

By contrast, the present study hypothesises that neither MSK nor LK is good a priori, but that either may or may not be appropriate to a given context, depending on whether or not it has been adapted to it. Specifically, each contains numerous and often conflicting strands, with disagreements among different farmers or communities vis-à-vis LK and among different scientists or institutions vis-à-vis MSK. Knowledge problems are thought to be especially likely during periods of rapid change, when peoples' adaptive capacity may have difficulty keeping pace with changing opportunities and constraints. Specifically, the suggestion is that either locals or outsiders can be mistaken about how best to manage natural resources[4] such as trees.

The goal of the study is to identify any characteristic problems plaguing LK in a poor agrarian community in Shinyanga District, Tanzania. Its specific concern is that farmers may fail to adapt their management of natural resources to shifting incentives associated with a changing rural context. While the study recognises that MSK may be as prone to knowledge problems vis-à-vis natural resources as LK[5], the latter is emphasised due to its immediate relevance to the welfare of the rural poor. In the process of examining potential problems with LK, however, various problems with MSK vis-à-vis development come to light. The picture that emerges is that people – whether 'indigenous' or 'modern' – are often unimaginative, failing to consider alternative possible perspectives on an issue. Moreover, this tendency towards inertia often persists despite clear and/or growing problems with existing formulations and practices.

It is hypothesised that among households with similar needs and assets, fundamentally distinct natural resource management patterns are pursued during periods of rapid change in resource constraints, some of which are better adapted to contemporary challenges than others. Notably, some households actively facilitate the regeneration of key natural resources and integration of farm components, whilst others continue to rely on natural regeneration and show little interest in better integrating complementary farm components. These differences in management patterns therefore *cannot* simply be attributed to differential household assets and priorities, as suggested by theory.

This may be termed the 'knowledge failure' model, given its similarities with the established concepts of 'market failure' and 'institutional failure'. All refer to situations in which an institution fails to deliver a beneficial outcome due to real-world constraints neglected by idealised conceptions of how it should work.

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[4] For a definition of the resources in question and the terminology used, see section 1.2.1.

[5] For instance, institutional decision making and the scientific knowledge on which it is often based may fail to fully account for growing natural resource scarcity, and hence may exploit resources beyond the economically optimal point. Farming irrigated land until it becomes salinised is one example.

1.1.3 Catalyst 1: Anecdotal evidence from Senegal

The idea that different households possess conflicting local knowledge, or 'indigenous technical knowledge', originated out of discussions with farmers held over the course of the author's two-year posting as an agricultural extension agent in Fimela District, Senegal. The essence of these ideas is encapsulated in two anecdotes drawn from this experience.

Some farms contained trees, while others did not. Moreover, some farmers protected naturally-occurring trees and even cultivated trees, while others systematically removed any trees seedlings sprouting on their farm. To make sense of these observed patterns, the author questioned numerous farmers. What soon became clear was that farmers simply disagreed about the role of trees on farms. After hearing a certain viewpoint on tree management, the author would point to a neighbouring farm pursuing a different strategy despite facing similar resource constraints and ask how the farmer explained his neighbour's strategy. Typically, the answer was a hushed, complicit assertion that 'they don't know what they're doing'.

One year the rainy season proved highly erratic. The rains began early with a powerful storm that caused the millet crop to sprout[6], after which it was completely dry for five weeks. When the rains finally resumed, a large majority of the millet fields had to be replanted, the original crop having died. Such fields had only a short rainy season in which to grow and the resulting production was low, imposing hardship on those households relying on them. A minority of fields survived, however, and these crops grew large and produced abundantly. Based on the author's straw poll of the farmers in question, what these farms had in common was farming practices such as retention of tree seedlings, manuring, and ploughing under rather than burning crop residues. The implication is that such farms had higher levels of organic matter than neighbouring farms due to these 'sustainable agriculture' management practices.

The first anecdote casts doubt on the idea that LK is by definition well-adapted to the local context, suggesting instead that different farmers possess contradictory technical knowledge. The second anecdote suggests that some management strategies are better adapted to the contemporary local context than others. The present study seeks to make sense of these suggestions and draw relevant policy lessons.

[6] Millet, the local staple crop, was planted before the onset of the rains to take full advantage of the relatively brief rainy season.

1.1.4 Catalyst 2: Language suggesting a passive view of natural resource management

Knowledge problems are also suggested by a second category of anecdotal evidence. Namely, when asked about how trees regenerate or whether decreasing local vegetation is a problem, households in Fimela District, Senegal often cited explanations that betray a fundamentally passive, non-analytical view of natural regeneration. Thus, they may suggest that natural resources such as trees are 'supplied by God' or 'grow naturally' and hence do not require active management, despite advanced signs of environmental degradation. The present study's household survey of Shinyanga District found similar views.

This passive view of natural resource dynamics is also reported in the literature. Lindskog & Delaite (1996) report that households in Cape Verde frequently have good knowledge of symptoms of environmental degradation, yet do not see themselves as agents in relation to nature. Instead, they attribute degradation to God or destiny and resign themselves to associated problems. Similarly, Khogali (1991) reports that people in Sudan saw the lack of rainfall and famine in 1983-84 as acts of God, even though contributory factors included the degradation of local natural resources. Finally, Mamun (1996) reports that rural Bangladeshis view river bank erosion either as an act of God or due to changing water flows, with the latter view associated with higher rates of schooling.

This same fatalism is reflected in other walks of life. Namely, a majority of women in Ethiopia, Nigeria and Ghana are reported to believe that God decides both when they become pregnant and how many children they should have (Mirgissa 2000; Feyistan & Ainsworth 1994; Mansa 1991, respectively). Similarly, in Guinee the prime causes of disease are believed to be fate and God, although tangible factors like diet and contagion are also sometimes mentioned (Diallo & Gbanace 1992).

1.2 Peasant agriculture and natural resources

1.2.1 Natural resources as critical production inputs

For well over a decade, poverty and environment have been viewed as functionally linked, in addition to being among the most pressing concerns facing developing world communities. The Brundtland Commission of 1987 cited poverty as a key cause of environmental degradation, while more recently this linkage has come to be viewed as a two-way street. Thus, the report of the 1992 UNCED conference states, "Without improving environmental management, development will be undermined, and without accelerated development in poor

countries (...) the environment will continue to degrade." The World Bank (1996) has cited making African development environmentally sustainable the key challenge facing the region.

In the context of rural Africa, this functional linkage has been described as either a 'poverty – environment nexus' or a 'population-agriculture-environment nexus' (Cleaver & Schreiber 1994; Dasgupta & Maler 1994; Durning 1989; Holden & Sankhayan 1998; World Bank 1992:27). According to this theory, these factors tend to move together in either a 'virtuous' or a 'vicious' circle. Specifically, it suggests that rapid population growth, agricultural stagnation and environmental degradation constitute a nexus of problems that must be resolved in an integrated manner. This 'nexus' has been called the central pillar of the reigning 'sustainable development' paradigm as it applies to the rural African context (Delgado 1995; 97). More generally, poverty alleviation over the long-term depends upon managing natural resources sustainably (World Resources 2002).

While some rural households diversify their incomes (Bryceson 2002), most still depend primarily on agriculture for their livelihood. Moreover, these alternative occupations often involve exploiting natural resources, and hence are similarly dependent on the ongoing viability of these resources (Belshaw & Livingstone 2002).

The ongoing vitality and changing dynamics of natural resource systems is particularly relevant to those households living in 'less-favoured' or 'low-potential' areas. These are defined as areas that face difficult agro-climatic conditions, such as poor soils, low and unreliable rainfall, steep slopes and short growing seasons. Additionally, these areas may be poorly provisioned with infrastructure such as roads, markets and irrigation works or services such as extension, schools and health centres (IFPRI 2003). Notably, these areas have been largely bypassed by the gains associated with the Green Revolution, due largely to difficulties accessing or financing the relevant agricultural inputs. Nonetheless, these lands are home to some 1.8 billion people worldwide, including most of the rural poor in developing countries (IFPRI 2002). Instead of Green Revolution agriculture, low-potential areas are characterised by complex farming systems involving strong interactions among farm components and emphasis on local knowledge (Farrington 1998).

Given their disassociation from high-input production technologies, these areas are largely "biomass-based subsistence economies", where people earn their livelihood directly from exploitation of the local environment (Dasgupta 1997; Holden 1997). Specifically, livelihoods in such areas depend on exploiting natural resources such as soil, pastures, trees and game (Upton 1996). While these resources might also be termed

'environmental', 'biological' or 'renewable natural' resources, the present study opts for the term 'natural resources' (NRs) in the interest of simplicity. Moreover, the term 'resource degradation' will [henceforth] be preferred to 'environmental degradation', to emphasise the fact that this process involves the loss of useful resources. More generally, 'environment' is arguably an unfortunate term that can easily lead to misunderstandings, since its meaning changes in different contexts[7].

Given the distinctive characteristics of low-potential areas, Wiggins & Proctor (2001) cite the need to devise distinct development strategies for these areas. In practice, however, agricultural policy has tended to focus on the most favoured areas while largely neglecting poorer, more marginal areas (Pinstrup-Anderson 1996). In view of this neglect, Pretty (1995) has dubbed such production 'the forgotten agriculture'. Notably, developing country ministries of agriculture tend to ignore environmental considerations such as the costs of soil degradation (Coxhead 1995), while many researchers and extensionists – including those serving Shinyanga District – continue to emphasise Green Revolution solutions to production problems. Similarly, the development economics literature has largely neglected the role of natural resources in underpinning rural production (Dasgupta 2001; Stern 1989).

1.2.2 Competing models of agricultural production

Three broad strategies of agricultural production may be distinguished within smallholder agriculture. The first is traditional peasant agriculture as practised in areas characterised by abundant land and natural resources, while the other two represent innovations on this 'historical' backdrop. The Green Revolution strategy emphasises purchased inputs such as chemical fertilisers and pesticides, hybrid seeds, irrigation works and mechanisation. The sustainable agriculture strategy emphasises innovative, intensified management of available natural resources and 'regenerative' technologies[8] such as agroforestry and soil-and-water-conserving (SWC) practices.

While agricultural development has tended to focus on Green Revolution strategies, it has paid increasing attention to sustainable alternatives in recent years, due largely to the difficulties of poor farmers with accessing

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[7] In western societies, 'environment' typically refers to quality of life issues such as air and water pollution, global warming and biodiversity loss. While such issues possess an economic aspect, their relevance to the economy is usually indirect, and the associated costs and benefits are social in nature. In African peasant communities, the relevant 'environmental' issues are of a different nature. They include manifestations of environmental degradation such as soil erosion, habitat loss and deforestation. Because local livelihoods may depend on the resources in question, such issues are directly relevant to the local economy, particularly in low-potential areas. Here, addressing 'environmental' concerns is often not a luxury to be addressed once growth has been achieved, as often suggested in the environmental literature (e.g., Kuznetz's curves), but an integral and necessary part of the path to growth.

[8] The study employs the term 'technologies' to highlight the fact that regenerative practices represent potentially potent substitutes for Green Revolution technologies. They may involve elaborate management formulas or simple innovations, e.g., digging in crop residues instead of burning them.

purchased inputs (e.g., Okigbo 1990; Phillips-Howard 1994). The former corresponds to Blaikie et al's (1997) neo-liberal paradigm, with its prescriptive, one-shape-fits-all policies, while the latter corresponds to their neo-populist paradigm, with its emphasis on local knowledge and participatory, locally-appropriate development. Farmers are "no longer defined as the problem" but rather as "part of the solution" (Ives 1989). The present study falls broadly in the latter paradigm, yet problematises some aspects of it, and seeks to offer a synthesis to the thesis and antithesis presented by these two competing paradigms. Table 1.1 contrasts the pure cases of these two innovative models.

More generally still, agricultural production systems may be divided into 'purchased inputs' and 'natural inputs' systems, with the latter comprising the 'traditional' and 'sustainable' agricultural strategies. 'Purchased inputs' production is the principal occupation of [...] people worldwide, while 'natural inputs' production is the principal occupation of [...] people (IFAD 2001).

The purchased inputs model may hold greater promise under favourable conditions, since it delivers higher production and provides greater access to markets for consumer and producer goods (Islam 1995). Yet this model is inappropriate to farmers who lack regular access to purchased inputs, such as most farmers living in low-potential areas. Thus, the productivity gains delivered by the Green Revolution have not been evenly distributed, but have accrued principally to those countries, communities and farmers best able to afford ample quantities of purchased inputs (Wolf 1986) while failing to benefit poorer farmers (CIMMYT 1996). Besides simple lack of cash, another reason why purchased inputs may be inaccessible or otherwise problematic is high transactions costs associated with poor transport or marketing infrastructure. Finally, purchased inputs production tends to be higher but also more erratic, which may prove problematic for poor, risk-averse farmers (Pearce & Prakesh 1993; Penfold 1995).

By contrast, a natural inputs emphasis *may* provide cash income and access to markets in addition to subsistence production. Even where it does not, however, it may represent an effective strategy for reversing agricultural stagnation and meeting basic needs, as well as a strong foundation for eventual market participation[9]. Specifically, increased reliance on renewable natural inputs promises both lower production costs and greater sustainability of production in areas of natural resource scarcity (Altieri 1992; Ngambeki

[9] In such cases of 'subsistence stabilisation', a shift from a purchased inputs model to a natural inputs model may appear undesirable for the rest of the world, which may stand to lose markets for exports while paying higher prices for agricultural commodities. But such benefits must be weighed against the risks of continued emphasis on this model in cases where it is inappropriate. Notably, possible effects of continued immiseration of poor farmers include accelerated resource degradation (i.e., see 'nexus'), increased refugee flows (Myers 1995:5), and civil conflict (IFPRI 1996; Kaplan 1994).

Table 1.1 Contrasting the pure cases of the two innovative models

Parameter	**Green Revolution model**	**Sustainable agriculture model**
Inputs into farming system	'Purchased inputs' such as chemical fertiliser	'Natural inputs' drawn from local natural resources
Means of accessing inputs	Cash and market participation	Differential allocation of labour inputs
Production destination	Primarily for markets	Home consumption, sometimes markets
Role of local natural resources	Relatively unimportant	Provide key production inputs
Benefit to farmers	Cash income and access to markets	Basic needs, sometimes cash income
Benefit to society	New markets, inexpensive goods, transfers	Deterrence of damaging feedback

Source: Summary comments from current discussion

1992; Dazhong & Pimentel 1992). This follows because natural inputs may represent readily available means of offsetting resource degradation costs that would otherwise be incurred, either in the form of outlays for purchased inputs or lost production (Pagiola 1996). One example of offsetting costs via natural resource management is the case of Kitai prison in Tanzania, where farmer-inmates cut use of chemical fertilisers by two-thirds without incurring production losses by using sunhemp as a green manure (Ouattara et al 1991). A second example is from Zimbabwe, where farmers using recommended levels of chemical fertilisers had difficulty repaying fertiliser loans, while those who used lower levels supplemented by natural fertilisers did not (Page & Chonyera 1994).

Some authors from the neo-populist school (e.g., Leach & Mearns 1995) have suggested that generalisations about functional linkages affecting rural households are simplistic and misleading, given the importance of context-specific cultural and institutional factors. While analyses must clearly be contextualised, the present study asserts that broadly-applicable underlying trends may nonetheless exist, and hypothesises one such trend. Notably, the idea of 'knowledge failure' regarding potentially advantageous investments in natural capital arguably represents a simple yet profound idea that cuts across diverse social, cultural and physical contexts.

1.2.3 Resource degradation as a key production constraint

One characteristic specific to low-potential agriculture is the direct significance of resource degradation to farm productivity, with degradation defined as reductions of resource stocks that cause a decline in the productive capacity of land[10]. Although it affects the rural economy generally, degradation is particularly threatening to peasant farmers, since agriculture in these areas relies directly on exploiting available natural resources (Pinstrup-Anderson & Pandya-Lorch 1994). Indeed, resource degradation is thought to affect a majority of African farmers (Oldemann et al 1990) and to be a root cause of poverty in rural areas (HDR 1998:56), while the poor performance of agriculture on low-potential lands is increasingly attributed to land degradation (Scherr & Yadav 2001). Moreover, anecdotal evidence of resource degradation is abundant[11]. Depletion of soil nutrients has been singled out as the key biophysical cause of declining per capita food production in Sub-Saharan Africa[12] (Sanchez et al 1997).

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[10] Types of degradation relevant to poor agrarian communities include depletion of soil nutrients or soil organic matter, soil erosion, salinisation, and degradation of pastures and tree stocks (Scherr & Yadav 2001). Degradation is typically caused by harvesting beyond the productive capacity of the resource, or 'overexploitation'.

[11] For instance, cassava yields in Nigeria fell from 10.8 to 2 tons per hectare as the average fallow period fell from 5.3 to 1.4 years (Lagemann 1977). Similarly, women and children in some areas of East Africa are reported to walk ever farther to find fuelwood, often many hours each day (Dewees 1997).

[12] In the 37 African countries surveyed, an average of 660 kg of nitrogen / hectare, 75 kg of phosphorous / hectare and 450 kg of potassium / hectare has been lost from cultitvated areas over the past thirty years.

Examining the nature and dynamics of natural resource systems helps elucidate the phenomenon of resource degradation. Natural resources represent a unique category of farm inputs. Their distinguishing feature is that they tend to reproduce themselves 'naturally', or without the help of labour or other human inputs. Because these resources are "free goods of nature" (Upton 1996), the rational peasant will use them liberally as production inputs. This regenerative capacity is not constant, however, and often depends on the level of current resource stocks[13] (e.g., Hazell & Garrett 1996). Simply put, the regenerative capacity of natural resources may be compromised when resource stocks are depleted beyond a certain point (see Appendix A).

Resource degradation shifts the resource constraints within which economic activity transpires. It effectively 'moves the goalposts' of the economy, raising the issue of whether institutions and bodies of knowledge adapt effectively to these changes or become outmoded. The danger is that resource degradation may undermine established management strategies – including both household farming systems and communal management regimes – that fail to adapt to resources no longer being abundant, as a result of which productivity may fall (Kosmarskaya 1989).

1.2.4 'Investing' in natural capital

Because natural resources can be destroyed by overexploitation or misuse, optimising their management can involve choices between current and future consumption. Any natural resource can be managed in any of four ways: (i) actively removed as harmful to livelihoods, (ii) simply exploited without regard to resource stocks (iii) exploited carefully in an effort to maintain resource stocks, (iv) sustained or increased through active management, such as the case of regenerating degraded land. Any of these four options can represent efficient, optimal management from the household's viewpoint, depending on its circumstances and the abundance of local natural resources. Household management of any natural resource will entail both deciding whether to remove, exploit without concern, maintain or regenerate the resource, and determining how to best achieve this end.

The last of these management options may be usefully characterised as 'investing' in natural capital. This follows because to the extent that natural resources represent 'natural capital' that creates value and underpins economic activity (DFID 2003; Pearce et al 1993:3), it makes sense to speak of them in the rigorous and respectable terms used for other forms of capital. Besides 'natural capital' itself, particularly useful terms in

[13] Notably, this regenerative capacity may be either diminished by resource degradation or bolstered by investment in natural resource stocks.

this regard are 'investment', 'saving', 'depletion' and 'depreciation', since they indicate changes to natural capital stocks over time. While these terms are sometimes used in the literature, notably in environmental economics[14] and 'green accounting', they are generally seen as wholly distinct from questions of natural resource management (e.g., Gylfason & Zoega 2001; Vincent 1997).

Although seemingly semantic, this distinction has profound consequences. Namely, the fact that these terms are seldom used outside highly specialised disciplines suggests that development practitioners and those writing about development may often not recognise the importance of natural capital to rural livelihoods and the profound implications of its newfound scarcity in areas facing pronounced resource degradation. While not directly relevant to rural people, who are unlikely to speak in such terms, this gap has a corollary in peasant communities. It mirrors a conceptual gap distinguishing those who recognise actively investing in natural resource stocks as a viable management option from those who do not.

This linguistic / conceptual gap is both understandable and unfortunate. It is understandable due to the unique behaviour of natural assets, whereby nature 'invests' automatically in natural resources on our behalf, if only it is left reasonably unperturbed. As such, it is not surprising that people may think of these resources and the goods or services they provide as 'free gifts of nature', and not recognise the possibility of facilitating natural regeneration. Yet this gap is also unfortunate, since it results in the relative deprioritisation of natural resources and obscures the possibility of natural resource investment.

In sum, there are two distinct stages of recognition which may prove challenging: (i) recognising natural resources as having newfound, fundamental importance, i.e., that they play a key role in farming systems yet are becoming scarce, (ii) recognising active facilitation as a viable management option, as opposed to simply continuing to rely on natural regeneration and nature's bounty. Thus, no matter how much a household may value a particular natural resource and its associated goods and services, it may nonetheless fail to see active investment in natural resources as a viable management option. As noted above, such a move represents a dramatic mental leap, and hence cannot simply be assumed just because it is advantageous.

The key justification for investing in natural capital is that economic systems in many areas have grown to the extent that the remaining natural capital has become scarce relative to other forms of capital, and may often represent the limiting asset in a production system (Daly et al 1994). In such situations, investments in natural

[14] Using such concepts, environmental economists characterise resource degradation as 'living off' or 'consuming' natural capital stocks.

capital may be required for these assets to provide or continue providing needed goods or ecological services (Wills et al 2001).

While the most obvious benefit of such investments is to local resource users, they may also involve other beneficiaries. For instance, increasing soil organic matter is also a means of sequestering carbon, as noted in the Kyoto Protocol. It thus represents an opportunity for both mitigating climate change and attracting sequestration payments to poor communities (Paudel & Lohr 2002).

1.2.5 Agroforestry and soil and water conserving practices as relevant 'investments'

'Sustainable development' is the reigning development paradigm in the post-Cold War era (Delgado 1997). A key aspect of this paradigm as it applies to rural Africa is environmental sustainability. The 1996 volume *Toward Environmentally Sustainable Development in Sub-Saharan Africa: A World Bank Agenda* opens as follows: "Caring about the environment in Sub-Saharan Africa is not a luxury but a prime necessity because African economies depend heavily on their capital of natural resources". It specifically calls for investing in natural capital stocks as a means of addressing the population-agriculture-environment nexus[15].

Concrete means of 'investing in' natural capital to address this nexus include agroforestry practices[16] and soil and water conserving (SWC) practices[17], which represent two key categories of regenerative technology. Such management options represent means of addressing both resource degradation and agricultural decline in low-potential areas, and hold promise of turning the 'vicious' circle represented by the nexus into a 'virtuous' circle of economic growth and environmental regeneration.

Production systems emphasising regenerative technologies are known as 'sustainable' or 'conservation' agriculture. Such systems actively maintain critical natural resources, as opposed to simply relying on nature's bounty or on purchases of external inputs[18]. Sustainable agriculture practices represent means of investing in natural capital, such as stocks of soil nutrients or vegetation (Pretty et al 1996). Typically, they actively

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[15] Beyond the narrow context of agrarian communities in rural Africa, ensuring environmentally sustainable development depends on actors taking account of changes in natural capital associated with their economic activities. This involves differentiating between resource stocks and flows as well as ensuring that any decreases in natural capital stocks are offset by positive investments in other relevant assets (Goodland, 95).

[16] Agroforestry involves integrating trees into farm systems to capture ecologically and economically symbiotic interactions between system components.

[17] Soil and water conserving practices common in Sub-Saharan Africa include mulching, manuring, crop rotation and intercropping. Other less common SWC practices including stone bunds, contour bunds, terracing and other organic fertilisers (Boyd & Slaymaker 2000).

[18] These latter two options correspond to farming systems associated with a shifting cultivation production strategy and a Green Revolution strategy, respectively.

facilitate processes of natural regeneration via innovative – and often increased – labour inputs. Cultivating and protecting trees is an obvious example, while applying manure or kitchen waste to fields is another. By harnessing linkages between farm components (i.e., crops, animals, trees), whereby by-products of one component become inputs to another, these farming systems are able to minimise the need for external inputs and increase efficiency. One example is crop residues and tree leaves serving as livestock fodder. A second is manure and leaf litter serving as fertilisers to crops while also helping to retain soil moisture within the farm system (Pretty 1995).

Sustainable agriculture practices can restore productive potential lost due to resource degradation or increase the overall carrying capacity of land. As such, they represent a means of meeting growing demands on land due to factors like population pressure (Scherr & Yadav 1996; Shah et al 1993; Laing et al 1993). Moreover, such practices are accessible to farmers in marginal areas due to their emphasis on inputs already existing in rural communities rather than external inputs to which they may lack access (Altieri et al 2001).

The promise of sustainable agriculture to improve livelihoods in poor rural areas has been amply demonstrated. Based on a multi-country analysis, Pretty et al (1996) report that adoption of agroforestry or soil and water conserving practices led to large productivity increases in low-potential, food-deficit areas of developing countries. On average, adopters had doubled their cereal production since adoption in addition to diversifying farm outputs, notably through production of useful tree products. Similarly impressive results have been obtained in Shinyanga District (Rao et al 1998; HASHI/ICRAF 2000), in nearby Kondoa District (Dejene et al 1997), and in Zambia's Eastern Province (Franzel et al 2002). Such impressive gains may largely reflect a need for increased soil organic matter[19], which a recent report called the key determinant of the relative stability and productivity of agricultural lands (WRI 2001).

Kenya's Machakos District is a notable sustainable agriculture success story, with its finding of large productivity increases[20] over time on degraded land (Tiffin et al 1994; Boserup 1965). While this work raises the exciting prospect of spontaneous and successful farmer adaptation to changing resource constraints, certain observations suggest it is a special case[21], a finding supported by a six-country follow-up study conducted by the World Bank (Lele & Stone 1989). A second multi-country follow-up study similarly found few examples

[19] Both agroforestry technologies and soil and water conserving practices serve to raise levels of soil organic matter.
[20] Specifically, this study reported a three-fold increase in productivity per capita and an eleven-fold increase in productivity per capita over the period from 1930 to 1990.
[21] Examples include ready access to large and growing urban and export markets for high-value vegetable crops and the fact that district farmers gained permission to grow coffee – a high-value perennial crop – during the period of the analysis.

of reversal of natural resource degradation (Boyd & Slaymaker 2000). Still other findings (Siedenburg 2003) suggest that the successes reported may be exaggerated, although still encouraging. Such caveats argue against complacency, and suggest a need to critically assess potential constraints on endogenous adaptation to change.

Given that the alternative farm management options are often either ineffective or inaccessible, sustainable agriculture may represent the only viable means for farmers to meet increased demand for food (Oram 1995; Whiteside 1998). Traditional management systems may break down under the strains imposed by rapid population growth and market liberalisation. Thus, continued reliance on shifting cultivation to restore soil fertility may prove ineffective once fallow periods become short, resulting in resource degradation and declining productivity (Pearce & Warford 1993:254; Whiteside 1998; Young 1997). Meanwhile, Green Revolution technologies emphasising purchased inputs may be inaccessible to poor smallholders, as exemplified by a trebling in the price of chemical fertilisers in Tanzania since the early nineties (World Bank 2000) following on already low use rates (IFDC 1996). These shifting incentives have resulted in a 78% fall in use of chemical fertilisers in Tanzania over the period 1989 to 1999 (World Resources 2002). Even when accessible, purchased inputs may be 'uneconomical' in poor agricultural communities due to factors such as low yield response and poor infrastructure (Hazell & Garrett 1996), as well as the fact that much smallholder production is for subsistence consumption.

Of the various regenerative technologies[22], agroforestry has sparked particular interest. It has proved highly successful in researcher trials and sometimes also on farms (Cooper et al 1996; Rao et al 1998). Farm trees provide two broad categories of benefits to smallholders: products such as fodder, fruit, timber and fuel, and support to field crop production, for instance by helping soils withstand intensified use and/or harsh tropical conditions (Arnold 1997; Young 1989). More generally, farm trees help maintain farm system stability and resilience (Hoekstra 1985; ICRAF 1996). Agroforestry is thus seen as a promising means of addressing the key problems facing poor farmers in degraded areas (Franzel & Scherr 2002b). Tree costs include labour inputs, competition effects and providing habitat to pests like ticks and the tsetse fly. Significantly, however, the *financial* costs of tree planting are marginal (Warner 1997).

[22] These practices are often referred to as 'agroforestry technologies' in the agroforestry and sustainable agriculture literature. This reflects the fact that such practices often involve highly specific, carefully controlled patterns of tree-crop or tree-livestock interactions whose dynamics and management have been optimised by researchers and/or farmers (e.g., Swinkels et al 2002; Franzel et al 2002). Yet given its focus on farmer knowledge vis-à-vis tree management among a representative sample of households, the present study employs only a general categorisation of tree management patterns. Given such aggregation, the more inclusive term 'agroforestry practices' is more appropriate.

Evidence of 'agricultural islands' documented from different parts of East Africa support the contention that sustainable agriculture farming systems represent technically and socially viable solutions to problems stemming from land scarcity in rural Africa, notably problems of resource degradation. These 'islands' are examples of traditional agricultural systems that remained productive over time despite strictly constrained available land. The critical lesson of these examples is that 'island' farming systems involved active maintenance of soil fertility and other key resources, e.g., livestock fodder, fuel, via indigenous regenerative technologies (Sutton 1989; Widgren 1999).

1.3 Adoption of regenerative technologies as limited

The present section examines household management decisions and how they are made. These decisions include both whether or not to adopt specific technologies and how to manage available natural resources, notably whether or not to allow them to degrade. Above, we established both the significance of resource degradation to productivity problems in low-potential areas and the potential of regenerative technologies as a response to this challenge. The practical issue linking these broad questions is household decision making.

1.3.1 Technology adoption

Technology adoption involves the uptake by rural people of technological innovations. Innovations involve novel ways of securing production outputs, whether via new inputs or different means of organising or managing production. In theory, they promise diverse improvements to agricultural production and are the vehicle of agricultural development. Typically, agricultural innovations offer higher productivity (Feder & Slade 1993; McIntire 1993) and often drive economic growth in rural areas (McGuirk & Mundlak 1991). Yet agricultural innovations can also meet other objectives, such as greater resilience vis-à-vis extreme weather conditions or better resistance to weeds or pests. An objective specific to regenerative technologies is compensating for economic losses associated with resource degradation. Regardless of the precise objective, however, innovation involves decisions by households regarding their perceived private advantage.

While some studies have demonstrated that adoption and diffusion of advantageous technologies are both spontaneous and rapid, these examples have generally involved marketable, high-status products with short payback periods. By contrast, regenerative technologies tend to provide mundane agricultural support services (e.g., fertilising soils) and tend to involve long payback periods. Examples of rapid and widespread technology adoption include hybrid maize in northern Nigeria (Smith et al 1994), hybrid wheat in Palanpur, India

(Lanjouw & Stern 1993), coffee and tea in Kenya (Bevan et al 1989), cocoa in Sulawezi, Indonesia (Pomp & Burger 1995), and tobacco in Malawi. In the latter case, tobacco was so profitable[23] that two-thirds of survey households also widely adopted a complementary investment, namely planting trees for the construction of drying sheds (Place & Otsuka 2001).

Building on this emphasis on high-value crops, Smith et al (1994) suggest that efforts to facilitate technology adoption should focus on areas where the 'preconditions for intensification' are already in place, notably a good transport system and a 'quantum leap' technological breakthrough in the form of a highly profitable cash crop. While understandable in light of the potential of such crops to dramatically increase both productivity and rural welfare (e.g., Cameron 1999), this suggestion has worrisome implications about neglecting low-potential areas. Moreover, these authors were writing at a time when fertiliser subsidies had not yet been removed and when 'sustainable agriculture' alternatives suitable to the area were still being researched, which begs the question of whether their case study still meets these preconditions.

More generally, the introduction of new technologies of whatever type to rural communities in Africa has generally met with only partial success, as measured by low rates of adoption. This is true despite the long-standing emphasis on development initiatives addressing perceived constraints to technology adoption, notably unfavourable tenure arrangements, poor transport infrastructure, erratic input supply and lack of credit, information or tools (Feder 1985). Even where successes are reported, one possible interpretation is that where the potential gains in question are sufficiently large, obstacles to adoption are swept aside, as suggested by Anderson & Hoff (1993). While this is encouraging, it begs the question of what happens with technologies that offer significant but non-dramatic gains, as is the case with many regenerative technologies.

If sustainable agriculture practices promise higher and more stable production in low-potential areas, as suggested, they would likewise be expected to be readily adopted by poor farmers and to diffuse quickly both within communities and to neighbouring communities. Yet despite their apparent promise and some notable exceptions[24], farmer adoption of regenerative technologies has tended to be limited[25]. That is, while research has identified a range of technologies and management strategies for developing better agro-pastoral production systems, adoption rates of these technologies have generally been low (Oram et al 1998). Notably, adoption of

[23] Nearly ten times moreso than maize, the local staple crop.
[24] For instance, Franzel et al (2002) report widespread interest in planting fodder trees to secure increased milk production in western Kenya.
[25] The technologies in question include both indigenous technologies and technologies advocated by extension agents and others. Yet the origins of particular technologies are not emphasised here, but rather whether advantageous technologies are adopted and the role of local knowledge in this process.

soil conservation practices has been largely unsuccessful, arguably due to competing demands on labour (Kayombo & Mrema 1994). The case of limited adoption of agroforestry practices in Shinyanga Region, Tanzania (Otsyina 1995) is thus but one example of a broader trend. Moreover, this finding holds despite intensive, long-standing forestry and agroforestry extension initiatives in the area.

Other evidence suggests that peasant farmers in developing countries are engaged in a continuous process of endogenous technological innovation (Biggs & Clay 1981; Reij & Waters-Bayer 2001). Yet closer examination of this evidence shows that the innovations in question tend to involve relatively minor adaptations of current practice, notably in the form of experimentation with new crop varieties or planting arrangements. Meanwhile, bolder innovations are comparatively rare, notably those involving regenerative technologies such as agroforestry practices (Nielsen 2001).

A recent book focuses on the issues of agroforestry and technology adoption in the African context (Franzel & Scherr 2002). Specifically, it describes how research partnerships with farmers can help assess the profitability of different agroforestry practices and hence develop practices that are better-suited to the local socio-economic and agro-ecological context. These partnerships emphasise dynamic, innovative farmers, who are seen as both partners in technology development and potential 'champions' of new technologies for wider adoption.

The book's relevance to the technology adoption decision is the light such research partnerships shed on perceived adoption constraints, which could indicate how best to present technologies to target beneficiaries. By contrast, the present study focuses on the differing characteristics of households exhibiting different tree management patterns. It does not address the question of how to develop state-of-the-art technologies with dynamic farmers, but rather seeks to understand why some households adopt agroforestry practices while other apparently similar households do not. It is thus fundamentally about the adoption decision itself, rather than the technology and its adoption *potential*, like the Franzel & Scherr contribution.

While recognising that agroforestry practices[26] are widespread in Africa, Franzel & Scherr (2002) see these as likely to be only approximate or low-intensity versions of the most promising agroforestry practices, and hence as needing improvement. Wider dissemination of existing agroforestry practices is thus not seen as the solution

[26] Whether indigenous or introduced.

to land-use problems[27]. By contrast, the present study focuses on existing agroforestry practices and why some households follow more or less intensive practices while others avoid them entirely.

While there is a substantial body of literature on the bio-physical potential of agroforestry practices in Africa (e.g., Cooper et al 1996; Sanchez 1996), the contribution of agroforestry practices to household incomes under farm conditions has rarely been rigorously assessed. The volume by Franzel & Scherr (2002) addresses this gap in the literature. By contrast, the present study does not assess the profitability of specific practices, but rather explores why advantageous practices may fail to diffuse readily among households.

1.3.2 Limited technology adoption and resource degradation

In low-potential areas, the issues of ongoing resource degradation and limited technology adoption are often intertwined. This follows because regenerative technologies (i.e., 'investments in' natural capital) can compensate for products and services lost due to degradation in cases where it imposes unacceptable costs[28]. While application of purchased inputs such as chemical fertilisers represents a second possible means of offsetting such losses, these inputs may be inaccessible in poor areas or simply too expensive. As such, purchased inputs do not generally represent a viable means of addressing resource degradation and its production impacts in low-potential areas.

Given this fundamental linkage, resource degradation and adoption of regenerative technologies may be usefully characterised as the two defining components of a degradation – technology adoption continuum. Seven distinct cases may be distinguished (see Table 1.2).

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[27] Indeed, it is implied that such practices may even impede optimal land use if they encourage rural people to view agroforestry practices as not particularly promising.

[28] Conversely, degradation may result if farmers in areas experiencing rapid population growth fail to adapt farming systems to intensified land use, notably by failing to maintain stocks of key natural resources such as soil nutrients and fuel via adopting regenerative technologies.

Table 1.2 Distinct cases along the degradation – technology adoption continuum

Strategy towards natural capital stocks	**View of renewable natural resources**	**Adopt sustainable agriculture practices?**	**Changes to local natural capital stocks**
Traditional, e.g., shifting cultivation	Useful but abundant, 'investment' in natural capital is unnecessary	No	Maintain
Eliminate them	Some represent economic 'bads'	No	Decrease
'Consume' them as a survival strategy	Natural resources are valuable but need to consume them now	No	Decrease
Represent a source of investment capital	Natural capital is not as valuable as other investments	No	Decrease
Sustainable agriculture practices are not worthwhile or inaccessible	Natural capital as non-essential	No	Decrease
Adopt to prevent production losses	Natural resources represent key assets and the basis of rural livelihoods	Yes	Maintain
Adopt to increase productive potential	Natural resources represent key assets and the basis of rural livelihoods	Yes	Increase

Passive maintenance of natural capital

1. Low population pressure allows natural regeneration to replenish any resources depleted via resource extraction

Depletion of natural capital

2. Active removal of natural resources perceived to be economic 'bads'. In such cases, resource degradation may be seen as economically favourable land improvement. In the context of Sukumaland, the case of vegetation seen to provide habitat for tsetse flies represents one such example.

3. The very poor overexploit existing resources and deplete resource stocks due to their pressing survival needs, or because they are 'forced' to do so. They have no choice but to prioritise present consumption even at the cost of jeopardising future production.

4. Natural resources are actively depleted and sold as a means to finance more advantageous investments. Regenerative technologies are not adopted, since other opportunities are more advantageous[29] (Pender 1998).

5. Population pressure places excessive demands on resources but regenerative technologies are not adopted, being deemed either inaccessible or not sufficiently advantageous.

Regeneration of natural capital

6. Adopted technologies regenerate depleted natural capital stocks to restore productive potential as it existed historically under low population pressure, where cultivation was interspersed with lengthy fallow periods.

7. Increase carrying capacity above its historical level via adoption of regenerative technologies, i.e., intensive natural resource management harnessing potential complementarities among different farm components.

In the context of Shinyanga District or any low-potential agricultural areas experiencing intensive population pressure, the relevant perspectives are numbers 3, 5, 6 and 7. Reiterating, 3 emphasises unsustainable resource degradation by the poor, 5 emphasises the failure of poor people to adopt regenerative technologies, while 6 and 7 emphasise successful uptake of regenerative technologies. Because the observed trend is towards

[29] Households may nonetheless adopt regenerative technologies if they view this as a means to transform labour inputs into financial inputs.

ongoing resource degradation and only limited adoption of regenerative technologies, the remaining discussion focuses on cases 3 and 5.

1.3.3 Explaining ongoing resource degradation

While it is widely recognised that rural people often act as key agents of resource degradation by overexploiting available natural resources, they are generally seen as being 'forced' to do so by factors beyond their control, notably sheer poverty (Bhalla et al 1992; Hazell 1995; HDR 1998:66; Pearce & Warford 1993:263-276; World Bank 1992:30). Commonly cited causes include high personal discount rates associated with poverty and institutional factors such as insecure property rights and poor access to needed inputs such as credit, fencing or seeds.

Some authors emphasise both sheer poverty and institutional factors as underlying causes of degradation. Pinstrup-Anderson & Pandya-Lorch (2001) suggest that because poor farmers lack the means to appropriately intensify agriculture, they are often forced to overuse natural resources to meet their basic needs. Pinstrup-Anderson (2002) stresses the role of both poverty and inappropriate policies and institutions as root causes of this situation. Similarly, Oram et al (1998) cite increasing population pressure on land and water resources coupled with changes to government support to agriculture, notably loss of subsidies under structural adjustment, as the twin factors that may drive poor farmers to degrade their environment. Finally, Shiferaw & Holden (1999) suggest that while Ethiopian peasants recognise that soil erosion is undermining their land's productive potential, they cannot act to address this problem due to factors such as market imperfections and poverty.

Others emphasise only rapid population growth given poverty as the critical factor forcing local people to degrade marginal lands (e.g., Brown & Haddad 1994). Mellor (1988) suggests that people in poor countries may be obliged to sacrifice long-term environmental stability for their short-term subsistence needs. Larson et al (1996) report that in Congo, insufficient fallow periods linked to population growth are causing land degradation and reducing productivity, such that farmers are having to work harder for less. The implication is that available management options are inadequate to cope with these challenges. Yet Boudet (1985) implies

that things may not be this simple, namely that land husbandry practices used by herders in the Sahel may themselves lead to situations where herders are 'forced' to degrade remaining resources[30].

Still others suggest that farmers should farm differently yet also seek to avoid viewing them as responsible for degradation. Thus, Hudson & Cheatle (1993) suggest that rural people may be 'forced' to farm marginal lands that are inherently vulnerable to degradation, yet also emphasise 'the failure to practice good land husbandry' and 'improved farming methods'. Dejene et al (1997) make similar arguments for Kondoa District, Tanzania.

Thus, local people are generally believed to be 'forced' to degrade natural resources by poverty, institutions or both[31]. One common thread, however, is that where local people are agents of resource degradation, this degradation is generally considered to be privately optimal given available opportunities and constraints (Pender 1998).

In extreme situations associated with warfare, it may be fair to speak about local agents being 'forced' to degrade natural resources. Similarly, people 'forced' onto marginal lands may cause degradation through using familiar with inappropriate technologies (e.g., Dickson 1979). Yet in the case of stable populations that have been living in an area for decades, the idea that people may be 'forced' to degrade the natural resources on which their livelihoods depend is questionable.

While the agency of rural people in causing resource degradation may be widely recognised, the question of agency vis-à-vis *responses* to degradation is less clear. For instance, the World Bank (96:xi) suggests that problems of resource degradation and the challenge of securing environmentally sustainable development "present Sub-Saharan Africa with the opportunity to view its development problems in a new light". While vague about agency, the implication is that these challenges apply to institutions rather than poor people.

1.3.4 Explaining limited adoption

One broad interpretation of limited observed adoption is that technologies are simply not worth adopting, since they compare unfavourably with available alternatives. While such technologies may be privately advantageous as measured by net present value, they are not the optimal management strategies available to

[30] Specifically, he reports that greatly diminished tree stocks in Sahelian pastures since the 1950s leave pastoralists largely dependent on grass fodder that is vulnerable to climatic variability. As a result, the prevailing dry spell forced herders to converge on the relatively small areas of remaining viable pasture, causing overgrazing and pasture degradation.

[31] Alternatively, resource degradation may be caused by governance failures. Examples include corruption and patronage, which lead to poor decisions vis-à-vis logging, mining and land-use that disrupt local ecosystems (World Resources 2002:vii-ix).

rural households[32]. The alternative possibilities are that such a technology is inherently poor, that it is maladapted to the contemporary farm context, or that it fails to address a key household need. In sum, although the household could access the technology, it opts not to adopt it based on calculations of private advantage. Interestingly, all the examples of this case drawn from the literature refer to regenerative technologies, as opposed to Green Revolution technologies.

Notably, would-be users are thought to face either hidden costs or insufficient, overly distant benefits that make these technologies unattractive relative to available alternatives (e.g., David 1995; Dewees 1997). To the degree that regenerative technologies address resource degradation, the implication is that allowing natural resources to degrade and coping[33] with the consequences may be preferable to addressing degradation.

This view is common in the literature. Cary & Wilkinson (1997) suggest that farmers' conservation behaviour is limited by the fact that costs of adopting regenerative technologies may exceed on-farm benefits, as a result of which farmers may lack private incentives to adopt. Fujisaka & Sinclair (1997) describe how adoption of a certain agroforestry practice only 'makes sense' to farmers under unusual conditions, given its associated costs and benefits. Joet et al (1998) find that Sahelian farmers spontaneously shift from removing wilding trees spouting in their fields once this becomes advantageous, implying that where this is not done it is not in the farmer's interest. In sum, farmers may recognise opportunity costs associated with ongoing labour inputs into natural capital investments while outsiders may fail to recognise them (Tiffin & Mortimore 1994).

The single key determinant of technology adoption by farmers is its perceived profitability[34] (Cary & Wilkinson 1997; Wijsen 1994:132). A general rule of thumb is that natural resources, like other factors, grow in value as they become scarce, and that adoption of regenerative technologies becomes profitable only once resources become scarce (Ehui et al 1992). The implication is that natural resources were either simply not valuable or not yet scarce to the point of being valuable.

The other broad interpretation of the limited adoption observed is that adoption is impeded by factors beyond the control of farmers. In these cases, while the household may view the technology as advantageous, it cannot access it. For instance, Thirtle & Ruttan (1987) suggest that technology adoption is affected by institutional

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[32] That is, the net present value of available alternative management options is higher.
[33] Common examples of coping strategies include households spending several hours each day gathering woodfuel or moving away from traditional lands.
[34] Conversely, if profitable technologies are adopted, the implication is that technologies that are not adopted are not profitable relative to available alternatives.

factors such as credit or extension services and property rights. Meanwhile, Feder (1985) emphasises the impact of problematic transport infrastructure and marketing bodies, while McGuirk & Mundlak (1992) emphasise insufficient roads and irrigation infrastructure coupled with difficulty accessing inputs. Finally, Kumar (1994) reports that key impediments to adoption of hybrid maize in Zambia include inadequate transport infrastructure, input distribution systems, credit and extension services.

Anderson & Hoff (1993) stress that whether or not farmers face incentives to conserve valued natural resources and adopt advantageous technologies depends fundamentally on property rights arrangements. Notably, private property is believed to create clear incentives for economic agents to produce efficiently and use available resources optimally. Such rights can create incentives to conserve environmental resources (Feder & Feeny 1993), while formal title to land may be a precondition to the wise management of natural resources (Mendelsohn 1994). Despite the logic of this argument, in practice it seems to make little difference whether rural people possess statutory rights or customary rights to land in the African context (Migot-Adholla et al 1993), implying that rural land titling may be an expensive but wasteful undertaking (Holden & Binswanger 1998).

Knowledge problems are also sometimes cited as possible impediments to uptake. Yet the problem is generally seen as farmers lacking 'modern' knowledge about introduced technologies, while LK about familiar, locally-available resources is seen as unproblematic[35]. Thus, when farmers first become aware of agricultural innovations, they may have inaccurate perceptions of their costs and benefits (Feder & Slade 1993). A period of disequilibrium follows, yet inefficiencies decline with experience (Schultz 1975).

Foster & Rosenzweig (1995) found that learning strongly influences technology adoption, implying that imperfect knowledge about the management of hybrid seeds was a significant barrier to adoption. Yet this barrier diminished as farmers learned about the technology, whether from their own experience or by observing neighbours. That is, observed lags between exposure to innovations and their adoption reflect the fact that farmers take time to accumulate information to inform the adoption decision via Bayesian learning (Fisher et al 1996). In Tanzania, adoption of improved maize and chemical fertiliser was significantly affected by farm size, educational achievement and contact with extension agents, suggesting a strong informational component to

[35] Information is typically seen as an external input to farm production that is procured by farmers according to its profitability to them relative to the cost of acquiring it. In this sense, it may be said to be a 'commodity like any other' (Hoff et al, 93). This interpretation applies only to MSK and its content, but not to LK, since LK is by definition that knowledge occurring within rural communities.

technology adoption (Nkonya et al 1997). This linkage with education may however simply reflect the fact that relatively well-off households are more likely to send their children to school.

A final potential impediment is sheer poverty, which may mean that a given technology is not accessible to households even where it is viewed as highly advantageous. While this impediment is more likely to apply in the case of technologies involving purchased inputs, it could also apply to regenerative technologies involving only inputs such as land and labour, notably where such technologies involve multi-year payback periods, such as the case of agroforestry practices.

Griffin (1973) summarises the received wisdom vis-à-vis limited technology adoption succinctly. "If peasants sometimes appear to be unresponsive or hostile to proposed technical changes, it is probably because the risks are high, the returns to the cultivator are low (...), credit facilities or marketing outlets are inadequate, or the necessary inputs – including knowledge – are missing."

1.3.5 Explaining limited adoption of regenerative technologies

The growing literature on factors affecting the adoption of 'sustainable agriculture' or regenerative technologies has emphasised the physical characteristics of adopting farms. Farm size in particular has consistently been found to be significantly related to adoption of regenerative technologies (e.g., Shively 1997; Sureshwaran 1996). The opportunity costs of land and labour are often central to the adoption decision, both of which are inversely correlated with adoption. That is, these technologies are less likely to be adopted in cases where attractive alternative uses of land and labour are available, such as near roads, on lands where high-value cash crops such as coffee are viable, or where off-farm employment is readily available (Neill & Lee 2001).

While a recent international symposium on this topic found soil improving practices including agroforestry practices to be privately profitable in rural Africa, it also found that poor farmers lack the capital and credit needed to make the initial investment in such improvements (Sanchez et al 1997). In both Honduras (Neill & Lee 2001) and Kenya (Migot-Adholla 1994), formal title to land was not found to be significant while private ownership was, implying that both customary and statutory tenure are perceived by local people as secure.

Beyond such broader institutional constraints, adoption of advantageous agroforestry practices might also be constrained by potential conflicts with established farming and resource management practices (Openshaw et al

1979). For instance, established practice may permit dry season grazing of livestock on neighbouring fields, making it difficult for individual households to retain or cultivate trees on their nominally private fields. Such factors are among the complex network of obligations and contracts that allocates factors in remote areas where conventional markets for labour, land and capital are missing (Anderson & Hoff 1993).

1.3.6 Examining a neglected possibility

In the cases of both resource degradation and limited technology adoption, the resulting outcomes tend to be explained in similar terms, namely as privately optimal to rural people given existing resource constraints, market opportunities, poverty levels and socio-cultural arrangements. This follows because the option chosen by any given household is deemed to be privately preferable to the available alternatives. Yet in cases where the resulting management strategy fails to secure the basic needs of households or where the long-term viability of strategies is questionable, such technically optimal outcomes are nonetheless problematic. Notably, the problem with characterising such situations as optimal is that this paints farmers as powerless to avoid jeopardising their own present and future welfare, or as helpless 'victims' of poverty, which is arguably both inaccurate and counterproductive.

By contrast, the present study examines a neglected possibility. Namely, it considers whether the knowledge informing the management decisions of farmers may itself be problematic, as a result of which shifting incentives vis-à-vis competing management options may go unrecognised. In such a world, the resulting outcomes may no longer be optimal even in the short term, and local people might fail to seize accessible, advantageous opportunities.

Given its focus on knowledge and the possibility of knowledge problems, the present study assumes that where technologies are not adopted or natural resources are allowed to degrade, this is for the first of the two broad reasons cited, i.e., because local people deem this to be their optimal management strategy. While in reality matters are seldom so simple, this may nonetheless be the dominant factor and single best explanation, since if technologies were sufficiently advantageous then households would arguably find ways to overcome any social or institutional impediments to adoption[36]. This is particularly true in the case of regenerative technologies, which emphasise natural inputs that tend to be readily available in rural areas and are only rarely marketed.

[36] Examples include convincing fellow villagers to adopt new management practices and taking individual remedial action, such as providing individual fencing to tree seedlings growing in fields grazed by neighbours.

1.4 Conceptual models as a source of obfuscation

1.4.1 The 'poor but efficient peasant' thesis

Since Schultz's landmark book of 1964, it has been argued that peasant farmers are rational economic agents who combine the resources available to them optimally in the aim of securing their basic needs. Simply put, peasant farmers are 'poor but efficient'. It suggests that through experience over time farmers have come to allocate available factors with a high level of efficiency, resulting in systems of proven adequacy. The implication is that 'no appreciable increase in agricultural production is to be had by reallocating the factors at the disposal of farmers' (Schultz 1964:39).

This thesis has been highly influential. Ali & Byerlee (1991) call it one of the most enduring themes in development economics, while Ellis & Biggs (2001) suggest that 'agricultural growth based on small-farm efficiency' is the paradigm that has most dominated rural development thinking over the last half-century.

Adherence to the 'poor but efficient peasant' thesis has been fuelled by both *a priori* logic and empirical studies (Ali & Byerlee 1991). These authors specify that the key reasons for assuming that peasant farming is efficient are that peasants both depend on their own resources and have had a long time to adapt to them, and hence are deemed to be intimately familiar with them. The current emphasis on participatory approaches to development builds on this idea. The empirical studies found that farmers respond to price movements and that observed ratios of marginal value product to marginal factor price suggest efficiency, yet these measures are controversial[37]. Other problems with these studies included their exclusive focus on farming communities employing Green Revolution technologies and their dependence on how production functions were specified[38]. A third possible reason for adherence to this thesis is that it fits peasant farmers neatly into established economic models[39] (Adams 1986; Lipton 1968).

The best-known critique of Schultz's thesis is *The Theory of the Optimising Peasant* (Lipton 1968). It points out that the neo-classical model of perfect competition implied by the 'poor but efficient peasant' thesis originated in Western societies under specific conditions that do not obtain in developing world agricultural

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[37] Specifically, these studies found that ratios of marginal value product to marginal factor price were 'sufficiently close to one' to confirm that peasants are allocatively efficient. Yet these studies were highly conservative about rejecting the null hypothesis that k was equal to one. Thus, k values as high as 3.6 and as low as 0.6 were interpreted as 'sufficiently close to one' (Ali & Byerlee 1991).

[38] For instance, if the test considers only labour inputs into traditional activities such as weeding and harvesting, it will fail to pick up inefficiencies involving labour inputs into activities like tree cultivation that may not have been practised historically. One possible result is that the test could find a farm economically efficient despite its being inefficient with regard to overlooked production inputs.

[39] This idea seems highly plausible, since efficiency and profit-maximisation are two sides of the same coin. Thus, assuming that farmers are efficient effectively ascribes to them the motive of profit maximisation, making them resemble firms in the market economy (Ellis, 93).

communities[40]. Moreover, the paper brands Schultz's thesis a 'doctrine of revolutionary pessimism', since it suggests that despite their often grave economic problems, peasant farmers have achieved what was possible with the old factors of production. The implication is that without considerable government or donor agency aid, they stand little chance of improving their lot.

Lipton (1968) suggests that the widespread acceptance of the 'poor but efficient peasant' thesis stems largely from perceptions of traditional agriculture as constant over time. Yet he argues that this constancy – which affords opportunities to optimise practices over time – has been disrupted by both population growth and development planning, resulting in a situation where "the man who merely 'learns from experience is' sunk". Arguably, perceptions of 'traditional' practices and 'subsistence' agriculture as stable fallback options into which people can safely retreat stem partly from these very terms. Thus by definition, subsistence agriculture is practised by farmers "capable of securing their own subsistence and reproduction without the assistance of (...) others" (Hyden 1980:29). By contrast, the present study suggests that such systems may be threatened by resource degradation, yet that poor farmers also have the capacity to redress this challenge and adapt to contemporary resource constraints by adopting regenerative technologies.

Adams (1986) is similarly critical, and suggests that this model's dominance will not wane until criticism makes clear its inadequacies and a superior alternative is available. Yet his work fails to identify such an alternative, instead simply emphasising the role of socio-cultural and personal factors in farmers' resource management decisions.

Such criticisms aside, it seems that members of the development community are loathe to consider possible shortcomings to the 'poor but efficient peasant' thesis. One reason is the way the debate has been framed as a choice between holding peasants to be either 'efficient' or 'irrational' (Adams 1986), making dissent from the efficiency thesis unpalatable. Similarly, would-be dissenters may fear being branded as neo-colonial. Given the prevalence of perceptions of peasant farmers as 'irrational', 'lazy' and 'perverse' during early independence and under colonialism (Ellis 1993), the desire to not *appear* to be harking back to such views is understandable. Nonetheless, any notion can be exaggerated and become a conceptual straightjacket, and the 'poor but efficient peasant' thesis is no exception.

[40] Specifically, he suggests that such farmers engage in 'satisficing' instead of profit maximisation and tend to follow time-honoured heuristic norms.

Arguably the key impact of the 'poor but efficient peasant' thesis has been to put the idea of farmer rationality firmly on the agenda (Hoff et al 1993). The problem with this thesis, however, is that it seems to have led many observers to obscure the distinction between *seeking* to be efficient and actually achieving it. The colonial perspective suggested that peasants did not even try to achieve this objective, while the 'poor but efficient' perspective simply assumes they achieve it. The present research does not question that peasants *seek* to achieve efficiency when managing their farms, yet it asks whether they may have difficulty achieving this objective given a rapidly changing rural context.

1.4.2 The Boserup hypothesis

The Boserup hypothesis is another relevant model, as illustrated by the celebrated case of Machakos District, Kenya described above. This model suggests that population growth coupled with market access can lead to large productivity increases while also reversing trends towards resource degradation. A key mechanism of these successes is investment in land improvement, or natural capital[41]. This model is presented as an alternative to the Malthusian model wherein population growth engenders output-increasing feedback loops rather than output-reducing feedbacks (Boserup 1965; Mortimore & Tiffin 1994). It also challenged once-prevalent ideas about peasant farmers being averse to innovation and their farming systems being static and unchanging (Meertens et al 1995:7).

The essence of the model is that rural people respond positively to the challenge posed by higher population densities through investments in technology. As a result, extensive fallow systems change spontaneously into intensive systems (Tiffin & Mortimore 1994c). While information about competing technologies is seen as critical to adaptation[42], this information is believed to follow naturally from increased population density and market activity. The policy implication is that rapid population growth and its impact on natural resource stocks need not be a problem.

1.4.3 The induced innovation thesis

The induced innovation thesis was first enunciated by Hicks in 1934. He wrote, "A change in the relative prices of the factors of production is itself a spur to invention (...) directed to economising the use of the factor which has become relatively expensive". At the time, the thesis was used to explain the push for labour-saving

[41] Such investment represents one means of adopting innovative technologies that focus on plentiful factors of production while conserving or improving scarce factors.
[42] Notably, optimal management depends critically on correctly assessing the costs and benefits associated with potential investments over their lifetime.

innovations in response to rising wages. More recently, it has been used to explain the process of technological change within agricultural development (Koppel 1995).

The theory of 'induced innovation' suggests that farmers innovate in response to changes in local opportunities and constraints (Binswanger & Ruttan 1978). Specifically, it suggests that farmers adjust factor proportions to changing relative prices[43], and that price changes also help generate new technologies (Evans 1983). Simply put, price changes spur invention. Thus, technological change is largely driven by changes in the economic environment in which the firm or public research agency finds itself (Ruttan 1996). Practically speaking, induced innovation is a key mechanism via which population growth leads to accelerated technological change (Roumasset & Smith 1981). The essence of this model is that farmers respond to population and market pressures via intensification and investing in conservation measures (Barbier & Hazell 1998). Following this line of thinking, Scherr & Dvorak (1993) propose a model whereby agriculture and agroforestry co-evolve in response to growing population pressure on land[44].

Induced innovation theory initially focused on technological change as endogenous to economic systems, or on providing an economic interpretation of technological change in agriculture. But it was later expanded to encompass processes of institutional change, notably the idea that officials, policy makers and scientists respond to resource scarcity as reflected in prices (Binswanger & Ruttan 1978a). Given this expanded model, agricultural development is believed to be driven by a dialectical interaction between technical and institutional change (Ruttan & Binswanger 78b). Despite this emphasis on induced change, enabling interventions such as farmer education and market-friendly policies are also called for (Hayami & Ruttan 1985).

While it has often been associated with Green Revolution technologies and case studies in Asia (e.g., Ruttan & Binswanger 1978b; Hayami & Ruttan 1985; Koppel & Oasa 1987), the model as stated applies generally to processes of technological innovation within agricultural development. Notably, Binswanger & Ruttan (1978) explicitly note the theory's relevance to non-market situations, such as those characteristic of peasant agriculture in low-potential lands. In such cases, opportunity costs of non-marketed resources play the role of market prices as indicators of value. Building on this idea, Scherr (1997) suggests that the microeconomic

[43] These prices, in turn, reflect relative resource endowments as mediated through factor and product markets (Ruttan & Giersch 1979). That is, induced technological change substitutes abundant factors for scarce ones (Runge 1987).
[44] Using the example of the Luo agro-pastoral system in western Kenya, they trace the changing role of trees on farms as land-use intensifies. The key stages of this evolution are shifting cultivation, fallow-based agriculture, expansion of the area under permanent cultivation, agricultural commercialisation and intensification, land degradation, and yield-increasing innovations.

changes associated with population growth induce technological and institutional changes in natural resource management (Scherr 1997).

While anthropologists and agricultural economists have often suggested that African peasant farmers show a conservative attitude towards innovation, this was seen as sensible given existing strategies well-adapted to meeting basic needs (Johnson 1972). More recently, others have emphasised endogenous innovation by farmers on the basis of systematic experimentation (Reij & Waters-Bayer 2001). Either way, the implication is that peasant farmers have well-adapted management strategies, with the only difference being their relative dynamism. By contrast, the present study suggests that this dynamism may be limited, and that the conceptual leap needed to keep pace with dramatic changes in resource constraints may not be forthcoming, resulting in sub-optimal management and failure to meet basic needs[45].

Perhaps the most basic problem with this thesis is that this process of technological change depends on markets reflecting the scarcity value of resources, yet prices of natural resources are often distorted by market imperfections. Possible consequences include overuse of these factors and inappropriate technology choice (Runge 1987; Ruttan & Giersch 1979). While such outcomes may be averted if households factor opportunity costs of non-marketed resources into their decisions, the present study questions whether this can simply be assumed.

A second problem with this thesis is that while the potential of rural people to innovate effectively may be clear, as demonstrated by impressive case studies, the pace of innovation may tend to be slow relative to population and market growth where such changes are rapid. Policy interventions to accelerate this process may thus be needed if ecosystem degradation and impoverishment are to be avoided (Scherr 1997). The present study examines this problem of lagged adaptation and explores the possibility that it is rooted in knowledge gaps.

1.4.4 Echoes in the agroforestry literature

Similar ideas about sound management of available resources and farmer responsiveness to changing incentives underlie the agroforestry literature. After its early emphasis on growing trees to address a perceived 'fuelwood crisis' met with widespread disinterest by farmers, agroforestry theory and practice shifted its emphasis to

[45] Compounding factors may include weak market forces and decreased emphasis on public research or extension.

understanding the economics of agroforestry from the farmers' viewpoint and addressing their perceived needs (Cook et al 1989). Such thinking echoes the broader trend of farming systems research, which emerged in the 1970s in response to disappointment with contemporary development efforts and concerns about ignorance of the farm context among researchers and extensionists. Such research employed a systems approach to examining production constraints, and included assessing socio-economic factors to ensure that proposed technical solutions were suited to the local context (Anderson 1991; Meertens et al 1995).

Evaluating a technology's merit on the basis of farmer assessments is believed to be particularly relevant to agroforestry, given the complexity of agroforestry practices with their multiple uses and status as multi-year investments. Researchers are also advised to pay attention to how farmers adapt recommended technologies to local resource constraints. Practically speaking, the implication is that outside researchers defer to rural households vis-à-vis the profitability of specific agroforestry practices under farm conditions and their suitability to the local context. More generally, rural people are deemed to allocate their limited resources among competing enterprises in ways determined by their priorities and their bio-physical and socio-economic circumstances (Franzel & Scherr 2002).

1.4.5 The 'tragedy of the commons' model

In his seminal paper 'The Tragedy of the Commons', Hardin (1968) argues that scientific debates are underpinned by an implicit assumption that the problem in question has a technical solution. The implication is that complex social or institutional issues may be sidestepped without jeopardising success. By contrast, Hardin suggests that technical solutions may not exist for some problems, since the key constraints may be social and institutional. This argument is illustrated using the case of communal grazing, but it applies equally to other natural resources that have historically been obtained from communal or off-farm areas, such as fuel or construction wood.

The fundamental problem is that the costs of a marginal increase in a household's herd are shared among all the users of the commons while the benefits accrue only to it. Given this situation, "the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd". The tragedy is that each household is compelled to increase its herd without limit in a world that it limited. "Freedom of the commons thus brings ruin to all[46]."

[46] This applies not only in the area of resource use, but also vis-a-vis waste disposal, where the calculations of private utility may lead to exceeding the assimilative capacity of natural systems, or "fouling our own nest" (Hardin 1968).

Such resource management problems occur in situations where population pressure from people and their livestock exceeds the regenerative or assimilative capacity of the natural resource base. That is, resource use need not be careful or efficient under frontier conditions, yet it becomes critical in situations characterised by resource scarcity[47]. When population density increases above a relatively low level, "the inherent logic of the commons remorselessly generates tragedy".

To address this tragedy, Hardin calls for changes to property rights, notably either privatisation of communal resources or nationalisation coupled with a system of regulated use. "The tragedy of the commons as a food basket is averted by private property, or something formally like it." The latter case involves government imposition of laws or taxing mechanisms that simulate private incentive structures, making it cheaper to use the resources in question carefully than to exploit them freely[48]. In both cases, therefore, it may be said that "private property ... deters us from exhausting the positive resources of the earth". Thus, the key implication of this model is that the 'tragedy of the commons' may be averted by privatising land or simulating private incentives.

By contrast, some authors have argued that Hardin's reading of commons management is flawed, since communal management can adapt its rules and practices to changing conditions (Pearce & Warford 1993:239; Runge 85). Others have argued that communal management arrangements represent promising solutions deserving the respect and support of outsiders (Matsumura 1994; Boonzaier et al 90) or have noted their suitability to the African context (Monu 1995). Still others have suggested that the argument as stated reflects an ideological agenda (Aguilera 91). Finally, some have simply documented instances of successful commons management (Feeny et al 90; McCabe 90).

The 'tragedy of the commons' concept has thus been used to advocate both privatisation of communal lands[49] and renewed emphasis on communal management structures. Yet the concerns with problematic knowledge raised by the present study apply equally to both interpretations.

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[47] The 'tragedy' thus develops out of management arrangements that are unproblematic as long as resources remain abundant. This obtained until recent decades in many parts of the developing world, since internecine warfare, the slave trade, poaching and disease kept human and livestock numbers low.

[48] This strategy applies particularly to the various natural resources not suitable to privatisation, including air, forests and water bodies.

[49] Or to draft laws to simulate private incentive structures on state-owned land.

1.4.6 What these models have in common

Despite their obvious differences[50], these various models nonetheless share a few fundamental characteristics. Most notably, they all assert farmers' responsiveness to incentives coupled with intimate familiarity with available natural resources. The 'poor but efficient peasant' thesis suggests farmers have optimised management of available resources, while the Boserup hypothesis and the induced innovation thesis – as well as the endogenous innovation literature – suggest they respond effectively to changing incentives. Finally, the tragedy of the commons model suggests that degradation of commons resources is due to perverse incentives and that these problems may be addressed via privatisation, which creates incentives for sound management.

The practical outcome of this focus is that when production or technology adoption outcomes are disappointing, potential problems with farmer responsiveness are not considered as a possible explanation. Instead, perverse or missing incentives of one sort or another are blamed. Notably, the technology may be deemed poor, or material or institutional obstacles may be blamed. Following these ideas, problematic natural resource management is only conceivable as a result of perverse incentives. Only two distinct scenarios are envisaged in the literature: Either households are 'forced' by their poverty to degrade natural resources or are prevented from managing them efficiently due to the 'tragedy of the commons'.

In the absence of a theoretical construct which allows local knowledge of natural resource management to be problematic, literature confronted with resource degradation and seemingly problematic resource management practices may tie itself into improbable knots. For instance, in writing about resource degradation in Kondoa District, Tanzania, Dejene et al (1997) first cite 'poor' resource management practices by locals and then pay homage to the ingenuity and resourcefulness of local people.

The policy outcome of these formulations is to focus on creating favourable incentives or developing new improved technologies. Thus, Todaro (1997) writes "We may conclude that peasant farmers do act rationally and are responsive to economic incentives and opportunities. Where innovation and change fail to occur, we should ... search for the particular institutional or commercial obstacles that may be blocking or frustrating constructive change." By contrast, the present study suggests that favourable incentives are necessary but not

[50] Notably, different authors have emphasised different factors as drivers of change in African farming systems. Boserup (1965) emphasised population growth, Hayami & Ruttan (1971) emphasised economic opportunities and available technologies, Ruthenberg (1980) emphasised local ecology, and Lele & Stone (1989) emphasised the policy environment. In practice, however, these factors often interact and overlap.

sufficient to secure advantageous outcomes and that farmers' capacity to respond to incentives may be constrained under certain conditions.

Looking ahead, the following chapter specifically examines contemporary theory regarding knowledge, particularly indigenous or local knowledge. Anticipating, this literature dovetails with the models described above in the sense that these various literatures all assume that farmer knowledge vis-à-vis the management of available natural resources is unproblematic. Due to this confluence, these literatures may be said to reinforce one another's failure to problematise local knowledge or to consider its role as a possible cause of disappointing outcomes. Yet insofar as difficulties responding to incentives are in fact the problem, these models and conceptual formulations may mislead policy from addressing critical constraints, and hence prevent it from achieving its goals.

Given the gravity and complexity of the problems facing African peasant farmers, development professionals must be sure to facilitate the efforts of farmers to address these challenges, not impede them. One potential pitfall lies in adhering to faulty theoretical constructs (Bromley 1998). At their best, such constructs help researchers analyse key linkages. Yet this requires that they be accurate shorthand approximations of the realities they represent. To ensure this, development professionals must continually reassess their conceptual frameworks. Only in this way can they be confident that they are helping target communities.

1.4.7 The 'tragedy of the commons' and 'knowledge failure' as distinct yet complementary

Although he did not assert it to be invariably true, Adam Smith's theory of the 'invisible hand' fostered a pervading belief that decisions reached individually will be the best decisions for society as a whole. This idea has had huge implications, favouring market-based approaches to problem solving and discouraging problem-solving interventions based on critical analysis. Within peasant economics and natural resource management, such thinking fosters a pervading belief about the optimality of local management decisions. Both the tragedy of the commons and knowledge failure models question the validity of such assumptions given population pressure. Specifically, both models raise concerns about patterns – whether of knowledge, management strategy or social organisation – that are holdovers from an era when natural resources were abundant, and hence are ill-suited to a contemporary context of relative resource scarcity.

The underlying reason for any problems with these patterns is the transition from relative abundance to relative scarcity of local natural resource stocks. Given abundant resources – which was the historical context in many areas of Africa including Sukumaland – these patterns are non-critical, allowing users to focus on harvesting resources or at most selective conservation of valued resources, e.g., not felling particularly valued trees when clearing areas of bush. Yet where these resources become scarce, their meaning and management strategy change fundamentally, creating potentially large adaptation challenges. The fundamental concern of both models is that rural people may fail to adapt established communal arrangements, household management strategies or local knowledge to growing resource scarcity, arguably due to taking historically abundant natural resources for granted[51]. In both cases, the policy implication is to identify means of helping to secure efficient use of valued natural resources and their conservation over time.

The fact that these two models highlight similar problems raises the question of whether the knowledge failure concept doesn't represent an extension to the tragedy of the commons model. Simply put, it does not. Despite their similarities, the differences between these two models are profound. Yet the two models are also complementary, highlighting two types of potential impediment to sound management of natural resources given population pressure.

The 'tragedy of the commons' raises concerns about social or institutional impediments to sound management of commons-based natural resources, which may create perverse incentives encouraging users to deplete valued resource stocks. Addressing the tragedy of the commons involves addressing these perverse incentives. By contrast, the 'knowledge failure' model raises concerns about informational or perceptional impediments to sound management of farm-based natural resources. The idea is that even where resource users face clear incentives to conserve valued resource stocks, they may fail to do so due to knowledge gaps vis-à-vis these same resources.

Thus, both models are concerned with potential obstacles to efficient outcomes vis-à-vis natural resource management. Yet they emphasise different types of obstacles as well as different tenure regimes with differing incentives[52]. Taken together, these models highlight potential obstacles to adaptation to change by local

[51] Many resources on which rural livelihoods in low potential areas depend are renewable natural resources. The special nature of such resources is that they reproduce themselves naturally, as a result of which they may be taken for granted, especially in areas where they have only recently become scarce.

[52] In common property areas, the incentives facing economic actors at best resemble those already existing on private farms, i.e., favouring long-term conservation and careful exploitation of valued resources. Efficient natural resource management is thus more elusive on commons land than on private farms, since it depends on appropriate institutional arrangements being in place in addition to addressing any

communities across all types of land tenure regimes, and hence across rural Africa generally. Employing both models involves identifying both institutional and knowledge obstacles to efficient outcomes.

The knowledge failure model builds on the tragedy of the commons model by highlighting how addressing perverse incentives may not be sufficient to address problems of resource depletion or deliver optimal resource management[53]. As such, the former represents a necessary complement to the latter, without which the envisioned solution to the 'tragedy' problem may fail. Arguably, a more profound implication is that those natural resources occurring on the vast swathes of privately-held rural land may not be managed optimally.

The tragedy of the commons model would be more effective if it considered potential knowledge problems, instead of assuming that securing sound management outcomes is purely a matter of ensuring favourable incentives. Two specific impacts of 'knowledge failure' on any reforms to common property institutions may be distinguished, regardless of whether these reforms involve privatisation. On the one hand, social or institutional arrangements may not be reformed in response to changing conditions, if local people do not recognise the need to institute these reforms. On the other, newfound incentives to conserve or invest in natural resources may not be heeded if users do not appreciate their rationale[54].

Whether on private farms or the commons, efficient management of natural resources may thus depend upon local people adapting to changing circumstances via a series of mental leaps. Three distinct mental leaps are identified, representing responses to progressively greater levels of population pressure on natural resources. These include mental leaps (i) from simple exploitation of unregulated land to regulating use of commons land in order to conserve resource supplies, (ii) from restricting use to drastically restricting use, given declining carrying capacity associated with overgrazing, (iii) from just exploiting NRs, albeit in a regulated manner so as to conserve supplies, to seeing a need to invest in their supply[55].

The third step involves the most dramatic break from past practice, and may prove a difficult transition both conceptually and in terms of management practice. That is, 'knowledge failure' is most likely vis-à-vis this

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knowledge problems. While there are fewer obstacles to optimal management of natural resources on private farms, such optimality can nonetheless not be assumed.

[53] Conversely, private farms are likewise affected by social and institutional structures, as elaborated below.

[54] While indigenous enforcement mechanisms *may* be sufficient to secure compliance with enhanced commons management regimes, the colonial experience with conservation measures suggests that rural people may be resistant to ideas involving reduced use of local natural resources. Maack (1996) describes one such case in her paper, "We Don't Want Terraces!".

[55] That is, intensification of natural resource management could lead not only to conservation of existing natural resource stocks via regulated exploitation, but also to positive investment in natural capital, for instance via tree cultivation or soil and water conserving practices. This is significant, as it highlights the possibility that resource stocks could be not simply maintained but actually increased, holding out promise of greater benefit streams to larger numbers of users. Yet such investment is comparatively unlikely in common property areas, given the organisational deands of labour inputs and organisational risks to harvesting the resultant benefit streams.

step. At the same time, this is the most relevant step to situations where population pressure on existing resources is acute or where depletion of natural capital is advanced, since this may be the only way to shore up natural capital in such situations.

Addressing instances of 'knowledge failure' may thus be a precondition to privatisation being an effective solution to the 'tragedy of the commons', since it is local people who must both reform these institutions and heed any reforms instituted[56]. This point has been neglected in the tragedy of the commons literature due to the same assumptions about well-adapted knowledge that permeate other literatures regarding natural resource management and agricultural development.

The 'tragedy of the commons' perspective likewise strengthens the 'knowledge failure' thesis. To ensure it is effective, assessing knowledge gaps is best done in conjunction with identifying any social or institutional factors that may create perverse incentives for rural actors, following the 'tragedy of the commons' model. This may occur even on lands that are privately held. In Shinyanga District, different categories of private property are associated with different levels of control over resources. While the home garden represents full-fledged private property, in the sense that users have full control over the inputs and outputs of this system[57], the household's fields represent a more ambiguous case.

Traditional institutions or the views and practices of other villagers may influence how fields are managed. Specifically, owners may not fully benefit from investments in land quality such as cultivating trees due to existing social conventions for managing natural resources or dealing with resource scarcity. In Shinyanga District, one such accepted practice is grazing livestock on neighbours' fields during the dry season, which can pose problems for more progressive households. For instance, grazing can kill tree seedlings, obliging farmers who value seedlings to take protective action. Livestock can also graze harvested fields bare of crop residues and weeds, thus leaving them exposed to wind erosion during the dry season. More generally, given context-specific socio-cultural ideas about trees, agroforestry must pay particular attention to constraints imposed by customary rules regarding land and tree tenure (Cook et al 1989).

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[56] Arguably, LK may in turn be informed by existing institutions, including those governing management of the commons. The operative distinction is arguably between leaders and their followers, since the former may help form institutions, while the latter may be largely formed by them.

[57] Notably, this area is both small enough and close enough to the household compound that households can either fence it in or chase away any people or livestock wandering into this area. Moreover, such restrictions are socially accepted in Sukumaland.

Arguably, a household that values trees can simply protect them via individualised fencing, as was sometimes observed in the household survey. Following the 'knowledge failure' thesis, those households who do this value farm trees more highly while those who fail to do so value them less. Yet a second possibility is that farmers in some villages may face stronger social sanctions against fencing in trees than others. Similarly, some households may simply feel timid about going against existing social conventions, despite strongly valuing trees. Thus, broader social and institutional factors may influence management outcomes on nominally private farms. As such, it may be hard to disentangle institutional effects from knowledge effects in practice, and whether or not a given household protects or cultivates trees cannot be assumed to indicate its knowledge about – and implicit valuation of – a given tree.

Attention to social or institutional arrangements is also complementary to examining knowledge gaps because it may shed light on patterns of farmer knowledge and perceptions. This follows because knowledge patterns may sometimes simply be perceptional, psychological or sociological reflections of tangible social structures.

In sum, in many rural contexts *either* knowledge problems or institutional problems could stymie desirable changes in management outcomes vis-à-vis natural resources. Because either or both of these mechanisms may apply in any given situation, it may be difficult to identify a particular instance of uneconomic natural resource management as either knowledge failure or the 'tragedy of the commons'. While these models are sharply distinct conceptually, in practice they overlap due to the complexity of peasant communities. On the one hand, social institutions and socially accepted practices may affect natural resource management on farmers' fields, while on the other patterns of local knowledge may affect any reform of communal institutions and peoples' adherence to these changes. Taken together, these two models highlight ways in which rural actors may be constrained by outdated local formulations, whether communal arrangements, management strategies or local knowledge.

Despite any similarities, the institutional concerns highlighted by the tragedy of the commons model are at least tangible arrangements among people, while the concerns raised by the knowledge failure model involve intangible factors. From a practical standpoint, the concerns raised by the KF model are thus comparatively elusive and difficult to analyse despite their potential importance. This is doubtless one reason why these concerns have been neglected in the literature.

1.5 Possible alternative interpretations of observed 'knowledge failure'

Despite the plausibility of the knowledge failure hypothesis, several theoretical considerations present powerful alternative interpretations for the phenomena in question, notably the observation that peasant households often fail to invest in advantageous regenerative technologies. These alternative explanations include the role of competing household objectives and the relation of both risk and discounting to household investment decisions.

1.5.1 Peasant households face competing objectives, including 'drudgery aversion'

In neo-classical economics, economic agents are conventionally assumed to hold profit maximisation as their overriding objective[58]. Peasant households are deemed to fit into this overarching framework, with the caveat that both marketed and non-marketed inputs and outputs of household production must be taken into account (Ellis 1993:66). Thus, it is virtually axiomatic within the literature that farm households possess a strong sense of economic calculation and strive to optimise farm production given their circumstances.

Besides profit-maximisation, peasant households may be characterised by several potentially competing objectives. For instance, the 'risk-minimising peasant' takes account of risk and uncertainty in his/her efforts to secure higher output, the 'drudgery-averse peasant' seeks a trade-off between objectives of higher production and more leisure, and the 'sharecropping peasant' seeks to compensate for market failures in land, labour and credit markets (Ellis 1993). Adams (1986) suggests that households may also possess social objectives such as status, personal objectives such as 'fulfilment' and spiritual objectives such as deference to ancestors.

One possible argument against the 'knowledge failure' hypothesis is that households may avoid advantageous investments in natural capital due to their preference for leisure over added 'drudgery'. That is, what might appear to be inefficient inactivity to some observers may represent optimal labour use from households' perspective. While this is possible, it seems implausible that households living in extreme poverty would prefer additional leisure to additional production if they perceived advantageous means of securing the latter.

[58] This objective corresponds to the goal of efficiency, since profit maximisation and efficiency logically imply each other, given standard assumptions of perfect competition.

1.5.2 Investing in natural capital is unattractive because it is too risky

Besides maximising net farm income, the objective of peasant households most frequently cited in the literature is minimising risk in an effort to ensure that subsistence needs are met (Ellis 1993). These two objectives are believed to work in opposite directions, requiring farmers to make trade-offs between them. Indeed, risk aversion is defined via this trade-off. Thus, risk-averse agents are defined as those who are indifferent between the certainty of receiving a lower income and running a specific risk to obtain a higher income. Within farming, such calculations are generally made over many periods, and the trade-off becomes one between higher *average* income over time that is more erratic from period to period and lower average income that is more consistent. The more risk-averse the agent or the more uncertain the outcome, the greater the reduction in expected income he will be willing to accept to obtain certainty (e.g., Todaro 1997:319; Angelsen 1991).

In general, the poorer the farmer, the more risk-averse he is expected to be, since the consequences of taking risks differ profoundly between the poor and the non-poor (Pinstrup-Anderson 2002). The poor are expected to place a premium on securing their basic needs, and hence may be unable to pursue risky but promising innovations (Scott 1976).

In the literature, risk tends to be associated with technological innovations, since farmers may be unfamiliar with innovative technologies (Feder 1985). By contrast, traditional or established practices are assumed to involve minimal risk. It follows that reducing risk depends critically on improved information, and that information is only problematic with respect to innovative technologies. If, however, knowledge of the costs and benefits associated with traditional technologies were also sometimes problematic, this could have dramatic repercussions.

While risk-averse peasant farmers may *seek* to minimise risk to ensure that their subsistence needs are met, the 'do nothing' option of not innovating may not always represent the more certain, less risky strategy. For instance, if a peasant farmer continues pursuing 'traditional' farming practices associated with shifting cultivation in a situation where this strategy has become ineffective, is this still a risk-minimising strategy? The relevant question is which strategy can reliably meet subsistence needs. The present study suggests that the answer to this question is not clear.

The myriad risk mitigation mechanisms employed by rural people are well documented. Examples include sharecropping, informal credit provision, clan and social obligations, and common property regimes (Hoff et al 1993). Such mechanisms are widely seen as resourceful and effective means of addressing complex and difficult problems with limited means (e.g., Mortimore 1998). More generally, they are seen as efficient means of allocating scarce factors of production, implying that these reflect the implicit value of associated goods and services (McIntire 1993).

The danger with these suggestions is that such structures could prove 'sticky' and ill suited to adapting to changing resource constraints. On this note, Dasgupta (1997) suggests that traditional practice may be perpetuated partly by conformism, or not wishing to break step with one's community. He cites the example of cultural factors encouraging high fertility, and suggests they may persist despite the disappearance of the practical rationale for them which once existed.

For the case of peasant agriculture, the question of whether innovating or not innovating better ensures that basic needs are met will be affected by a household's farm-based natural resources and those occurring on surrounding lands. If these resources are abundant, the farmer may be more successful at meeting his needs, whereas if they are degraded, he may have greater difficulty. Thus, one means of assessing the relative riskiness of alternative management options is to ask which one tends to result in a more dynamic and vital resource base.

The standard case in the literature is that innovating implies development that reduces natural resources, while not innovating implies resource conservation due either to non-exploitation or continued exploitation using strategies of proven innocuousness. Given this portrayal of the 'innovate' and 'do nothing' options, not innovating may be less risky, since the economic agent retains the 'option value' of using these resources in the future (Fisher and Krutilla 1985:185). Innovation, meanwhile, could lead to irreversible resource loss whereby the choices available to the agent are significantly reduced[59] (Henry 1974:1006). If, however, the 'do nothing' option implies reduced natural resource stocks while the 'innovate' option involves replenishing them, as in the case of 'regenerative' technologies, then these roles would be reversed. In this case, innovation could result in reduced risk, while 'doing nothing' could involve rising risks to meeting subsistence needs.

[59] As Arrow & Fisher (74:317) state, "If we are uncertain about the payoff to investment in development, we should err on the side of underinvestment rather than overinvestment, since development [may be] irreversible, [whereas] mistaken underinvestment can be remedied."

1.5.3 Investing in natural capital is unattractive due to high personal discount rates

Discounting is a tool used to permit comparisons of current and future costs and benefits associated with current choices. It helps show if an investment involving both current and future impacts makes economic sense, based on the underlying idea that the further in the future a positive or negative impact falls, the less significant it is to current choices[60]. The literature typically discusses discounting as it applies to decisions by business, government and other institutions, with rates of 7 to 10 percent being common.

Because African peasant farmers often lack access to credit markets or banking services, their relative weightings of present and future value are typically guided by 'personal discount rates' (PDRs), or informal assessments made in their heads. Regardless of the variety of discount rate, the precise rate applied is critical to decisions involving costs and benefits occurring over time, given the sensitivity of future values to discounting[61].

Two recent studies on PDRs found extremely high rates among poor farmers in developing countries. Both see these findings as caused by a mix of missing credit markets, poverty and risk. Pender (1996) found that approximately one-third of his sample in rural India have PDRs of over 100 percent. Holden, Shiferaw and Wik (1998) found rates of 105 percent among peasant households in northern Zambia and 53 percent among smallholders in a high-potential cereal zone of Ethiopia. Average annual incomes were $108 in Zambia and $196 in Ethiopia. Cash shortages seemed to have a strong impact on PDRs in Zambia, while relative wealth level measured in livestock had a strong impact in Ethiopia. The implication of these findings is that the 'intertemporal externality' observed may create incentives for nonsustainable resource use among rural people (Holden & Binswanger 1998), i.e., for mining available natural resources and failing to invest in natural capital.

One reason to question these findings, however, is that they are based on observations of farmers' actual conduct *assuming no gaps in farmer knowledge.* PDRs are a function of farmer perceptions, including perceptions of present and future capital productivity, wealth and risk. It follows that lagged or otherwise biased perceptions with regard to any of these factors could generate outmoded or inappropriate PDRs. In the Tanzanian context, for instance, lagged farmer perceptions could remain partly geared to shifting cultivation

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[60] Two key justifications of discounting are capital productivity, which gives an expectation of future income growth, and time-preference or impatience. Yet the former rationale is problematic, since future income growth may be undermined by ongoing resource degradation, or 'mining' of natural capital (World Bank 1996; Van Zyl et al 1995).

[61] Taking the example of impacts falling one hundred years in the future, lowering the discount rate from 10 to 5 percent increases the present value of the gain or loss incurred by over one hundred times (Angelsen 1991).

even in areas where this system is no longer appropriate due to altered resource constraints. Since resources in a shifting cultivation system are essentially open-access, the resulting PDRs could be erroneously high.

1.6 The study and its difficulty

1.6.1 Steps in the data analysis

The data analysis involves three distinct steps (see Figure 1.1). The first step is treated in chapters four and five, while the second is the focus of chapter five and the third is the focus of chapter six.

The first step involves defining key variables, and sets the step for the subsequent statistical analyses. Some variables used in the analysis emerged naturally from the raw data and required only minimal judgement. Variables falling into this category include the resource variables, soil-and-water conserving variables, and 'outside influence' variables. Other variables were more problematic, and as such their definition was discussed at greater length. These include the local knowledge variables and the dependent variables of the tree management models.

The second step constitutes the heart of the data analysis, namely assessing the explanatory power of household-level tree knowledge. It compares the explanatory power obtained using different sets of explanatory variables in regression models of tree management. Specifically, it assesses whether incorporating local knowledge variables into such regressions significantly increases their explanatory power.

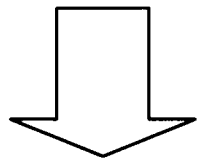
The final step of the data analysis explores local knowledge of trees in greater detail. It examines households' knowledge of particular tree species, and how some households have a more inclusive view of a given tree than others. It then seeks to shed light on the underlying patterns in tree knowledge via assessing a large number of associations between species-specific tree knowledge and other factors. The resulting findings suggest an anatomy of several distinct knowledge profiles existing within rural communities. They thus set the step for further research into such knowledge.

Figure 1.1 Steps in the data analysis

SETTING THE STAGE: DEFINING KEY VARIABLES

◊ Define tree management models based on different breakdowns of observed tree management practice

◊ Define local knowledge (LK) variables based on tree characteristics cited by households



ANALYSING THE EXPLANATORY POWER OF HOUSEHOLD-LEVEL TREE KNOWLEDGE

◊ Run a logistic regression of each tree management model with different sets of explanatory variables



Resource variables only

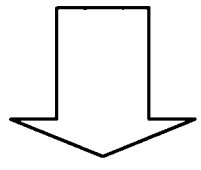
Resource and outside influence variables

Resource and outside influence variables as well as local knowledge (LK) variables



Assess differential explanatory power afforded by incorporating LK variables into regressions

{ Criterion: If LK variables significantly increase explanatory power, the data support the 'knowledge failure' hypothesis }



EXPLORATORY ASSESSMENT OF ASSOCIATIONS WITH SPECIES-SPECIFIC TREE KNOWLEDGE

◊ Identify species-specific knowledge of particular tree characteristics

◊ Assess associations of species-specific knowledge variables with diverse variables

- ✦ Resource variables
- ✦ Outside influence variables
- ✦ Management variables, including crop choice and soil-and-water conservation
- ✦ Perspective variables



Summarise observed associations, resulting in a suggestive anatomy of distinct knowledge profiles

1.6.2 Practical difficulty of the research

Despite the plausability of these ideas, empirically assessing them was difficult. Due to the intractability of the subject matter, this assessment is bound to fall short of being a definitive treatement of the issues.

One difficulty is identifying all the key resource determinants of management outcomes. Only if all such effects are already factored into the analysis is it possible to identify independent knowledge effects, i.e., to isolate knowledge effects over and above the various resource effects. Another identification issue is the inherent difficulty of specifying knowledge variables, since knowledge may be more continuous than discrete. As such, identifying the specific knowledge profile of a household vis-a-vis a given issue may require multiple overlapping questions.

A second difficulty involves measuring key knowledge differences. Obtaining knowledge data involves inferring knowledge effects based on interview responses, since knowledge cannot be observed directly. Specific measurement difficulties include reliance on households' goodwill and understanding of survey questions, and the interpretation of household responses.

Given the complexity of knowledge variables and the difficulty of apprehending them, inconclusive results are thus virtually inevitable in such an exploratory study. Yet these qualifications do not detract from the study's importance due to the potential significance of the issues explored. Moreover, future research into local knowledge could build on these foundations, avoiding key pitfalls encountered and focussing on fruitful avenues of enquiry.

Chapter 2

Reassessing Knowledge in Theory and Practice: The Case of Farm Management Strategies

2.1 Knowledge in economic theory

Economic theory does not generally problematise knowledge. On the contrary, knowledge is assumed to be good as well as universal, having been produced via the rigours of the scientific method. It follows that more knowledge is better than less, that knowledge helps economic agents make sound decisions, and that conflicts among competing strands of knowledge are not envisaged.

Instead, economic theory tends to see the actual distribution of knowledge and the information from which it is drawn as unproblematic, given functioning markets. Theory recognises that the heroic assumption of 'perfect information' – whereby economic actors have access to all the information relevant to the decision in question – often does not obtain in actuality. Yet instances of 'imperfect information' are interpreted as indicating that the information in question is excessively costly, since if it were advantageous agents would have obtained it (Varian 1999). Practically speaking, this may mean that many poor people do without useful information because they are unable to express 'effective demand' for it due to their poverty. Given the goal of poverty reduction, this market-based distribution of information may therefore be inadequate in developing country contexts, and non-market provision of useful information may be justified.

Given these assumptions about information and knowledge, the actual behaviour of economic actors may be taken as 'best practice' for meeting their needs and wants. Formally, the 'revealed preferences' approach involves observing a consumer's choices between competing consumption bundles, which are taken to reveal his preferences. This approach follows directly from the theoretical model of consumer behaviour[1]. Critically for natural resource management, this approach may be used to make judgments about how a consumer values inter-temporal choices (Varian 1999). Since peasant farms are characterised as joint production-consumption units (Ellis 1996:7), the revealed preferences approach may also be applied to farmers' production and management decisions, which are directly linked to their consumption opportunities. More generally, firms are

[1] Consumer theory teaches that people choose the best things they can afford. Those goods and services qualifying as 'best things' are determined by the preferences of consumers, rather than any objective criteria. The underlying assumption is that given any two consumption bundles, the consumer can rank their relative desirability. A key pillar of consumer theory is the transitivity axiom, which

assumed to choose factors of production that minimise production costs and to maximise outputs per unit input whenever inputs are costly.

Given these powerful assumptions, it is perhaps no surprise that the literature generally fails to address potential problems of adaptation to place and context. Specific dangers include that this knowledge may be either ill-suited to the farm context or inaccessible to local actors. Given abundant evidence of precisely such problems, the role of knowledge in agrarian African communities needs to be problematised.

The conventional view of information problems within economic theory focuses on the phenomenon of asymmetric information, where the buyer and seller possess different information about goods or services being sold in a market. This occurs where the information needed to verify quality is costly, since in such cases the seller is likely to have better information than the buyer. While the resulting equilibrium is inefficient relative to the full information case, it is optimal given the information costs in question. Were these information costs not excessive, the information in question would be provided either by private actors or by the public or voluntary sector (Varian 1999).

2.1.1 Theory vis-à-vis knowledge for development

The 1998/99 World Development Report, *Knowledge for Development*, outlines the conventional view of knowledge and its role in development. The Report suggests that poor countries – and poor people – differ from rich ones not only because they have less capital, but also because they have less knowledge. It specifically emphasises technical knowledge and knowledge about attributes, such as a product's quality, a worker's diligence or a firm's creditworthiness. More generally, information is the lifeblood of every economy. In more traditional economies, it may be less codified and often conveyed via personal interactions, but it is vital nonetheless (WDR 1999).

As an illustration, the Report compares the average per capita incomes of Ghana and South Korea. These figures were comparable in 1960, but by the 1990s the figure for South Korea was over six times higher than that for Ghana. The Report suggests that half of this difference is due to Korea's greater success at acquiring and utilising knowledge. The policy implication of this analysis is clear: knowledge gaps must be narrowed,

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suggests that if a consumer prefers X to Y and Y to Z, then he must also prefer X to Z. Without this assumption, it is impossible to determine a single 'best' choice among competing options (Varian, 1999).

notably knowledge vis-à-vis technology (WDR 1999). Bilateral development agencies such as the UK's Department for International Development take a similar line[2].

Many of the difficulties faced by LDCs involve knowledge gaps. Knowledge problems are especially severe for the poor, and often lie at the root of their difficulties. Conversely, narrowing knowledge gaps promises more efficient and productive agriculture, and would go a long way towards spurring economic growth and eliminating poverty. When knowledge gaps persist, markets cannot function properly. Generally, this occurs where the relevant institutions are weak or missing, i.e., those that set standards or enforce contracts (WDR 1999).

Within agriculture, this scientific knowledge has consisted of Green Revolution technologies and production strategies, notably innovations vis-à-vis seeds, other inputs and irrigation. This 'revolution' was highly successful, allaying Malthusian fears about the world's capacity to meet people's food needs by enabling food supply to exceed population growth despite rapid increase in the latter. A key problem with this rosy scenario was that it cited aggregate figures while neglecting problems faced by particular subsets of farmers. Notably, adoption of these technologies and strategies was concentrated among relatively wealthy and educated farmers, while many poor or remote farmers were bypassed[3]. Moreover, Sub-Saharan Africa remained a problem area, as food supply in this region failed to keep pace with population growth (WDR 1999; Sillitoe 1998).

Despite its successes, the Green Revolution has been running out of steam for years, and may be nearing the end of what it can accomplish (IFAD 2001). Two promising new directions for agricultural development are the 'doubly green revolution' emphasising genetically modified crops (Conway & Ruttan 1999) and 'sustainable agriculture' emphasising practices such as soil and water conservation, integrated pest management and agroforestry (Pretty et al 1996). Farmers in the 'less-favoured lands' may have to rely on the latter, since capital-intensive technologies may either be inaccessible or not economically viable in these areas. Sustainable agriculture strategies may be said to be information-intensive, as opposed to the capital-intensive nature of the two 'green revolutions' (Sillitoe 1998). Knowledge is thus critical to addressing the needs of farmers who lack access to capital-intensive technologies (Richards 1980; Howes & Warren 1980).

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[2] "The elimination of poverty and protection of the environment require improved access to knowledge and technologies by poor people.", DFID 1997 White Paper.

[3] This made sense, since such farmers were better able to bear the associated risks and recognise the associated opportunities. More recently, microcredit schemes have emerged to address these obstacles to adoption and the delay between the introduction of new technologies and their widespread use.

To close knowledge gaps, the World Development Report (1999) suggests that farmers must position themselves to take advantage of opportunities and minimise risks through acquiring and using existing global knowledge. A key requirement is investing in education to increase people's capacity to use MSK, while information technology is seen as a promising means of accessing MSK. Taken together, these interventions promise to make people more aware of their circumstances and possible alternatives, to help them overcome obstacles, and to enhance their capacity to articulate their concerns and priorities. Types of information of particular significance to agriculture include information on relevant technologies and the dynamics of complex natural systems.

This condensed characterisation raises several questions. Most fundamentally, it refers to 'modern scientific knowledge' (MSK), yet largely neglects 'indigenous knowledge' (IK)[4]. Moreover, it portrays knowledge as an uncontroversial good, with more being preferable to less. It thus neglects potential contradictions between MSK and IK or between distinct strands within either of these broad types, as well as the fact that some knowledge may be inappropriate to the local context[5]. Finally, it emphasises keeping abreast of 'the knowledge frontier' instead of how existing technologies might most usefully be applied to specific contexts, which is arguably a more relevant question.

2.1.2 Peasant economics and indigenous knowledge

One danger is that the theory cited above may not apply in communities practising semi-subsistence agriculture, where peoples' day-to-day decisions are governed primarily by indigenous knowledge. This knowledge is generated by local people based on their families' historical experience and their own day-to-day observations. It cannot therefore be said to entail procurement costs as such, generally speaking. The exception to this rule are indigenous innovations (see section 2.2.3), which involve additional investments of time, labour and other resources in generating novel IK. More fundamentally, the above emphases on global knowledge and the importance of knowledge to economic success suggests a view of IK as inadequate and in need of being supplemented by powerful MSK.

Despite this implicit criticism, IK is portrayed in the literature as sound, vital and dynamic, and as a key source of environmental information and know-how. In practice, it is seen as essential for tailoring institutional interventions and MSK to the local context, based on consultations with target populations. The underlying

[4] See section 2.1.4 for a discussion of the terms 'indigenous knowledge' and 'local knowledge'.

logic is that the poor know their circumstances, needs, worries and aspirations better than anybody. Far from seeing problems with IK itself, the problem is now seen as the possibility that this knowledge may be lost due to neglect and disuse[6] (WDR 1999).

IK is considered particularly useful for informing interventions in less-favoured agricultural areas. IK vis-à-vis natural resource management is believed to be especially accurate in such areas, given the critical importance of efficient management to securing livelihood objectives under these conditions. (Alcorn 1995; Zuberi 1998; Chambers 1983). Notably, these areas tend to have complex, interdependent farming systems, making attention to IK and a multi-disciplinary approach particularly necessary[7] (Gupta 1995). Finally, purchased farm inputs are often unprofitable and/or inaccessible in such areas, obliging local people to rely on the effective management of available natural resources, among other alternatives.

Within peasant agriculture, sound knowledge is reflected in the efficient management of land and natural resources. Since the seminal work of Schultz (1964), it has been widely accepted within the development literature that peasant farmers are 'poor but efficient'. That is, they are considered rational economic agents who combine inputs in such a way as to maximise profits. This view has been highly influential. Indeed, Ellis and Biggs (2001) argue that 'agricultural growth based on small-farm efficiency' is the paradigm that has most dominated the landscape of rural development thinking throughout the last half-century[8].

Because efficiency and profit maximisation are two sides of the same coin, the 'poor but efficient peasant' thesis ascribes to peasant farmers the objective of profit maximisation. That is, the farm household is believed to function like a firm. In the context of peasant agriculture, profit maximisation does not require monetary profits, but simply that no adjustment of inputs or outputs would give a higher net income, whether physically

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[5] On the contrary, these distinct strands of either IK or MSK are seen as unproblematic, with each applying optimally to a distinct set of circumstances, and with economic agents successfully discerning which knowledge applies where.

[6] On the one hand, IK has often been neglected by scientists and others working in development. On the other, the diversified traditional farming systems informed by IK have often been displaced by demographic and commercial pressures, causing the subtler aspects of IK to be disused by farmers.

[7] By contrast, IK and a multidisciplinary perspective may be comparatively unimportant in high-potential areas employing purchased inputs to agriculture.

[8] One problem with the 'poor but efficient peasant' thesis is that it emphasises allocative efficiency while ignoring issues of technical efficiency. Allocative efficiency assumes that economic actors allocate inputs and outputs optimally with regard to price. Yet such a farm could still be technically inefficient if it failed to properly employ the best available production technologies, and hence was operating on an inferior production function (Ellis 1996:ch. 4). Empirical studies have found that peasant farmers generally demonstrate allocative efficiency (e.g., Norman 1977; Ali & Flinn 1989), but that technical inefficiency among them is rife (e.g., Shapiro 1983; Ali & Byerlee 1991). The former finding suggests that farmers are doing the best they can given their resources, while the latter suggests that some farmers are nonetheless more technically competent than others.

or monetarily. In plain terms, farmers have been observed to demonstrate a strong element of economic calculation, i.e., responsiveness to changing prices, which is assumed to lead to efficiency[9] (Ellis 1996:ch. 4).

2.1.3 The rise of indigenous knowledge as a key concept in development

Over the past two decades, indigenous knowledge has become a key concept in the theory and practice of development. Its rise is part of a broad shift within development from a 'top-down' transfer of technology approach to a 'bottom-up' participatory approach, or from viewing target communities as passive recipients to active partners. Although it may sound revolutionary, in practice this shift is more evolutionary, with IK being essentially grafted onto the transfer of technology approach as a means of tailoring interventions to particular contexts.

Under the 'top-down' approach to development, poor farmers were encouraged to adopt 'modern' technologies and practices designed by outside experts. IK was typically ignored as unscientific and unproductive at best, and irrational and an obstacle to development at worst (Murdoch & Clark 1994; Long & van der Ploeg 1989:236). A typical example is described by Zuberi (1998) for the case of Bangladesh. Here, the practices farmers were pressured to adopt often had adverse effects on natural systems, including their biodiversity, soil fertility and water availability. In areas where 'modern' inputs were accessible, a common result was short-term increases in production associated with progressive resource degradation. This strategy also had social effects, marginalising the old experienced farmers who were previously considered wise. The net effect of this approach was to de-legitimise IK in the eyes of its holders and the wider society (Murdoch & Clark 1994).

Until recently, the attitudes of development professionals towards IK tended to range from disinterest or neglect to disdain. But thanks to the work of early proponents[10], IK has captured their imagination, and it is now widely agreed that incorporating IK into development efforts is essential to achieving sustainable development (Sillitoe 1998). Using the North as a blueprint is giving way to a negotiated, situation-specific approach that demands dialogue among the various parties to an intervention (Titiola & Marsden 1995). Many

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[9] Parenthetically, painting farmers as profit maximisers fits neatly with a free market view of the world, suggesting a potential ideological basis for this view of peasant agriculture.

[10] One of the earliest proponents of IK was Simmons (1974:33), who wrote, "Before the advent of Western culture, some 'primitive' groups had been notably successful in adapting to extreme environments in which there appears to our eyes to be a paucity of resources". Another early voice in this literature was the Brandt Commission report of 1980, which disavowed 'scientific imperialism' and using the North as a blueprint, and instead called for locally appropriate NRM systems based on IK. The first use of the term 'indigenous technical knowledge' was by Belshaw & Hall in 1972, while it first rose to prominence with the publication in 1980 of the seminal volume *Indigenous Knowledge Systems and Development* by Brokensha et al. Many of the early contributors to this literature had in-depth field experience and were disillusioned with the top-down approach to development, and some even changed disciplines and become anthropologists. Another watershed was the publication of *The Cultural Dimension of Development* by Slikkerveer et al in 1995, which heralded the expansion of IK research to over twenty distinct disciplines in both the natural and social sciences (Warren 1998).

authors go further, arguing that IK is a superior form of knowledge for informing development interventions, as it is seen to better represent the local natural and socio-economic context (Murdoch & Clark 1994).

In light of these developments, the problems of rural development are no longer generally seen to reside in traditional cultures, but rather in the partial and biased understandings of development agents, specifically in insufficient attention to the social and institutional context and IK (Roy 1987:159). Indeed, deference to traditional culture now tends to be seen as a necessary basis for any effective development initiatives (Titiola & Marsden 1995), while participatory approaches seek systematic incorporation of IK into development interventions.

2.1.4 Defining indigenous knowledge

Despite its prominence, the concept of IK remains contested. One indication that the concept remains in flux is that various competing formulations still persist in the literature. Although *indigenous knowledge* is the most common term, others include *indigenous technical knowledge*, *local knowledge, rural people's knowledge* and *traditional environmental knowledge* (Sillitoe 1998). Because the present chapter draws heavily on the literature, it follows convention by using the term 'indigenous knowledge'. In the remaining chapters, however, the discussion employs the term 'local knowledge'. This was done because the term 'indigenous knowledge' implies that the knowledge in question is indigenous in origin, which may be inaccurate. By contrast, 'local knowledge' is descriptive and leaves open the question of origins.

Although the specific elements included as part of IK vary, it is consistently portrayed as a broad, inclusive concept. Mundy & Compton (1995) suggest it comprises concrete pieces of knowledge, attitudinal factors and skills; Chambers (1983) suggests it comprises peoples' concepts, beliefs and perceptions as well as the processes by which these are acquired and transmitted; Thrupp (1993) and Flora (1992) suggest it comprises the categories, meanings and practices that local people use to make sense of their world.

IK has been defined as locally-specific, fluid, embedded in a broader cultural matrix[11], and orally transmitted or derived from practical experience (Ellen & Harris 1997). IK may be characterised as a 'concrete' historical tradition in which knowledge is encoded in rituals, religious observances and other cultural practices[12], while

[11] In working out how to use nature, local people operate within a web of myth, ritual and belief, in which nature and culture are seamlessly intergrated (Latour 1993:106).
[12] Although IK includes both socio-cultural and technical knowledge, the present study focuses on the latter. Nonetheless, insofar as socio-cultural knowledge influences technical knowledge, it is also directly relevant.

MSK is seen as an 'abstract' tradition in which scientists make claims in accordance with logic, testing and argument (Redclift 1992:402; Feyerabend 1987; Howes & Chambers 1979; Rhoades 1987; Murdoch & Clark 1994). Thus, farmers may be expert at growing potatoes, but unable to explain the basis for this effect, while scientists may be unable to translate their abstract knowledge into actually growing potatoes. IK arguably involves 'stories' wherein diverse human and non-human elements are situated based on their relation to other elements, and whereby local people link themselves to each other, their surroundings and their ancestors. MSK, by contrast, involves classification of elements based on their intrinsic characteristics, arguably involving the separation of elements rather than forming linkages (Ingold 2002). It is also fundamentally concerned with determining causality.

One problem with these various definitions is that they downplay IK's interactions with knowledge from outside the community, notably the often dynamic adaptations of modern scientific knowledge (MSK) to the local context. Another problem is that IK seems to be defined in opposition to an authoritative 'we' of western scientists, which has often been interpreted as implying that 'they', conversely, are passive and possibly ignorant (Ferradas 1998).

More fundamentally, some authors have called into question the distinction between MSK and IK, suggesting that upon closer examination this apparently sharp boundary breaks down. They suggest, instead, that the knowledge informing the decisions of rural people is the result of knowledge encounters in which diverse strands of MSK and IK get mixed together, and that what is needed is a better understanding of how these are or can be combined in practice (Long 1992:27; Agrawal 1995; Murdoch & Clark 1994).

While globalisation expands the reach of western culture and science and IK and MSK necessarily interpenetrate, the fact remains that non-western societies continue to inculcate people with different understandings of the world. As such, an us / them dichotomy is inescapable[13]. To pretend otherwise – e.g., based on feelings of liberal guilt – is "dangerous obscurantism" (Sillitoe 1998). Yet highlighting such a dichotomy need not imply superiority and inferiority, only different perspectives.

[13] Moreover, some remote communities exist largely without access to MSK, and rely instead on IK.

2.1.5 *Indigenous knowledge research*

IK research has been described as a new specialisation within development-orientated research[14]. Its remit is to study local people's understanding of their management practices and environment, while its aim is to achieve a sympathetic understanding of local peoples' perspective, then link their aspirations to modern technology and development practice (Brokensha et al 1980; Richards 1985; Wamalwa 1989). It is now widely recognised that simply presenting novel technologies for rural people to adopt is ineffective, and that development professionals must engage with the perspective of locals to effectively assist them. Notably, working with and through existing knowledge systems and organisational structures can result in projects that better fit the local cultural and environmental context, and hence in interventions that are more cost-effective and sustainable (Warren 1998). Conversely, ignoring local views can lead to inappropriate interventions and breed local resistance to initiatives (Sillitoe 1998). "Sustainable strategies of rural development... are best designed from where rural people are than from where 'experts' would like them to be" (Titiola & Marsden 1995).

One particular way in which IK can help development interventions better fit local conditions is by broadening the perspective of outsiders to take into account the various factors of interest to local people. The fact is that MSK often focuses on a single objective, while IK typically addresses several distinct objectives at once. For instance, Belshaw (1980) reports that the agricultural development literature historically tended to neglect intercropping due to its failure to appreciate this technology's capacity to address five key household objectives at once.

While closely related to applied anthropology, IK research also straddles various other disciplines in both the natural and social sciences. Indeed, the advent of IK research may be seen as the explicit incorporation into development of the anthropological perspective. Practically speaking, this involves employing knowledge brokers between target communities and outsiders to help tailor interventions to local conditions (Mettrick 1993; Sillitoe 1998). This work is part of a broader trend towards increasing cross-disciplinary collaboration within development research (Titiola & Marsden 1995). Key domains for IK research include ethnobotany, agriculture, natural resource management and health[15] (Alcorn 1995).

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[14] This new specialisation is relevant to both of the paradigms that currently predominate development thinking, namely the market paradigm emphasising market forces and the neo-populist paradigm, which emphasises participation and empowerment (Biot et al 1995). In both cases, the question of how households respond to available opportunities is critical, and this is largely a function of IK in agrarian communities.

[15] The IK literature falls into two broad categories based on differing views about the appropriate role of IK in development. Some authors advocate using IK to help planners design development interventions and scientists to overcome problems facing specific fields, such as soil science and agronomy (e.g., Guillet 1995; Thurston & Parker 1995). For instance, Mundy & Compton (1995) argue that interventions must build on IK and local practices rather than simply replacing them with alien practices, if they are to be effective. Meanwhile, others advocate the construction of a 'peoples' science' and call for fundamental reversals of the way development interventions are conceived

Because it involves scientists examining rural people's knowledge, research into IK is naturally concerned with the divide between IK and MSK and how these bodies of knowledge might be synthesised to better inform development interventions. Because it examines knowledge systems that view the world holistically, with natural and socio-cultural concepts intertwined, the sub-discipline is inherently interdisciplinary. Notably, it straddles the divide between the natural and social sciences. IK research thus stands outside the modernist perspective, which divides phenomena into distinct categories (Latour 1993:10), yet fits with the recent emphasis on interdisciplinary approaches.

The simple fact is that the separation of natural from socio-cultural phenomena is untenable in the context of contemporary rural development (Murdoch & Clark 1994). In working out how best to utilise available natural resources, local people operate within a web of myth, ritual and belief in which the natural and socio-cultural dimensions are seamlessly integrated (Latour 1993:106). Natural, socio-cultural and economic systems have co-evolved over long periods and have become functionally intertwined (Norgaard 1992:80). "Embedded in these cultures is the traditional knowledge about how ecosystems can and cannot be transformed, how ecosystems can be managed, and how social systems might be designed to mesh better with ecosystems" (Norgaard 1984:875).

2.2 Evidence of indigenous knowledge from the literature

Evidence of IK cited in the literature typically takes one of two forms: a priori argumentation and case studies. Both are problematic. A priori arguments for the significance, accuracy and power of IK may be countered by opposing a priori arguments suggesting fundamental problems with IK under contemporary conditions of rapid change. Meanwhile, case studies may not be representative of the broader community.

2.2.1 A priori argumentation

Along with case studies of innovative farmers or communities, the main source of evidence for the idea that IK is dynamic and appropriate is *a priori* argumentation. While such arguments are routinely put forward as

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and executed (e.g., Chambers 1983; Chambers & Jiggins 1987; Richards 1985). They typically emphasise the need to 'empower' the rural poor by treating them as full partners and 'local experts', and suggest that after being given access to technological alternatives, farmers are best left to their own devices. They also sometimes suggest that local people set the research agenda instead of leaving this to the discretion of scientists. Yet some in this latter group are sceptical about or even hostile to involving anthropology in development work, citing concerns about rapid assessment techniques such as RRA and the integrity of the data so obtained (Brokensha 1998; Ellen 1998). Much recent work has focused on bringing these two strands of the literature closer together, notably via strengthening the links between the natural and social sciences and between 'locals' and 'outsiders' via application of participatory and farming systems approaches (Titicla & Marsden 1995).

evidence for IK's strengths, *a priori* arguments suggesting potential weaknesses of IK are seldom heard. Yet a balanced picture of either IK or MSK requires consideration of both strengths and weaknesses.

Examples of a priori argumentation

* Traditional techniques of farming and resource management represent 'best practice' under conditions that are often marginal, having been employed, tested and refined over generations (Titiola & Marsden 1995).

* Each agricultural technology represents "centuries of active and methodical observation, of bold hypothesis testing by means of endlessly repeated experiments" (Rhoades 1987).

* Knowledge of the soil is based on accumulated experiences of cultivating it and hearing others comment about it (Sirkana 1993).

* Folk taxonomies of tropical plants and animals are often more detailed than their scientific counterparts (Posey 1998).

* Traditional practices based on IK successfully and sustainably exploited the resource base for centuries (Sillitoe 1998).

* Given management systems that have evolved over generations of experimentation, farmers may simply follow these proven practices without any need for analytical discourse (Moore & Golledge 1976).

* "If one is a farmer, one just knows. These practices work, and that is sufficient for people" (Sillitoe 1998).

* "Conservation measures beyond prudent cultivation practices informed by generations of experience are unnecessary" (Hausler 1995).

* "It is the powerful who are ignorant; it is they who have to begin as learners, and rural people who can instruct them. Small farmers are, after all, professionals. They cannot afford not to be." (Chambers 1983).

A priori arguments commonly cited as evidence for IK's importance

* It's in local people's interest to optimise management of locally-available resources

* Local people are intimately familiar with locally-available resources, since they have relied on them for centuries, and observe and manage them continually.

* Their survival over the centuries is evidence of these people's success, and the environmental sustainability of their livelihood strategies.

* They experiment with alternative practices, adapting technologies to changing circumstances and discovering novel technologies.

* They communicate regularly with neighbours, providing a means for advantageous technologies to disseminate.

* IK is not static, but constantly changes and adapts to new conditions (Richards 1989; Bebbington 1988; Ellen 1982).

2.2.2 *Case studies*

These focus either on farmers in a given community or on one or more individuals within a community, and typically involve providing an account of the complexity and subtlety of their knowledge. For instance, Neinz & Maguire (1979) report that !Ko women could identify 206 out of the 211 plant species growing locally.

Despite being a strong advocate of IK, Chambers (1983) acknowledges the danger that such evidence may be unrepresentative, warning that because those selected as informants may be the most knowledgeable, dynamic individuals, they may give an unrepresentative picture of IK in the community. The heterogeneity of knowledge within indigenous communities makes this danger particularly great. As Brokensha & Riley (1980:121) note, "even within a group, one individual will stand out because of keen powers of observation, prodigious memory, curiosity and intellect".

Many of the characteristics of farm systems identified in IK case studies are in the form of dichotomies. While any given individual dichotomy may be criticised as imprecise, the net picture created by such dichotomies may be both nuanced and accurate. Taken together, "these concepts seem to facilitate... an exact interpretation of a plot's condition" (van der Ploeg 1989:148). Using information theory, Chapman (1977) demonstrated that assessments based on rough data for several related variables – e.g., rainfall, temperature, wind – may give a more accurate picture than those based on very precise readings for a single variable, e.g., rainfall. Thus, five variables each measured on a scale comprising only three categories convey an equivalent amount of information to a single variable with 243 categories. A second sense in which IK may take account of a greater

range of relevant data is that it may employ a broader range of human faculties. For instance, !Ko bushmen identify plants not only by observation, but also by touch, smell and taste (Heinz & Maguire 1979).

2.2.3 Indigenous innovation

An increasingly prominent subset of the case study literature emphasises farmers as experimentors and innovators. This focus highlights the dynamism and adaptability of IK as well as its scientific credentials, demonstrating that local people not only observe and compare, but also experiment, analyse and attempt to predict (Reij & Waters-Bates 2001; Chambers 1983). This body of evidence suggests that smallholder farmers tend to be systematic folk scientists, both in the creation of indigenous technologies and in the testing and adaptation of introduced techniques (Rhoades & Bebbington 1995; Chambers, Pacey & Thrupp 1989).

Historically, smallholder farmers were seen as efficient, yet constrained by low levels of investment, traditional culture and marginal environments (Schultz 1964). They were not seen as engaged in systematic innovation or technology development, but rather as reliant on shifting cultivation and as prospective adopters of introduced technologies (Rhoades 1987). Since the 1960s, farmers have generally come to be seen as innovators, notably vis-à-vis the management of available natural resources[16]. However, more recent evidence suggests that farmer innovations involve mostly relatively minor adaptations of current practice (Nielsen 2002).

As noted above, indigenous innovations are the sole case where the theory of 'excessive costs' may explain why farmers lack a piece of relevant IK, since they involve additional investments of time, labour and other resources in generating novel IK. Innovations have been found to be common in African agrarian communities. Yet most involve only small, incremental changes to established practice, notably in the form of experimentation with new crop varieties or planting arrangements. Meanwhile, bolder innovations are comparatively rare, notably those involving shifts from relying on natural abundance to provide key natural resources to securing increased supply and/or retention of these resources via active management (Nielsen 2002). Examples include the shifts from relying on ambient rainfall to micro-irrigation or water-retention schemes, from relying on naturally-occurring trees to provide needed tree products to cultivating farm trees,

[16] Early reports of farmer innovation date from the 1960s. Sauer (1969) emphasised the inventiveness of smallholder farmers based on field work in Latin America, while Johnson (1972) suggested that farmers do not blindly follow tradition, but act creatively and individually. Thompson (1973) suggested that experimentation is particularly likely where farmers encounter unfamiliar environments, and hence need to adapt. Biggs & Clay (1981) report that farmers engage in ongoing experimentation and purposive selection, drawing on detailed knowledge of their environment to meet their diverse needs. Based on a survey of recent work, Rhoades & Bebbington (1995) write of the "near ubiquity and irrepressibility of farmers' propensity to conduct experiments" and of a "thriving 'peoples' scientific community"

and from relying on fallowing to regenerate soils to actively nurturing them using manure, green manure, compost, intercropping, or trees.

Following economic theory, one could call this situation of widespread but largely conservative innovations optimal, since arguably the bolder innovations are simply not worthwhile (or perhaps not even accessible), given households' resource constraints. The present study questions whether a failure to adopt bolder innovations necessarily indicates that these innovations are not advantageous. While the informational costs of innovation may be real, they must be weighed against the costs of inaction, notably those associated with progressive resource degradation and the foregone benefits of innovation. The study thus seeks to elucidate one of the great mysteries of contemporary development, namely the widespread failure of farmers to adopt bold 'sustainable agriculture' innovations despite the large production gains associated with these technologies (e.g., Pretty et al 1996).

2.2.4 Indigenous communication channels

Discussions of IK commonly note that it is transmitted from one generation to the next, yet few explore how knowledge is shared between individuals or communities. Indigenous communication has primarily been studied by cultural anthropologists, who have typically focussed on entertainment, social discourse and conveying values rather than technical knowledge (Mundy & Compton 1995).

Knowledge involves the process of knowing or cognition. It resides in people, and is a product of their communications with others and perceptions of their environment. By contrast, communication involves transferring information, whether explicitly or by observation. In either case, information must be decoded by the recipient, then integrated with his existing knowledge. Because this decoding is done in peoples' minds, different individuals may see the same phenomena or understand the same communication in different ways (*Ibid.* 1995).

Channels of indigenous communication retain great practical significance in many rural societies because modern alternatives such as schools, extensionists, radio and newspapers often fail to access rural people (*Ibid.* 1995). Such channels include folk media, indigenous organisations, personal instruction, unorganised contacts, and observation. Because these channels are familiar to local people and controlled locally, they often enjoy

high credibility (Rogers 1983). While they may therefore be harnessed by information provision initiatives, locals may resent this (Lent 1982; Compton 1983).

Thanks to such structures, useful information *may* diffuse spontaneously among rural people. Yet one problem is that farmers may be sceptical about the relevance of outside ideas to their needs. Thus, in East Africa IK of farming technologies was found to be highly local, with technology transfer particularly limited between ethnic groups (Stigter 1995; Allen 1965). Similarly, the San of the Kalahari mistrust hearsay and answer questions about their knowledge with detailed descriptions of their observations (Blurton et al 1976:330).

A second concern is that some types of information may be more likely to spread via indigenous channels than others. Notably, 'sexy' technologies that bring dramatic near-term gains may spread easily, such as a new high-yielding crop variety or source of microfinance. By contrast, technologies that are unglamorous and deliver only gradual welfare impacts may spread less readily. While plausible, this distinction is often overlooked[17].

2.2.5 *Countering the perceived anti-IK bias*

To understand the IK literature and the nature of the evidence it cites, it is helpful to consider the broader political context and intellectual debate into which this literature falls. Namely, to counter perceived anti-IK biases, some prominent authors (e.g., Leach & Mearns 1994; Chambers 1983) have advocated IK forcefully as a means of shifting the debate to what they see as a more sensible centre ground. The argument is that, given the force with which outsiders' knowledge has been put forth, positive discrimination to reverse such attitudes and behaviour is called for. In practical terms, this has often meant that the IK literature has been provocative, overstating the virtues of IK, while being hesitant to criticise its weaknesses.

Arguably, the position of these forceful advocates is excessively nuanced, since they themselves warn of the dangers of undue faith in IK. On the one hand, they note the danger that IK documentation may paint an unrepresentative picture. On the other, they warn against uncritically painting indigenous people as rational peasants whose perfectly judged actions are exercises in optimisation (Chambers 1983). Yet at the same time, they argue forcefully in favour of IK. This approach seems confusing at best, and seems to run the risk of both failing to convince IK sceptics and creating uncritical champions of IK. While this approach may have played

[17] For instance, Chambers (1983) suggests that if they are good, indigenous technologies spread rapidly.

a useful role at one time by forcing the scientific and development communities to take note of IK, continuing down this road in the current context seems unwise.

2.2.6 *Imputed morally-inferior motivations*

In addition to stating their case forcefully, some IK authors also frame their argument such that any who do not subscribe to it appear morally suspect. Notably, they suggest that dark, subterranean impulses animate scientists' views of IK. For instance, Sillitoe (1998) suggests that some scientists have difficulty admitting that they are not the only ones to have made impressive technological advances, and are simply waiting for IK research to fail so that they can return to designing technologies on their own terms. Likewise, Chambers (1993) suggests that scientists working on development issues tend to be sceptical if not hostile to IK and participation, seeing them as an attack on their specialist status. That, these authors suggest that many scientists are self-righteous, domineering and determined to jealously guard their professional turf.

Others take a negative view of scientists with a professional interest in IK, suggesting that this interest does not grow out of desire to help the poor, but out of efforts to appropriate IK for private gain (Ferradas 1998; Shiva 1997; Greaves 1994). While it is true that IK is sometimes extracted for private gain, this occurs mostly vis-à-vis one type of IK, namely ethnobotanical knowledge of interest to pharmaceutical companies. By contrast, IK vis-à-vis farming and resource management practices is not amenable to being commodified, since it involves low-tech, relatively unproductive forms of land use not of interest to the wider market. The confusion arises out of lumping together different sub-types of IK.

Given such comments hinting at questionable motives, it is perhaps no surprise that some Southern NGOs have taken their cue from these voices to proclaim themselves the sole rightful guardians of IK (Sillitoe 1998). Impugning the motives of others and claiming greater authenticity is risky, as it invites others to do likewise. While it may sometimes be warranted, as a general approach it is an unproductive way forward, and no way to facilitate collaborative problem solving.

2.3. Reassessing theory vis-à-vis indigenous knowledge

The practical result of contemporary theory is that indigenous knowledge is simply accepted, and that questions about its accuracy or relevance are expressed only hesitantly. Again, this state of affairs parallels that of MSK, with the prominent exception that competing schools of thought within MSK often challenge each other

vigorously. In such cases, however, their criticisms typically have a theoretical basis. Thus, despite the very different origins and perspective of MSK and IK, both bodies of knowledge arrive at a similar endpoint, given contemporary theory. Namely, in both cases private actors (i.e., farmers) naturally maximise their own welfare[18].

The underlying test of all theory is whether it is a reasonably accurate description of the world or competent predictor of how people actually behave (Varian, 1999). To the extent that IK research may be judged by the success of the interventions it has spawned, the verdict is not encouraging. Whether a different body of development theory and practice could have done better is an open question, but clearly contemporary theory vis-à-vis African peasant agriculture has no grounds for complacency. Indeed, in cases where theory fails to adequately predict phenomena or solve existing problems, the theory in question is arguably ripe for fundamental change, or 'scientific revolution'.

The Structure of Scientific Revolutions (Kuhn 1970) was a watershed in the development of scientific thought, sowing doubts about the objectivity and universality of scientific advances. This volume argued that scientific theories and facts are only acceptable as long as they conform to the reigning paradigm. Specifically, the orthodoxy directs the attention of scientists to certain questions, and findings that 'fit' are emphasised while those that do not are disregarded. This persists until the opposing evidence and supporting arguments become sufficiently compelling to usher in a new orthodoxy via a 'scientific revolution'. Subsequent studies in the sociology of science (e.g., Knorr-Cetina 1981; Collins 1986; Rouse 1987:21) have suggested that scientific knowledge has no special epistomological basis, and that it is not intrinsically different from other forms of knowledge. Notably, evidence for any given theory is based on work conducted at a particular time in a particular place.

While IK research itself represented a paradigm shift from the top-down development model, it is suggested that yet another paradigm shift is now needed. Namely, it is suggested that the contemporary IK literature represents an example of narratives that no longer fit the evidence and that downplay findings that do not support the IK model. While potential problems with IK are sometimes noted in passing in the literature, they

[18] In this sense, IK theory may be said to integrate the knowledge of peasant farmers into a broader framework that fits neatly into a free market view of the world.

are not explored[19]. Moreover, the text in question invariably concludes by emphasising the strengths of IK and the importance of its being used to inform development interventions.

2.3.2 *Indigenous knowledge problems cited in the literature*

Although IK may often be sound, it is conceivable that local people might make mistakes in their observations and assessments of natural phenomena. People often subscribe to myths about the world, yet these myths may be technically erroneous. For instance, highland farmers in Papua New Guinea sometimes burn old pieces of netting to stop the rain or squash certain plants to end a drought. While such ideas may have wider cultural associations, "people who believe these practices influence the weather are [technically] wrong" (Sillitoe 1998).

Some authors suggest that IK may not always be 'in harmony' with the local natural environment and that practices based on IK can lead to serious resource degradation[20]. Indigenous people may thus rely on "beliefs that are ineffective" in terms of their own interests. Although this is contested by prominent voices in the literature[21], IK may be most likely to be inadequate in situations of rapid change, such as that associated with rapid population growth or progressive resource degradation, given peoples' limited capacity to innovate and adapt. "Sometimes knowledge that was once well-adapted and effective for securing the people's livelihoods... becomes inappropriate when confronted by rapid socio-economic changes and interventions"[22] (Thrupp 1989:15). For instance, this might occur when fallow periods are reduced due to population growth to the point that they fail to restore soil fertility and lead to land degradation, or when people migrate to an area where their knowledge is inappropriate (Sillitoe 1998). Thus, in southern Malawi, continuous cropping has replaced shifting cultivation and striga weed is adversely affecting yields, yet innovative practices such as manuring and composting that reduce striga infection while improving soil fertility remain uncommon (Riches et al 1993). More generally, Murdoch & Clark (1994) suggest that simplistic portrayals of IK as an appropriate, 'green' alternative to MSK may be misleading.

Other IK 'problems' are ambiguous. That is, while some decisions based on IK may seem unfortunate to outsiders and may work against the objective of sustainable production over time, they may nonetheless be

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[19] This is reminiscent of the limited critical perspective on the ways in which MSK may be inappropriate.
[20] The study elaborates various reasons why this may occur, examines fresh data to assess its incidence, and explores implications for development policy.
[21] Thus, Brokensha & Riley (1980) and Howes & Warren (1980) suggest that using IK to address the needs of rural people is *especially* relevant and effective given conditions of rapid change.
[22] Similarly, the present study hypothesises that IK may be well adapted to the local context when first generated, yet become outmoded after failing to adapt to a changing rural context.

optimal from the farmer's perspective. For instance, given unrestricted access to agricultural technologies, as advocated by some of the more populist IK literature, poor farmers would likely choose industrial fertilisers, biocides and machinery. Reasons for this include that these modern inputs may require lower labour inputs and offer quick solutions to problems while also being perceived as markers of success. Yet these inputs may be inappropriate, notably due to requiring abundant financial resources while failing to sustain key natural resources. For instance, highland farmers in Papua New Guinea want 'soil medicines' (i.e., chemical fertilisers), but lack the resources to access them without significant subsidies. Thus, farmers' wishes may not suit their circumstances (Sillitoe 1998).

Similarly, farmers might perceive 'low-tech' yet appropriate options such as agroforestry or soil and water conservation technologies as unattractive alternatives to 'modern' technologies, and hence be uninterested in adoption (Ellen 1998; Sillitoe 1996). This is particularly likely in areas where poor farmers previously had access to subsidised agricultural inputs, and hence may have grown accustomed to these powerful technologies. A related issue is that some farmers opt to discard 'low-tech' practices that sustain both culture and environment in favour of 'high-tech' practices which provide immediate benefits but store up problems for the future (Ellen 1998).

Whether such choices are optimal for the household in question will depend on the personal discount rates of its leading members as well as on their preferences. Thus, poorer households will more strongly prioritise current gains over future welfare, making short-termist practices relatively more attractive to them. Otherwise, if a household has strong preferences for having high status in the eyes of its neighbours, it might be happy to utilise 'soil medicines' even where these are disadvantageous. Such prioritisation of status symbols is arguably reflected in the widespread preference observed in Shinyanga District for growing maize as a staple food crop instead of sorghum or millet[23], despite the fact that the latter two crops grow more reliably in the zone and are more nutritious.

While such choices may thus be optimal given the household's preferences, this assessment is open to question. The issue is whether or not the household fully recognises any negative future consequences of its choices, or has a clear picture of the trade-offs involved. The following observations suggest possible reasons why actors may not fully recognise these adverse consequences when making resource management decisions.

[23] Potentially, surplus maize production could also be sold on local markets, but given the levels of production observed this prospect is deemed to be relatively rare. Moreover, sorghum and millet can likewise be sold on local markets.

2.3.3 *Three fundamental questions regarding indigenous knowledge*

The present study asks three fundamental questions regarding indigenous knowledge. The first is why the management strategies employed by farmers might be problematic. It is suggested that this might occur due to cultural or social patterns that hinder farmers' capacity to recognise and respond to shifting incentives. Deleterious outside influences may also hinder farmers' capacity to adapt to a changing farm context.

The second overarching question is why problems with IK are neglected in the literature. It is suggested that IK is seen as unproblematic for the same reason that MSK is seen as unproblematic, namely because the conceptual models used to understand and explain each of these broad knowledge types do not allow for this possibility. Any such problems are thus obscured by these models. While these models frame these two broad types of knowledge in different ways, both formulations dovetail around a view of knowledge as unproblematic. They also dovetail with farmers' sense of their knowledge (i.e., indigenous knowledge) as unproblematic.

The third overarching question is why the incorporation of IK into development interventions falls short. It is suggested that this occurs in part due to practical difficulties with gathering IK in a useful form and in part due to a failure to convince development practitioners of its practical value.

The study focuses primarily on the first of these questions, specifically on examining whether the IK used to inform farmers' natural resource management decisions may be problematic. Taken together, the three questions seek to clarify how the theory and practice of development may fail to tap the full potential of IK to make both farm practice and development interventions more effective.

2.4 Question one: Why might farmers' management strategies be problematic?

2.4.1 *The management decisions of peasant farmers emphasise renewable natural resources*

Management decisions within peasant agriculture on low-potential lands emphasise natural or 'environmental' resources such as soil, water, trees and pastures, since these areas are largely biomass-based subsistence economies[24] (Dasgupta 1997). The management of these resources is complex. They provide diverse goods and services as well as imposing costs, and often display intimate interlinkages. These costs and benefits act

[24] Besides provision of resource inputs, the other broad economic role of environmental resources is the assimilation of waste products. The former is more significant to low-input agriculture, while the latter is more relevant to high-input agriculture and industry.

over time, providing both present and future consumption streams. The relationship between the size of resource stocks and their rate of regeneration is also complex (see Appendix A). Finally, the viability of these resources depends on the interaction of natural and social processes.

As rational agents and efficient managers, farmers are believed to avoid farming in ways that cause yields to decline in successive years, under normal circumstances (Boserup 1965; Tiffin et al 1994). When resource depletion and associated agricultural stagnation are observed, they are attributed either to short-termist exploitation associated with uncertainty or acute stress, or to the breakdown of customary management systems (Ellis 1996:ch. 12). This theory arguably sits uneasily with the widespread reports of resource degradation in rural Africa and the fact that this phenomenon is increasingly cited as a key cause of agricultural stagnation and rural decline (Delgado 2001). Worse, it appears to rationalise these developments as inevitable given existing resource constraints and cultural pressures. Indeed, such rationalisations are common in the literature, typically involving suggestions that rural people are 'forced' to degrade needed resource stocks (e.g., Hazell 1995; Human Development Report 1998:66; Pearce & Warford 1993:263-276; World Bank 1992:30). Yet arguably this view is not only fatalistic and defeatist, but inaccurate.

An alternative explanation for resource depletion is the difficulty of assessing environmental values given the absence of defined prices for environmental goods (e.g., woodfuel) and services (e.g., the fertilisation effect of certain trees on soils). Notably, rural people could fail to adapt their management patterns to a changing rural context[25], failing to conserve and/or regenerate local 'natural' resources in cases where doing so would be advantageous. Simply put, their management of farm-based natural resources might be plagued by knowledge gaps.

Typically, prices act as a sensitive measure of economic value based on the intersection of supply and demand, providing the information needed for economic actors to allocate resources efficiently. But environmental goods and services are unusual in that they are not generally exchanged in markets, and hence do not bear defined prices[26]. Historically this was unproblematic, since these resources were abundant. Yet given

[25] Key changes over recent decades include rapid population growth, resource degradation, market proliferation, and major shifts in government policy.

[26] A related problem is that key environmental data are not reflected in national accounts. Notably, these data fail to provide evidence of the degradation or depletion of natural resources. The danger is that such accounts data may give misleading policy signals that a community or nation is on an environmentally sustainably path when this is not in fact the case. The need for such indicators to better reflect environmental value has led to 'green national accounting', which subtracts out environmental costs when calculating GDP and other economic indicators. A useful statistic emanating from this literature is the 'genuine saving' rate, which indicates whether countries are maintaining or building up their capital stocks, or rather depleting these stocks, and hence essentially mortgaging their future to fuel current consumption. This concept is useful because it makes trade-offs between the economy and nature explicit, and alerts resource managers and policy makers to unsustainable practices and trends.

increasing resource scarcity coupled with a tradition of relying on natural regeneration of needed natural resources, how these resources are valued has become a pressing question.

2.4.2 *Implicit valuation places a great burden on indigenous knowledge*

The fact that 'environmental' resources typically lack prices places a great burden on the IK of peasant farmers, since farmers must base their management decisions on 'implicit valuation' of these resources in cases where they are scarce. The concept of implicit valuation is posited by the present study to describe how peasant farmers integrate environmental values into their decisions, and may be seen as an analogue to formal environmental valuation[27]. Implicit valuation involves assessing the net value or 'implicit price' of each key natural resource based on the various goods and services it provides and any costs it imposes. This process is conducted entirely within farmers' heads, i.e., without clipboards, pencils, mathematics, or methodological tools such as net present value. Each resource is simply 'sized up' by farmers. For instance, farmers are expected to fully recognise the value to the household of goods such as fuelwood and fodder and environmental services such as nutrient, energy and hydrological cycles that underpin natural resource-based production. More generally, the choices between competing farm management strategies are likewise simply sized up by farmers.

In the case of peasant agriculture, the analogue of conducting formal environmental valuation and 'getting the prices right' is thus ensuring that farmers are fully aware of relevant environmental values. While implicit

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[27] Environmental valuation, or assigning monetary values to non-marketed environmental goods and services, has risen to prominence over the past decade. Valuation responds to the need to take explicit account of formerly abundant but increasingly scarce environmental goods and services whose economic value has traditionally been either taken for granted or ignored. Its practical purpose is to ensure that non-marketed environmental costs and benefits are factored into decision making.

While controversial, assigning monetary values to non-monetised goods has been justified by the need for a common measuring rod by which to compare the diverse costs and benefits – both marketed and non-marketed – associated with a given initiative (UK Department of the Environment 1991). Specifically, pricing environmental goods and services permits recognition of their economic significance and relative scarcity in the cost-benefit calculations which typically form the basis of project and policy decisions. Thus, economic assessments increasingly involve explicit consideration of environmental costs and benefits, with these factors often proving critical determinants of whether or not initiatives go ahead (Willis & Corkindale 1995; Hanley 1995).

Environmental valuation addresses the root cause underlying degradation of environmental resources, namely that agents have traditionally not faced any incentive to protect these resources, since they did not appear on the balance sheets of profits and losses (Pearce et al 1989:5). The danger is that without explicit recognition of their economic worth, natural resources will be deprioritised and become degraded (Hanley 1995). Economic consequences could include inefficient resource use, squandered assets, and unsustainable development (Holdgate 1995).

The case of soil degradation illustrates the significance of these environmental values to agricultural production, while also suggesting that they are being neglected or deprioritised. Worldwide, an area the size of India has suffered severe degradation, while an area the size of three Indias is still capable of being farmed, but has lost a significant proportion of its productivity. The associated economic costs are enormous (Holdgate 1995).

Without environmental valuation, economic agents may ignore privately and/or socially significant environmental costs and benefits (Laslett 1995). By contrast, environmental values are assumed to be fully accounted for as long as agents have private ownership of resources. It follows that one way to secure environmental valuation is by privatising the resource in question, since if it is in an agent's private interest to conserve or invest in a resource, he will tend to ensure that this is done (DoE 1994). Despite this assumption that private ownership gives proper valuation of natural resources, this is not necessarily the case. Indeed, the present study is predicated on the idea that private ownership in itself may not be sufficient to secure proper valuation of natural resources.

valuation may not be as rigorous as formal valuation, it is both systematically conducted and cost-free, since it is part of households' day-to-day management decisions. This contrasts with formal valuation, which necessarily raises the question of whether conducting the valuation is justified by the likely gains from better-informed decisions (Glass & Corkindale 1995; Newbery 1995).

As discussed in chapter one, decisions on natural resource management may also affect future generations, either by building up or drawing down natural capital stocks, notably on private farms. The necessity of assessing both present and future impacts of current management decisions further complicates the task of implicit valuation[28]. For instance, farmers are expected to recognise how much investments in soil improvement promise to increase crop production or investments in farm-based fodder supplies promise to bolster livestock production. This concern with longer-term impacts is encapsulated in the concept of sustainable development.

Given the diverse costs and benefits associated with resources such as farm trees, implicit valuation may be highly challenging. Yet it is arguably made vastly more difficult by the contemporary process of resource degradation, as a result of which many previously abundant resources have become scarce. The practical implication is that the significance to livelihoods of some natural resources may have changed fundamentally over a short space of time, along with the most advantageous strategy for managing them. The management question is whether farmers keep pace with and fully adapt to these changes, or whether their management practices sometimes prove 'sticky' and fail to keep pace with a changing farm context. This key question ultimately depends on farmers' IK and their implicit valuation of local natural resources[29].

To illustrate how the meaning of natural resources can shift given resource degradation, consider the case of trees in a semi-arid agricultural zone with minimal access to purchased farm inputs, such as Shinyanga District. As natural tree stocks become increasingly scarce, households might be expected to emphasise more subtle

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[28] Notably, many types of natural resource management involve 'investing' in natural capital, such as permanent crops, livestock, and soil fertility management. For such capital investments, investment appraisal is required to inform management decisions, since single-period budgeting is inadequate to assess either their feasibility or profitability given cost and benefit streams accruing over time (Upton 1996).

Investment appraisal involves both estimating the costs and benefits expected over the investment's lifetime and evaluating their present value using discounting. Taken together, these define an investment's 'net present value' (NPV), with investor decisions based on comparing the expected NPV with alternative investment options and the possibility of not investing (Pearce et al 1989:124). Thus, finding that investing available funds in an orchard promises net private benefits is not sufficient reason to invest in it, since this option must also be compared with alternatives such as buying livestock or paying school fees. Similarly, before a farmer invests his labour, he must first assess the relative profitability of his various alternatives, such as continuing to pursue a 'traditional' strategy or seeking wage labour.

While investment appraisal is generally associated with capital investments involving marketed costs and benefits measured in monetary terms, in the case of peasant agriculture it also includes non-monetary values that must be valued implicitly (Serageldin 1996). Again, the absence of market prices for such resources imposes large demands on the analytical and adaptive capacity of indigenous knowledge.

goods and services associated with trees in addition to more obvious ones, since these various goods and services will tend to become more significant and precious given their scarcity value. Where natural tree stocks are abundant, households might emphasise only obvious, high-value tree products such as fruit and timber. Where stocks are partly depleted, households might also emphasise other products such as herbal medicine, fodder and fencing. Where stocks are scarce, households might emphasise both tree goods and tree services, such as soil fertilisation and microclimate functions. Meanwhile, households' emphasis on the costs associated with trees is expected to decrease as natural stocks become scarce, since these negative impacts are density-dependent. Notable costs to the farm include obstructing sunlight to crops and harbouring tsetse flies and crop-eating birds. Given these shifts in meaning, households are expected to become more willing to cultivate farm trees and to cultivate these trees more intensively as natural tree stocks become increasingly scarce. While the meaning of farm trees tends to shift and the incentives associated with removing, retaining or cultivating trees likewise tend to shift, this fact is arguably distinct from whether how farmers view trees likewise shifts.

While resource degradation occurs both in developing and industrial countries, the significance of this shift is different in these two contexts. In industrial countries, resource degradation is a quality of life issue with only an indirect welfare impact on a relatively well-off population. In rural parts of developing countries, particularly where people lack regular access to industrial farm inputs, resource degradation is a basic needs issue with a direct welfare impact on a relatively poor population. In the industrial country case, the primary concern is that the capacity of 'environmental sinks' to assimilate pollutants may be exceeded. In the developing country case, the primary concern is that stocks of key natural resources (e.g., fertile soil, fodder supplies, woodfuel, water) may become depleted. In sum, the welfare significance of resource degradation is both greater and more immediate in developing countries, where the ongoing viability of these resources may be critical to the livelihoods of poor households.

2.4.3 The possibility that rural people might get management decisions 'wrong'

The present study hypothesises that rural people may sometimes get these resource management decisions 'wrong' in terms of their own private interests, given the rapid changes in the rural context associated with population growth and resource degradation. That is, such knowledge may not be 'too expensive' in terms of

[29] While it may also depend on the effectiveness of outside interventions into local development, these too ultimately depend largely on local peoples' receptivity to the solutions advocated, and hence on IK.

resource investments, but 'affordable' yet neglected for other reasons[30]. One possibility is that resource stocks are still in fact sufficient to generate needed resource flows, as a result of which it is not worthwhile paying close attention to these resources. A second possibility is that information about natural resources such as trees is not generated – or heeded when suggested by outsiders – due to outdated views of these resources and/or biases against them. In cases such as these, the decision to not innovate is sub-optimal[31], and may be said to represent 'knowledge failure'[32].

This formulation of knowledge problems is distinct from framing these problems in terms of knowledge gaps, as is typical in the literature. Speaking in terms of knowledge gaps implies that all knowledge is good, and that the only question is whether an actor has access to it or not. Yet given the contention of the present study that knowledge may constitute misinformation that misleads farm practice where it is maladapted to the local context, a different formulation is called for. If it is context-dependent, knowledge may be characterised as either appropriate or maladapted, while situations where knowledge fails to accurately reflect incentives are said to be characterised by knowledge failure.

Specific dangers to natural resource management given a rapidly changing rural context include the following:

(i) Some production inputs may not be recognised as costly when in fact they are. This might occur where these inputs were historically abundant but have become scarce in recent years. It is particularly likely where this transition from abundant and costless to scarce and costly has been gradual, since such changes may be difficult to discern.

(ii) Technologies and strategies that respond to these newfound scarcities may not be recognised as available and viable management options, and hence may not be considered when households make management decisions. This is particularly true where such technologies represent a dramatic break from past practice, for instance from simply retaining naturally-occurring trees in fields to actively cultivating them. Indeed, some smallholder farmers may not exercise choice at all, since they may recognise only

[30] The difference between these two cases – i.e., neglecting accessible, advantageous opportunities or simply lacking access to potential opportunities – involves the question of efficiency. Where information is 'too expensive', information gaps are consistent with the efficient allocation of resources. Yet where these gaps are due to other factors, management is inefficient, since alternative allocations of available resources could secure more advantageous outcomes.

[31] While this decision may be roughly optimal as long as the resources in question are abundant, it becomes sub-optimal if these resources become scarce.

[32] Reiterating, the study hypothesises that such 'failures' plague farmers' management decisions vis-a-vis natural resources during periods of rapid change.

one 'correct' management option vis-à-vis a given resource, explaining simply "this is the way it is done"[33].

(iii) Where these newfound scarcities involve drawing down local stocks of natural capital, households could be essentially living beyond their means by 'consuming' key capital stocks. This situation is analogous to the case of a household living beyond its means via borrowing. Critically, the household could be drawing down these stocks and reducing their farm's future productive potential *without realising it.*

Thus, some management options available to households may not be recognised as such, and household choices may be based on incomplete information. In areas where local natural resources are key economic inputs, as is often the case in poor rural areas such as Shinyanga District, successful implicit valuation implies 'getting the prices right' as guides to economic activity[34].

Summarising, the implication is that development interventions cannot simply defer to IK as a 'silver bullet' for making development interventions efficient and sustainable, nor can it simply be assumed that IK accurately informs farmers' year-on-year management decisions. Like MSK, IK may be taken as roughly optimal where it is suited to the local context, but it may be or become ill-suited to the local context under certain circumstances[35]. As advocated by the IK literature and contemporary development literature generally, engaging with local people as full stakeholders is essential to success. Yet such engagement must balance cultural sensitivity and receptivity to alternative viewpoints with a critical perspective. Research into the characteristic faults affecting knowledge under commonly encountered circumstances can facilitate this process. The present study examines one characteristic fault that may plague IK under conditions of rapid change, namely the failure to intensify natural resource management given falling resource stocks and rising demands on these stocks.

Where rural people lack useful knowledge, targeted information provision that addresses knowledge gaps may be a powerful means of improving peoples' welfare. Alternatively, where institutional constraints are limiting, institutional reforms may be called for.

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[33] Such responses are particularly likely in remote societies with comparatively little contact with the wider world, such as Shinyanga District.

[34] This work thus concerns the majority of the rural poor who are largely bypassed by market forces, specifically the problem of people depleting the natural resources on which livelihoods depend in order to meet short-term needs. Both are neglected by the World Bank's 'New Poverty Agenda' (Belshaw & Livingstone 2002).

[35] Notably, MSK may be ill-suited to the context where the associated inputs are inaccessible or unaffordable, while IK may be ill-suited to the context when management strategies fail to keep pace with a changing context.

2.5 Question two: Why are problems with indigenous knowledge largely neglected?

2.5.1 The challenge of 'implicit valuation'

Despite the logic of this preceding argument, the challenges of 'implicit valuation' of natural resources are neglected by the literature. More generally, the literature fails to problematise IK, instead emphasising its strengths and the importance of using it to inform development initiatives. As with the failure to problematise MSK discussed above, this state of affairs may be attributed to theory.

For one thing, the existing literature and its underlying models strongly suggest that this knowledge is unproblematic, as highlighted above. Arguably, the IK literature is guilty of mimicking the MSK literature with its assertions of the accuracy and power of this knowledge. The MSK literature bases these claims on its faith in the scientific method and on the notable technological and economic advances associated with its discoveries. The IK literature suggests that indigenous people are likewise experimental and 'scientific' and notes their proven capacity to survive and sometimes flourish in hostile climates. Moreover, the fact that diverse conceptual models in various disciplines are built on an assumption of sound knowledge – whether MSK or IK – effectively 'locks in' this view.

The view of IK as unproblematic is additionally 'locked in' by political considerations. Notably, criticisms of IK are easily seen as suspect, notably as instances of 'blaming the victim' and evidence of a neo-colonial attitude. Such suspicions may be understood as a strong adverse reaction against the old 'transfer of technology' model, which discounted the perspective of local people, or to the condescension of the colonial era. While these suspicions may sometimes be justified, hypersensitivity to criticism is not conducive to scientific enquiry, nor does it facilitate problem solving.

A second theoretical problem is the absence of a model elaborating how and why rural people living from the land might come to possess problematic IK. Given this lack of a credible framework for situating and explaining how IK might become problematic, any weaknesses of IK cited in the literature tend to be muted in a broader argument emphasising its strengths. This is unsurprising, since without such a framework criticisms of IK may appear to be indictments of rural people and their abilities. Furthermore, without a framework for understanding the nature of such problems, citing them might be seen as merely creating problems without shedding light on possible solutions.

2.5.2 *Alternative conceptual model: Context-dependent knowledge*

In its efforts to explain how rural households might come to base their resource management decisions on problematic IK, the present work builds on existing critiques of IK in the literature (see section 2.3.1). Building on these ideas, the present study hypothesises that failures to adapt to change such as that reported by Riches et al (1993) may be due to knowledge gaps. Specifically, it hypothesises that IK may be well-suited to the local context when first generated, yet may fail to keep pace with changes to this context to farmers' detriment. Of course, economic theory demonstrates that degrading one's farm *can* be optimal for an individual farmer if his personal discount rate is high or if land is abundant (e.g., Pender 98). Yet given the various reasons cited below to doubt the accuracy of IK under conditions of rapid change, the possibility of knowledge gaps plaguing IK must be examined.

Various reasons why knowledge gaps might plague agrarian communities in low-potential areas of Africa are postulated below. Specifically, these reasons offer alternative possible explanations for why a given piece of knowledge may be ill-suited to the farm context. First, several reasons are identified which explain why the MSK provided to rural communities may be problematic. A second set of reasons then suggests why the IK originating in these communities might likewise be problematic. The underlying premise is that each of these broad bodies of knowledge (i.e., MSK and IK) is comprised of diverse strands, and that each of these strands is either better or worse suited to a given context. Knowledge is said to be problematic in cases where a particular strand of knowledge is ill-suited to the context in question. The challenge facing development institutions is to determine which strands of knowledge are appropriate and which are not.

The characteristic problems plaguing MSK are that it may be either inaccessible or unprofitable. The more basic problem is that farmers may simply lack access to MSK or associated agricultural inputs, such as hybrid seeds and chemical fertilisers or pesticides. Specifically, farmers may lack sufficient cash to purchase these inputs, while also lacking access to credit. Farmers are particularly likely to lack access to MSK and associated farm inputs where they consume most of their own production, since such farmers may earn little disposable income from their farm.

The more nuanced problem is that farmers may opt to avoid participating in markets and employing purchased farm inputs, which may in turn severely limit their use of MSK. One possible reason for doing so is because farmers are risk-averse, and perceive market participation to be excessively risky. Specific risks might include

unreliable timing of input delivery or fluctuating input and output prices. The second broad reason for doing so is that farmers may simply deem market participation to be unprofitable. Specific disincentives might include stagnant output prices associated with falling commodity prices or collusion among buyers, or high transactions costs associated with accessing markets, given poor infrastructure. All of these factors are observed in Shinyanga District.

The characteristic problem plaguing IK is that it may be inappropriate to the contemporary farm context, given difficulty adapting to changes such as rapid population growth, resource degradation and negative effects of market liberalisation. Constraints on the adaptation of IK to the contemporary farm context may be either endogenous or exogenous.

One endogenous constraint on the adaptation of IK is that the previous experience of farmers may serve as a poor guide to current challenges. Farmers' assessments of technologies, management strategies and investment options depend largely on their previous experience and what it suggests about future returns and complementarity with other components of the farming system. Yet the significance of key natural resources may have changed fundamentally in recent years, if these shifted from relative abundance to scarcity. Accordingly, the relevant management strategy for these resources may likewise have changed fundamentally, notably from passive management (e.g., selective harvesting and waiting for the resource to regenerate naturally) to active management (e.g., planting and nurturing). A second endogenous constraint is that management strategies towards key natural resources may be culturally embedded. Given a rural context that is stable over time, such embedding makes sense as a means to ensure that strategies are remembered. Yet embedding may also make changing established practice elusive, since justifications for the practice are cultural, not empirical or analytical.

One exogenous constraint on the adaptation of IK is that outside institutions may provide inappropriate information about natural resource management to local people. Such information may either mislead local actors or simply discourage them from having faith in IK solutions that may be more appropriate. One example is the module taught in Tanzanian primary schools that advocates the removal of all trees from fields, disregarding potential symbioses with crops and livestock (Mshana 1992:11; Tanzanian Institute of Education, 91). A second example is the fact that many extensionists forcefully advocate 'modern', input-intensive agriculture even where it is largely inaccessible, as found for the case of Shinyanga District. A second exogenous constraint is that dramatic swings in agricultural and settlement policy over recent decades may

have caused the loss of indigenous knowledge or skills among farmers. The fact is that farmers may have come to rely on subsidised industrial inputs during the period that these were subsidised, and may have abandoned key traditional practices. Once subsidies were abolished and these inputs became largely inaccessible, such farmers may have had difficulty identifying a successful alternative farming strategy.

2.6 Question three: Why does integration of indigenous knowledge into development interventions lag?

Despite this strong emphasis on IK within the literature, actual incorporation of IK into development interventions lags badly (Stirrat 1998). For instance, Stone (1998) notes that only 1.1 percent of development projects undertaken by DfID include an IK component, suggesting that integrating IK into development is problematic. Closer examination of the issues surrounding extracting IK and its use in resource management may help explain this apparent paradox.

One possible explanation for the limited use of IK is that accurate IK may be difficult for outsiders to obtain, given the remoteness of many rural communities, poor roads, language barriers and cultural differences. Socio-cultural issues such as gender issues may also complicate this task. Even those institutions that have gathered IK and are sympathetic to using it may not have a clear sense of how best to employ it.

While the question of whether IK is incorporated into development interventions is important, it is less profound than the questions examined above of whether IK itself may be problematic and whether such problems are perceived by researchers. This is because the latter impacts not only the effectiveness of development interventions, but also the management decisions of farmers untouched by these interventions. Because the coverage of interventions is limited in peasant communities, IK may affect farm management decisions much more strongly than outside initiatives in such areas.

2.6.1 The potential of indigenous knowledge may seem excessively difficult to harness

While stakeholder groups such as a given rural community may appear to be coherent, they typically comprise various differing voices and competing versions of IK (Blunt & Warren 1996). One possible explanation for this local diversity of IK is that the interpretation of shared knowledge differs based on how it affects peoples' interests, as determined by their household assets and social position (Gupta 1995; Sillitoe 1998). An alternative possibility explored by the present study is that some households adapt more effectively than others

to changing circumstances. In the latter view, two households may have similar assets and social characteristics, but quite different IK and resource management strategies.

Some authors have suggested that it is a mistake to assume all IK is encoded verbally and can be readily articulated by local people. This may complicate the attempt of IK research to reduce IK to words. It is increasingly clear that much practical knowledge is not learned or stored in this way, but rather absorbed by watching, then applied. Given management systems that have evolved over generations of experimentation, Moore & Golledge (1976) suggest that farmers may simply follow these proven practices without any need for analytical discourse. Similarly, Sillitoe (1998) suggests that people live rather than reflect on much of their knowledge, and that "if one is a farmer, one just knows". Likewise, if farmers are asked what it is about their soils that allows them to farm in a certain way, they are liable to say, 'They just do', or to explain that they are following the time-tested ways of their forefathers.

Assuming researchers succeed in eliciting verbal articulations of IK, other obstacles await. Most obviously, before IK can be apprehended, it must first be translated from the local language and its idioms. Another problem is that IK is inherently dynamic, constantly adapting to changing circumstances, creating another difficulty for those seeking to apprehend and represent it (Cox et al 1995). A third problem is the geographic and cultural specificity of IK, which makes it difficult to obtain widely applicable generalisations about IK, and hence complicates its use in development. Finally, respondents may purposely mislead interviewers. One possibility is that farmers may 'show off' by presenting 'modernised' versions of their knowledge or simply making up information (Zuberi 1998), while another is that they may seek to show politeness by 'telling their guests what they want to hear', or second guessing the desired answer to any question (Grosh & Glewwe 1996).

Although some researchers abstract IK out of its socio-cultural and environmental context and treat it as free-standing technical information (e.g., Sinclair 1995), others discourage this on the grounds that local knowledge and practices tend to be culturally embedded[36]. The latter group suggests that the socio-cultural context is typically central to understanding IK, and that extracting IK from its context and treating it as mere technical information risks misinterpretation (McCall 1995; Ellen 1998). The implication is that rather than extracting information from its context, resource management is best simply devolved to local people (Ingold 2002). The former group responds that arguing that IK is less amenable than MSK to being extracted, stored and

transferred to other contexts is to apply a double standard, since all knowledge systems adapt in response to changing circumstances, and hence all knowledge loses some relevance when extracted from its context (Warren 1998). Either way, the fact that smallholder farms tend to be complex natural and social systems complicates the task of interpreting IK[37].

Finally, obtaining and using IK may involve thorny political issues. Deciding on whose knowledge to heed and how to use it can further the interests of one subset of a population over another, and hence is inherently political[38]. More powerful members of the society may feel threatened by such interventions, and seek to obstruct them. Such variations within local views must be recognised and examined, so that IK research can make informed decisions about whether it is possible to represent local people generally and, if not, whose knowledge to privilege. Given these political considerations, development initiatives should ideally involve negotiation among all stakeholders, and should candidly acknowledge any political considerations (Sillitoe 1998).

Due to these various perceived difficulties, IK may be viewed by development practitioners as excessively complex and arcane, and hence ill-suited to inform development interventions. In particular, overemphasising the local specificity or cultural embeddedness of IK may result in accounts that strike would-be users as esoteric and unusable (Ellen 1998; Sillitoe 1998). For instance, much IK research vis-à-vis agriculture is essentially ethnographic accounts of production systems, which are not formulated analytically and hence are not amenable to identifying researchable production constraints.

2.6.2 Indigenous knowledge may appear to be irrelevant or unnecessary

In theory, science involves systematic study by emotionally detached actors. It has come to be accorded high status based on its perceived rigour, predictive power and the success of its practical applications. By contrast, indigenous knowledge systems have traditionally been seen to be lacking these qualities (Murdoch & Clark 1994).

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[36] For instance, Posey (1998) reports that local myths may systematically encode technical knowledge.

[37] Notably, some concepts central to agricultural science may not be appropriate to understanding such systems. For instance, the concept 'useless weeds' may be inappropriate to shifting cultivation systems, since 'weeds' may be used to prevent erosion, as a source of fertility or to prevent nutrient losses via leaching (Sillitoe 1998).

[38] Moreover, development is a contested domain, with many stakeholders trying to promote different interests and agendas, who may emphasise different aspects of IK to support their agenda (Grillo & Stirrat 1997). A broader political issue involves the overall relations between IK and farmers, on the one hand, and MSK and institutions, on the other (Murdoch & Clark 1994). One danger is that IK could simply be appropriated by existing powers and employed as an instrument of oppression and exploitation (Thrupp 1989). Conversely,

While much scientific knowledge retains utility beyond its context of origin, such successes arguably require the partial reconstruction of their original conditions (Rouse 1987:118; Bijker & Law 1992:10). Specifically, science often involves generating outcomes in the artificially controlled conditions of the laboratory or field station, then asserting their universality. More generally, science may be viewed as the ongoing efforts of humans to gain mastery over nature. In agriculture, technologies based on scientific advances simplify and control formerly complex systems, e.g., chemical pesticides kill whole hosts of insects, rendering obsolete delicate balances between farming systems and species developed over centuries of co-evolution (Kloppenburg 1991; Flora 1992). Thus, the 'universality' of science may thus depend on the exercise of power – by the state, international organisations or corporations – to make existing conditions favourable to its theories and associated technologies (Murdoch & Clark 1994; Ingold 2002).

As 'universal' knowledge, science has been able to safely discount IK, since it could be confident that underlying these systems lay its core principles and insights. In short, this universality has allowed scientists to ignore IK as at best redundant (Murdoch & Clark 1994). Yet this has meant that science has often ignored useful insights into the local context, even though the answers to concrete problems arguably take different forms in different situations (Bazin 1993:41).

2.7 The search for a 'best practice' approach to harnessing indigenous knowledge

If it heeds all the various complexities cited above, the danger is that IK research may no longer be readily accessible to practitioners. Specifically, the danger is that such research merely contributes to the accumulation of exotic ethnographic documentation that is sterile from a development perspective (Agrawal 1995). Unless IK research leads to a degree of reliable generalisation, it can only hope to contribute to local development efforts undertaken by sympathetic agencies such as NGOs, although even these may struggle to put it to practical use (Sillitoe 1998). The end result is that any positive essence contained within IK that could help make development interventions more culturally acceptable or environmentally sustainable may be squandered. A second result is that IK is seen as so subtle and complex that outsiders cannot analyse it effectively, and must simply accept it[39].

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knowledge may serve as a basis for resistance, or 'the refusal to be subordinated to a world view dominated by essentially alien values and assumptions" (Redclift 1992:402).

[39] This is reminiscent of how MSK is typically presented, i.e., as rational and universal, yet impenetrable and opaque to the uninitiated (Murdoch & Clark 1994).

To negotiate such complexity, commentators have often suggested that IK is best obtained by anthropologists, given their cross-cultural skills and training (e.g., Bentley 1998). Yet the idea of relying on anthropologists to distil IK is problematic, since their role as knowledge brokers may be compromised by ideological agendas[40]. Examples include seeking to portray IK as 'ingenious' or to 'secure the revolution' of incorporating IK systematically into development interventions[41] (Sillitoe 1998). Given such tendencies, some researchers have been accused of holding a romanticised view of IK as ecologically sound and projecting onto it their critiques of modernity (Ferradas 1998), instead of viewing it with a lucid and critical eye. Moreover, while long-term anthropological research may represent the best means of apprehending IK, this approach may be incompatible with development imperatives, such as limited budgets and the need for near-term outputs. Instead, gathering IK may only be possible via rapid methods such as RRA or PRA. In such cases, these methods are preferable to not having any IK input into interventions, which may be the only realistic alternative (Brokensha 1998).

More fundamentally, while IK is no doubt complex, its complexity and inaccessibility may be overstated. After all, the practical choices of farm management informed by farmer knowledge are fairly straightforward, often involving choosing among a small number of distinct alternatives. Examples include (a) burning crop residues or ploughing them into the soil, (b) whether or not to practice manuring or composting, (c) whether to actively cultivate livestock fodder or to rely on naturally-occurring stocks.

2.7.1 The promise of combining indigenous and scientific knowledge

Since the practices and knowledge of indigenous peoples relate to the same natural world studied by scientists, combining these two perspectives promises to produce a more rounded understanding of both the local natural environment and strategies to raise farm production sustainably (Bentley 1998; Quiroz 1996). Moreover, IK and MSK have potentially complementary strengths (see Table 2.1), and together they may be able to achieve advances that neither could on its own (Chambers 1983; Murdoch & Clark 1994).

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[40] While this is ultimately true of all researchers, anthropologists may be especially likely to be so compromised by falling into the role of IK advocates.

[41] Sillitoe (1998) closes his review of recent IK research by observing that the battle to include local people's knowledge and practices more integrally in development has largely been won. Yet he cautions that many battles remain before the revolution transforming informants into partners is secure, and concludes with the battle cry, 'Vive la voix indigene!'

Table 2.1: Comparing IK and MSK vis-a-vis agriculture and natural resource management

Characteristic	Indigenous / local knowledge	Modern scientific knowledge
Origins	Ongoing observation of and experience with relevant context	Limited observation, often in specialised circumstances or based on statistical sampling
Experimentation	Context-relevant experimentation involving simple comparative treatments and replication across seasons	Controlled, rigorously measured experiments, possibly involving statistical sampling and careful replication
Categorisation criteria	Relate to uses or practical concerns	Relate to abstract criteria
Context-specificity	Specific to local socio-cultural, agro-ecological context	Meant to apply to a wider population
Cultural embedding	Includes socio-cultural elements, which may facilitate its use locally	Abstracts technical elements from their context; may impose standardised context
Ownership	Users feel a sense of ownership, given its fit with local values	May seem imposed from outside and/or clash with local values
Status	May be low status	Tends to be high status
Extrapolation	Users tend to be sceptical of extrapolation to other contexts	Users tend to think in terms of and seek generalisable results and laws
Codification	Continually repeated or practiced to ensure it is not forgotten	Typically written
Transmission	Derived from own observations and experience or transmitted orally	Transmitted via institutional contacts such as education or extension
Costs	Essentially 'free', the principal cost being the need for careful observation	May be 'costly' and thus inaccessible to poor farmers
Marketing	Given the absence of financial costs associated with production, marketing farm outputs is non-essential	Given the need to purchase production inputs, failing to market outputs is problematic
Risk vs. productivity	Associated production strategies are resilient given marginal conditions yet production is comparatively low	Associated production strategies are more risky, yet promise higher production
Knowledge gaps	Private incentives are considered sufficient to ensure IK is appropriate, since users adapt it to meet their needs. Knowledge gaps not foreseen.	Private incentives are taken to be sufficient for appropriate MSK to be employed *only if* the benefits of procuring it exceed the costs. Hence, gaps may occur.

Farmers possess two key advantages over scientists vis-à-vis problem solving. The first is their capacity to observe local phenomena continually, while scientists spend much of their time at a desk or in the laboratory. The second is that, as the end users, they are in a better position to determine key problems, and thus to guide research towards practical, relevant solutions (Rhoades & Bebbington 1995; Lightfoot 1987; Ashby 1984). Because IK is believed to be strongest vis-à-vis directly observable phenomena, agriculture is one area where IK has a key advantage over MSK, and where the latter has often been particularly inappropriate (Chambers 1983; Richards 1980:185).

By contrast, scientists have superior technology to measure precisely and examine microscopically, e.g., identifying a missing trace element in the soil or a bacterial agent of infection. They can also get an 'objective' overview of a situation via statistical sampling, and may have relevant comparisons based on their familiarity with other geographic areas. Yet paradoxically these strengths can pose a problem, giving a false sense of confidence in MSK that obscures oversights of relevant factors. Likewise, the dramatic results associated with innovations such as chemical fertilisers and pesticides or vaccines for humans or livestock can blind outsiders to the relevance of IK to securing success in the local context (Chambers 1983). Potentially, such dramatic results may additionally blind local people to the relevance of IK, leading them to consider it old-fashioned and weak and to neglect it. This is particularly likely where farmers grew accustomed to subsidised farm inputs, even if these have since become inaccessible due to market liberalisation.

2.7.2 Competing environmental narratives

For years, researchers have collected environmental data in the old disciplinary clothes of either the natural or social sciences. Each has collected evidence selectively, then called the resulting findings 'truth', even though these competing accounts have often contradicted one another. Yet each of these viewpoints is merely an incomplete and variegated window onto a common reality, like the proverbial blind men each feeling only part of the elephant. Anthropology has stood out among these disciplines in its emphasis on IK and the adaptability and management skills of rural people, as well as in questioning alarmist accounts of environmental change propounded by outsiders (Forsyth 1998). Anthropology's version of 'the truth' vis-à-vis natural resources is thus the view propounded by local actors via their IK. Yet because local actors may subscribe to sharply differing versions of IK, the resulting representations of IK will depend on which strands are emphasised. The end result is a set of often competing views of environmental phenomena, both from different scientific disciplines and from differing anthropological accounts of local views.

Arguably, scientific explanations for biophysical phenomena are social constructions. While these narratives at least partly explain the underlying biophysical reality, this reality and people's experience of it are distinct. An example of a constructed scientific narrative about environmental change is the 'theory of Himalayan environmental degradation' from the 1970s, which suggested that a vicious circle of population growth, deforestation and soil erosion was leading to ecological collapse. More recently, anthropological accounts have disputed this theory, suggesting that hill farmers may adapt well to changing biophysical constraints. In this alternative view, alarmist narratives reflect western fears and the uncritical acceptance of natural science as the basis of environmental understanding (Forsyth 1998). 'Desertification' is another social construct of environmental processes that has recently been contested (Thomas & Middleton 1994; Leach & Mearns 1996; Swift 1994). While the persistence of these divergent narratives may reflect the selective choice of data based on prior ideological views (Murdoch & Clark 1994), they almost certainly reflect a paucity of firm, reliable data. Local explanations and IK may likewise be socially constructed (Agrawal 1995; Latour & Woolgar 1986).

One response to these competing narratives and disciplinary perspectives is to not seek to discover a 'correct' or 'final' explanation, but rather to make environmental explanations and associated development interventions more relevant to poor peoples' stated needs (Forsyth 1998). This reflects the anthropological tenet of cultural relativism, or refraining from judging the practices of others. The implication is that development interventions should, insofar as possible, allow local people to maintain control over their own lives according to their own values (Sillitoe 1998). Factors favouring this viewpoint include that this would confer a sense of ownership, that taking responsibility would allow people to learn from their mistakes, and that they may in any case know best how to meet their own needs. A key problem, however, is the question of which voices within IK to heed, where these compete.

While the principle of deferring to local views makes sense when applied to social or cultural practices, the case of technical knowledge is arguably different, since such views may directly affect peoples' material welfare. The point is that some phenomena are not strictly relative, such as those directly associated with economic welfare. While the best means to ensure such economic welfare may be debatable, it is clear that this matter is not strictly relative, particularly in cases where some people fail to meet their basic material needs, as in the case of Shinyanga District. Arguably, a second reason for not simply deferring to the myths and values of locals is that local solutions increasingly affect others in an increasingly interconnected world (Cleveland &

Murray 1997). One possible alternative is assessing strategies and practices on the basis of sustainability, once the precise meaning of sustainability has been negotiated[42].

2.7.3 Highlighting both strengths and weaknesses of indigenous knowledge

Given the potential importance of IK to development yet its minimal practical use, the question that arises is how IK research can best ensure that IK maximises its positive impact on development interventions. As seen above, some anthropologists suggest that this is best done by engaging anthropologists to interpret and represent IK, since this is the best means to ensure that the IK informing development accurately represents local views. An alternative possibility is that the scepticism of some scientists vis-à-vis IK is partly justified, and hence that greater use of IK will depend on its worth and applicability being convincingly established (Blaikie et al 1996).

In this case, a distilled, critically assessed version of IK might be more compelling, and might provide a better basis for tailoring development interventions to local people's needs. Specifically, it may be necessary to highlight not only the strengths of IK, but also its shortcomings in order to ensure that IK enjoys widespread credibility. Credibility is paramount, since until technicians and development planners take it seriously, IK and participatory input generally will have only limited impact on development practice. Such an exercise would respond to the real though perhaps unstated concerns of scientists and development planners vis-à-vis IK, which may plague even those most enthusiastic about it.

Most basically, current levels of poverty and agricultural productivity and trends over time in these indicators do not suggest success. Thus, Alcorn (1995) reports that outsiders commonly associate the relative poverty and low socio-economic status of farmers with their reliance on IK. While these problems may have nothing to do with IK, the obvious association between outcomes and management decisions informed largely by IK must nonetheless be addressed. Yet at present, such obvious considerations are neglected by the anthropology literature. For instance, Sillitoe (1998) cites problems affecting western societies[43] as evidence for the shortcomings of scientific knowledge, yet fails to apply this same criterion to the problems facing African societies. Similarly, some sociologists and environmentalists emphasise the role of science in the ecological destructiveness of western society yet remain silent about the problems afflicting other societies (Yearley 1992:514).

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[42] One simple definition is maintaining constant capital stocks overall as well as constant stocks of natural capital (Pearce 1989).
[43] Notably, the squandering of natural resources, environmental pollution and feelings of social alienation.

If the goal is to make sense of the pressing problems facing agrarian communities in Sub-Saharan Africa, it is unhelpful to look for scapegoats. Rather, what is urgently needed is a toolkit for understanding and grappling with these complex, heterogeneous systems (Bijker & Law 1992:306). The question is what these 'tools' will look like, specifically how knowledge might constitute such a tool.

Murdoch & Clark (1994) have coined the term 'sustainable knowledge' to describe the hybrid knowledge best able to intelligently inform development interventions, and hence to secure sustainable development outcomes. Criteria are needed to identify such hybrids, i.e., to determine how best to combine knowledge of various types – natural and social, Western and non-Western – in different situations. That is, what is needed are simplifying generalisations vis-à-vis the characteristic strengths and weaknesses of IK and MSK in particular types of situations, and how to negotiate the IK-MSK divide. Given its location-specific nature, simplifying generalisations are particularly necessary for IK, since development demands a generic approach. The fact is that IK will only systematically inform development interventions if connections can be made between IK from different areas. Yet the challenge of negotiating the IK-MSK divide should not be underestimated, since these are not simply different ways of knowing, but also represent different social and cultural systems (Sillitoe 1998).

An example of a simplifying generalisation is dividing IK into stable and dynamic components. For instance, van Beek (1993) describes two types of agricultural IK found among the Dogon of Mali, one generalised across society and one specific to an individual's experience. He argues that lumping these types of IK together would be a mistake due to the inflexibility[44] of one and the dynamism of the other. A contrasting formulation postulated by the present study distinguishes between types of IK that must adapt to changing circumstances[45] in order to remain relevant and others that remain relevant regardless of such changes. IK vis-à-vis agriculture and natural resource management fall into the former category, while IK vis-à-vis botany, zoology and health fall into the latter category. Given fundamental changes to the rural environment associated with rapid population growth and resource degradation, the question becomes whether the former type of IK succeeds in keeping pace with changing circumstances, and hence whether it remains adapted to the local context.

[44] The Dogon "view their ecosystem as stable even if geared to a situation of the past" (van Beek 1993).
[45] Notably, rapid population growth, resource degradation, market liberalisation and phasing out of agricultural subsidies.

2.7.4 *Critically assessing competing narratives*

Although this is a delicate and controversial area, indigenous practices and statements may be compared with scientific findings in order to highlight the characteristic merits and shortcomings of each. For instance, local people's comments about shifting cultivation may be compared with outsiders' observations of productivity trends and environmental impact. A second example is comparing local views and scientific findings of costs and benefits associated with specific types of farm tree, as done in the present study. Such comparisons highlight both areas where IK could be usefully supplemented by targeted MSK[46] and areas where IK may advance scientific understanding of local phenomena by challenging established scientific concepts and models (Sillitoe 1998). Ideally, these findings would highlight clear trends that could form a basis for simplifying generalisations regarding the characteristic strengths and weaknesses of different forms of knowledge. One danger of comparing IK and MSK is ethnocentrism by outsiders, or imputing inappropriate concerns and predetermining problems. An opposing danger is the temptation to romanticise and idealise IK (Stirrat 1998).

Some commentators (e.g., Posey 1998; Stirrat 1998) reject this idea of seeking to critically assess IK, suggesting that any attempt to determine which parts of IK are or are not 'scientific', 'useful' or 'correct' is just a continuation of colonialism, albeit of a nuanced shade. They suggest that anthropologists simply accept local people's knowledge, even if it sometimes seems whimsical or destructive to them, and become "researchers for and consultants to indigenous peoples". The implication is that IK researchers should simply represent local people within collaborative partnerships and the broader development debate.

This concern notwithstanding, renouncing critical analysis of IK is deeply problematic. Most fundamentally, either MSK or IK may become reified into a simplistic and fixed set of concepts with little relevance to a given situation, instead of being recognised as context-dependent outcomes of dynamic processes. As seen above, MSK may be uncritically framed as universal. By contrast, some influential environmental critiques (Capra 1983; Bookchin 1982; Dobson 1990) have characterised MSK as 'imperialist' and reductionist, engendering an exploitative relationship with the natural world. Meanwhile, IK is often framed as a preferable way of knowing, given the goal of sustainable development. Specifically, it may be seen as reflecting an intimate relationship with the local natural environment and recognition of the interdependence of living things, leading

[46] For instance, farmers may be unfamiliar with – and hence unable to demand – certain potentially useful technologies, suggesting a continuing role for supply-side interventions (Gupta 1995).

to a mythology of IK being 'in harmony' with nature[47] (Murdoch & Clark 1994; Richards 1993). Yet for the various reasons discussed above, local people may subscribe to reified views or narratives, just like scientists and development practitioners.

Once knowledge becomes reified, its specific characteristics – e.g., its content, origin, form – may become 'black-boxed', and be treated as unproblematic givens. That is, it may be assumed that the knowledge in question is appropriate simply due to its status as either 'indigenous' or 'scientific'. Too often, the unsatisfactory result of this formulation is a contest between 'right' and 'wrong' knowledge, where MSK and IK can play either role, depending on the commentator in question (Latour 1987; Murdoch & Clark 1994).

The ultimate test of knowledge – whether IK or MSK – is its practical success, e.g., does the technology work? does the theory predict? If the strategies based on this knowledge are sound, then babies will be healthy and crops will grow tall. By contrast, if babies are malnourished and crops fail, then the knowledge underlying institutional policies and/or livelihood strategies may be questioned (Murdoch & Clark 1994). In such cases, these strategies and the IK informing them should arguably be problematised. More generally, those conducting IK research cannot be expected to be taken seriously if they conduct themselves as advocates for IK instead of critically-minded scientists.

[47] Pearson (1989:13) challenges the romantic, idealistic view that indigenous peoples possess ecological wisdom that forms the basis of their culture and management practices. Instead, he suggests that traditional religions may often be viewed as codified rules for resource conservation meant to restrain exploitative human instincts (e.g., Barrow 1988; Maydell 1986).

Chapter 3

Data Collection and Analysis Methodology

3.1 Data collection

3.1.1 Overview of fieldwork

The data that form the basis for the present study were gathered in Shinyanga Rural District, Tanzania between June 2000 and January 2001. These data were gathered via a household survey conducted specifically for the study. Based on a random sample of 20 villages and 350 households from across Shinyanga Rural District, the survey gathered in-depth data on farmer practice and household knowledge in the District. This sample size follows the rule of thumb identified in Grosh & Munoz (1996:64) that a statistical sample should include a minimum of 300 to 400 households in order to give statistically valid results[1] Particular attention was devoted to gathering data on farmers' knowledge and practice vis-à-vis trees, whether located on private farms, the village commons, or elsewhere. In addition to the household survey, the field study included a series of expert interviews.

Secondary data including recent studies of the District and other existing documentation were also consulted. Although these did not address the specific concerns of the present study, they nonetheless provided valuable context for the study and helped it formulate its objectives and approach.

3.1.2 Location of fieldwork

Several factors explain the study's geographic focus on Shinyanga District, Tanzania. One is that the challenges currently facing District residents – rapid population growth, declining soil fertility, shortages of food, fodder, and fuel – are common in semi-arid areas of Sub-Saharan Africa. This increases the likelihood that the study's findings will be relevant to other parts of Tanzania and Africa. A second factor is that the Tanzanian government has designated Shinyanga a priority area for agroforestry research, given the perceived potential of agroforestry to address its problems. A third reason is the fact that the study builds on and responds to the work of a prominent and long-standing agroforestry project.

[1] Such a sample size was also deemed to represent a good compromise between the dangers of sampling error and non-sampling error, as stressed by Casley & Lury (1987:62).

3.1.3 Institutional partners

The HASHI/ICRAF Agroforestry Project served as the host institution to the field study. This government-donor collaboration was initiated in 1985 to address the challenges facing rural people in Tanzania's Lake Zone, which comprises Shinyanga Region and Mwanza Region, two of the twenty regions that constitute the United Republic of Tanzania. HASHI stands for *Hifadhi Ardhi Shinyanga* (Shinyanga Soil Conservation Project), and is the Government of Tanzania's afforestation and soil conservation initiative for Shinyanga Region. The International Center for Research in Agroforestry (ICRAF) is the institute within the group of international agricultural research institutes[2] that focuses on agroforestry practices and their role in addressing land management challenges. The Shinyanga project is the institute's Tanzania country office.

The aim of this collaborative project is to alleviate problems associated with natural resource degradation in the Sukuma agro-pastoral system, including woodfuel scarcity, dry-season fodder shortages and declining soil fertility. These problems are among the key challenges faced by farmers in the area. The project addresses these challenges by developing appropriate technologies and promoting their adoption, notably by raising awareness of key environmental constraints on local livelihoods and extending promising tree management technologies to rural households. The present study builds on and responds to this ongoing work by examining the key determinants of local tree management practices, notably the role of a household's knowledge in determining its tree management decisions.

3.1.4 The choice of random sampling

The survey data were collected using random sampling instead of either a case study or purposive sampling. The key advantages of random sampling relative to these and other alternatives are that it allows fairly rapid, in-depth sampling of a large population at modest cost, yet in such a way as to allow results to be generalised to the whole population (Poate & Daplyn 1993:33). More generally, random sampling ensures that the various differences in opinion and behaviour existing among any large aggregate of people are represented in the subset of people examined by the study (Bernard 1995:81).

This approach of examining tree management among a random sample of farmers differs from the standard approach to assessing farmers' practice and attitudes towards trees, which focuses on areas already targeted by

[2] The Consultative Group on International Agricultural Research (CGIAR). These institutes conduct strategic and applied research on the entire range of problems affecting agricultural productivity. Moreover, they link these problems to broader concerns about poverty reduction, sustainable management of natural resources, protection of biodiversity, and rural development, in support of ongoing efforts to realise the Millennium Development Goals.

agroforestry initiatives (e.g., Arnold & Dewees 1997; Current et al 1995; Franzel & Scherr 2002). That is, the standard approach involves either purposive sampling or a case study approach focussed on assessing the impact of specific agroforestry interventions[3].

Yet collecting data from randomly selected households is revealing, since it provides an overview of actual views and practices vis-à-vis trees in the District, i.e., among ordinary African peasant farmers facing population pressure but living on degraded lands. Notably, such an approach ensures that the study considers a statistically representative range of household types, instead of simply the more dynamic households in villages with better access to transport infrastructure and services.

This approach may be seen as taking assumptions of farmer efficiency and endogenous innovation as its points of departure, then critically examining ways in which these underlying tendencies may be constrained. Specifically, it works from the assumption that farmers can adapt effectively to a changing rural context by adopting innovative natural resource management practices, including agroforestry practices[4]. While interventions may nonetheless be significant, their role may no longer be critical if farmers are fundamentally innovative and dynamic.

To critically assess these ideas, the study examined the impact of institutional interventions on household practice and attitudes vis-à-vis trees, notably the impact of interventions by the HASHI and ICRAF initiatives. Fortunately, these initiatives have been active in the District for so long that purposive (i.e., non-random) selection of villages to ensure that some had had project contact was unnecessary. Instead, statistical selection of villages resulted in a situation where seven survey villages had been targets of HASHI agroforestry extension efforts, two had been targeted by HASHI as well as being the sites of ICRAF field trials, and eleven had had no contact with either initiative.

One practical consequence of employing statistical sampling is that many of the households surveyed had not previously had contact with any extensionists or projects, much less any agency advocating agroforestry. It also meant that many households were not particularly interested in trees or even had hostile attitudes towards them, since such attitudes seemed to be common in the District. While such findings may seem 'unfortunate'

[3] This is unsurprising, since purposive sampling is appropriate for studies that test the viability of research station findings under ordinary farm conditions (Poate & Daplyn 1993:32), which is a common focus of agroforestry research. By contrast, the present study is not interested in particular technologies and their uptake, but in farmer practices and views vis-à-vis trees generally.
[4] An associated assumption is that the origin of technological innovations is insignificant, since innovations may originate from outside interventions, endogenous adaptation to change or some combination of the two.

from the viewpoint of agroforestry extension, they are powerful in the sense that they form a representative snapshot of opportunities and constraints facing agroforestry in a low-potential area such as Shinyanga Rural District. As such, these findings form a solid platform on which to build efforts to encourage the broader use of agroforestry practices to address key livelihood constraints facing District households.

3.1.5 Hiring field assistants

The process of hiring field assistants involved several steps. The first was to draft a job advertisement and post it on the notice boards of several key offices in Shinyanga town. The next was to ask around at the ICRAF and HASHI offices for names of suitable candidates, as well as descriptions of why the candidate was deemed suitable. Because the community of individuals working in agriculture and natural resource management in Shinyanga Region is not large, news of the initiative spread fast among this community. Moreover, given the employment situation in the region, the prospect of several months of well-paid, interesting work was guaranteed to attract attention. Ultimately, eight candidates were interviewed out of the many candidates who expressed interest in the jobs.

Criteria for selection included relevant training and experience in agriculture and/or natural resource management, excellent oral communication skills, good written communication skills, fluency in English, Swahili and preferably also Sukuma, and genuine interest in the situation facing District farmers. Other criteria were the balance and presentability of team personnel. Balance involved ensuring that the team included both men and women, ideally with two of each. Including at least one or two Sukuma among the field assistants was also deemed essential, given the Sukuma peoples' mistrust of outsiders. The presentability of the team essentially boiled down to ensuring that at least some of the field assistants were old enough to make the team as a whole look venerable and serious. If these individuals stood a good chance of already being known and respected in at least some of the sample villages, this would be an additional advantage. Where possible, character and professional references were also sought.

Ultimately, the doctoral candidate selected four field assistants. All spoke fluent English and Swahili, and two also spoke fluent Sukuma. Two were men and two were women. All were formally trained as either agricultural or livestock experts, and all had experience in both extension and research. Between the four of them, the field team possessed over ninety years of relevant experience, the vast majority of it gained within

Shinyanga Region[5]. Faustin Magalatta and Anna Ncheye were both Sukuma, while Judith Kalwani and Albert Tuju were from other Tanzanian ethnicities. All four were long-term Shinyanga residents.

Besides the candidate's co-supervisor, Dr. Judith Heyer of Somerville College, Oxford, two key advisors to the field study were Dr. Robert Otsyina and Mr. Wendelin Mlenge. Dr. Otsyina directs the Tanzania office of the International Council for Research in Agroforestry, which is based in Shinyanga. Mr. Mlenge directs the HASHI Agroforestry Project and served as the study's primary government contact. Both provided day-to-day expert advice during the study's fieldwork component, notably on the research context and how best to adapt to it.

3.1.6 Training field assistants

The training for the four field assistants lasted four days. On one level, the purpose of the training was to share insights and experiences. This was only natural, given the relative seniority of the four field assistants, and the fact that each had worked in a slightly different area of extension and research. Beyond this, the candidate (henceforth 'team leader') covered a number of specific themes highlighted in the literature on fieldwork.

The training thus served as an opportunity to discuss various issues faced when gathering field data. With each issue, the team leader began the discussion by describing the issue and highlighting alternative ways of dealing with it drawn from the literature[6], then asking the field assistants to share their experience with it and thoughts about it. The various alternatives were then discussed by the team, and where possible a consensus decision was made as to the best approach to adopt. In cases where consensus was not achieved, the team leader considered the alternative options in consultation with Dr. Heyer, Dr. Otsyina and Mr. Mlenge before coming to a final decision.

Specific issues discussed included introductions, potential benefits to farmers, establishing and maintaining rapport, maintaining interview flow, skipping questions, interview length, failure to understand a question, avoiding suggestion,

conveying bias, probing, cultural obstacles to obtaining data, recording data, gifts, choice of informants, language of communication, and direct observation.

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[5]The candidate had two years' field experience as an agricultural extension agent in an area of Senegal similar in many respects to Shinyanga District.

Besides these more general discussions, the training also involved honing the interviewing skills of field assistants, discussing the various questions in the questionnaire, and determining the best wording in Swahili for the questions. Interview skills were honed via discussion of formal interview technique, followed by conducting mock interviews. These interviews were conducted both with each other and as part of a brief pilot study, and were followed in each case by an open discussion of the interviewer's technique and how it might be improved.

3.1.7 Presentability of the field team

Another aspect of the team that was important to its presentability and acceptability to local people was its perceived independence. Notably, it was essential that the field team not be associated with the Tanzanian Government, given the relatively high levels of mistrust of the Government prevailing in the District[7]. This was achieved by presenting ourselves as an independent study by a foreign university and an international research institute collecting data on the problems facing rural people in the District. It was also important to avoid mentioning either trees or the HASHI project, in order to avoid associations with former tree planting initiatives and the fixed ideas of the best way forward that often accompany them.

A helpful factor in avoiding being associated with the government was the fact that the doctoral candidate is white. While the remainder of the field team could conceivably have been working for the government tax collection authority, it was inconceivable that a young white man would do so. The fact that the candidate speaks Swahili[8] was also helpful to the team's acceptability, as competence in the national language conferred credibility and suggested genuine interest in the target community. The candidate's race also piqued the interest of local people, with some reactions giving the impression that some villagers – notably children in remote villages – had never seen a white person before.

The end result was a field team that was well-balanced and presentable. Given the suspicious nature of the Sukuma, the most important requirement was that the team should inspire trust and confidence. The mix of team personnel seems to have achieved this, by all indications (see discussion below). Key features of the final

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[6] Notably, Casley & Lury 1987; Grosch & Munoz 1996; Oppenheim 1992; Poate & Daplyn 1993;

[7] Explanations for this mistrust relate to past and ongoing negative experiences of Government, notably its collection of tax revenues in areas where government services were often virtually non-existent. Other negative associations include government requirements that livestock be vaccinated at villagers' cost, fines for harvesting trees from protected areas, and memories of government resettlement programmes from previous decades.

[8] Building on his initial Swahili language training in the UK, the candidate located a Swahili language teacher, Mr. Simon Masubi, and met with him regularly. Besides conversational Swahili, the candidate and Mr. Masubi worked with Swahili language textbooks used in Tanzanian schools.

team were its balance between men and women, strong representation of Sukuma people, venerability[9] and experience.

3.1.8 Data collected

This process of defining the study focus was conducted in collaboration with the study's partner institutions, who were also the most immediate users. While painstaking negotiations about the precise study focus are common (Casley & Lury 1987:23), these negotiations proved simple in the case of the present study. Fortunately, the objectives of the doctoral candidate and the two Tanzania-based partner institutions were similar, with the latter both excited about the relevance of the study theme to their joint goal of 'scaling up' agroforestry interventions to a broader population of target beneficiaries. As a result, disagreements about the study focus and central questions were minimal, and attention was focussed instead on how best to examine these themes.

Given the various constraints on gathering field data discussed below, it was necessary to prioritise the types of data most important to the study. These priorities followed directly from the study hypothesis and the principal linkages being explored. Notably, these include the extent to which (i) households' resource constraints explain their management of natural resources, (ii) households' knowledge/perceptions explain any residual variation, (iii) tree management patterns correspond with other aspects of household management practice, (iv) distinct knowledge profiles may be identified.

The four principal categories of data sought during the household survey were resource constraints, patterns of natural resource management, knowledge/perceptions/attitude vis-à-vis natural resource management, and performance indicators. The case of trees was emphasised throughout, notably vis-à-vis patterns of natural resource management and patterns of household knowledge/perceptions/attitude.

Specific types of data collected include the following:

Land	Landholdings, tenure, market access, soil types, degradation.
Labour	Weighted household labour, labour hired in or out, gender ratio, age profile, sex of household head.

[9] Mr. Magalatta and Mr. Tuju were both older, having gray hair, while Ms. Ncheye and Ms. Kalwani were in their forties and fifties, respectively.

Capital	Livestock, non-farm income, purchased agricultural inputs, credit, housing
Social factors	Ethnicity, religion, migration patterns, housing.
Cropping	Crop types, cropping patterns, inputs used, any crop failures.
Tree management	Trees removed, retained or cultivated; tree management practices; farm tree numbers; key tree locations; off-farm stocks
Soil & water conservation	Practices employed and reasons.
Perceptions about trees	Significant species; key goods, services, costs; trends in tree stocks over time.
Influences on knowledge	Formal education, extension contacts, project contacts, media exposure, work outside village
Performance	Total yields of different crops, patterns of yields over time, any sold; patterns of livestock over time & any sold; determinants of neediness.
Market participation	Types of inputs or outputs, changes over time, comments.
Expenditures	Which of various basic and luxury goods household has bought in past year.
Map	Includes home garden, fields, soil types, contours, tree stocks & prominent features.
Women's perspective	In the absence of men, asked about control of household resources, gathering fuel and water, household's food security, and any alcohol-related problems.

Of necessity, certain types of data were not gathered. These include ...

* Precise details about tree management practices. It was sometimes difficult getting farmers to talk about trees, perhaps due to the negative associations of trees with the tsetse fly. In such cases, even completing the fairly general questions asked sometimes seemed to try interviewees' patience.

* Data about other tree species not among the three species cited as most significant to the household.

* Details on intra-household dynamics and differing views among household members[10].

* Details on individual household members, beyond general facts about their approximate age, education level and patterns of residency in the household.

* Probing questions exploring the details of delicate topics such as livestock holdings, non-farm income, expenditures, and market sales (see discussion below).

* Visits to farmers' fields to observe farm tree patterns, land quality, and signs of land management strategy.

* Repeated visits to households to observe management practice and performance or differences in answers to certain questions over time, e.g., questions about expenditures, food security, or other household difficulties.

3.1.9 Constraints on the data collection process

Ideally, a study examining the determinants of differential tree management practices would collect detailed data on the full range of household resources, management practices, indicators of success, and knowledge and attitudinal factors. In reality, the interview process was constrained by various factors, notably the fact that household surveys tend to be expensive (Poate & Daplyn 1993:14). As noted by Casley & Lury (1987:25), the relevant question when conducting a household survey is "What results can I usefully achieve given the [available] resources?"

Perhaps most fundamentally, it was constrained by the willingness and capacity of sample households and interviewers alike to remain focused on the themes covered in the interview. Poate & Daplyn (1993:95) emphasise the importance of ensuring that the burden placed on the respondents' time, attention and patience be kept at an acceptable level, and suggest a maximum of one hour as a rule of thumb. Despite this suggestion, the field team found that interviews of up to two hours were unproblematic[11], with respondents appearing patient and content to speak about the household for this length of time. This greater patience encountered in the present study may be due to the fact that the survey was conducted during a trough in the agricultural calendar, when demands on the household's time were relatively few. This suggestion, in turn, seems to be

[10] Several observations suggest that the traits of individual household members are relatively unimportant to determining a household's management of natural resources, and hence that de-emphasising intra-household differences is a legitimate simplification. One is that in Sukuma society, the household head usually exerts strong leadership over the household, including farm management. A second is the tendency of household members to conduct farming activities in groups. Finally, because interview questions were asked about households as a unit, it is to be hoped that the answers given take account of any differences among household members.

supported by the high proportion of cases in which field assistants found, on their first visit to a household, that the household head and their spouse were both at home as well as amenable to being interviewed immediately.

What is clear is that interviews which continued until or beyond the point where respondents became impatient would be on dangerous territory, since obtaining good quality data depends on maintaining the goodwill of respondents (Black 1999:201). Namely, such an interview would run the risk of interviewees giving cropped or possibly even misleading responses simply to get rid of the interviewer. Any developments within the interviewer-interviewee interaction that were thought or found to lead away from this ideal of goodwill and openness were therefore avoided. Notably, interviews were kept to a maximum of two hours in length.

A second set of factors constraining the interview process was limited resources available for the field study. Most fundamentally, these involved material constraints such as the availability of field personnel and access to vehicles and petrol for transport to sample villages. Given its limited funds and competing demands on required institutional infrastructure[12], the study had to set strict limits on its depth, breadth and geographical cover. Notably, it was not possible to pay multiple visits to survey households.

A related set of constraints on the data collection process were time constraints. These constraints were tangible, as these were associated with the onset of the short rainy season in December. This impending event strictly constrained the time available for the field study due to the effects of rain on vehicle access to remote parts of Shinyanga District. Simply put, many parts of the District become inaccessible once the rains arrive. This stemmed from the poor quality of many District roads, particularly the smaller roads leading to remote villages. Roads passing through areas of black clay or *mbuga* soil were said by HASHI/ICRAF staff – and later by survey households – to become virtually inaccessible during the rainy season. The field team experienced the truth of this warning first hand on several occasions. During the later stages of the data collection process, the field team encountered brief spells of rain. Typically, these resulted in situations where the entire team, bar the driver, would have to get out of the vehicle, remove their shoes and wade into the muddy water to push the vehicle out of a slippery hole. If villagers were in the area, they would often come and help. On the worst occasion, the range rover carrying the field team remained stuck in a hole for

[11] When interviews lasted longer than two hours, however, as during the pilot study, respondnts seemed to tire of being interviewed and grow impatient.
[12] The HASHI/ICRAF project needed both its vehicles and the staff it seconded to the field study for its ongoing work, notably the process of distributing seedlings to target villages before the onset of the long rains.

approximately half an hour, and only managed to break free after some twenty people worked to dig out the wheels and push it from behind.

Due to these time constraints, the household survey had to finish its work by early December. Since the field team began interviewing sample households in September, this meant that it could not afford to spend more than two or three days in each village[13], if it was to finish surveying the entire sample before the roads became impassable. Fortunately, this time frame fitted well with a sample size of 20 villages and 350 households and a target interview time of two hours per household.

These material and time constraints imposed geographical constraints on the study. During the preparatory phase, it was decided that it would be unrealistic to include any villages in the sample that were more than two hours' away from Shinyanga town, where the field team was based. For one thing, this would make it impossible to complete the full series of interviews before the onset of the rainy season. For another, it would impose unmanageable costs. Fortunately, Shinyanga town is located near the centre of Shinyanga District, so most of Shinyanga Rural District fell within this range. Yet the most westerly and easterly reaches of the District were outside the range, given an estimated travel time of three hours in each direction. These areas were therefore omitted from the sample frame. The study is nonetheless approximately representative of household practice in the District, since only four out of the District's fourteen Divisions were omitted from the sample. Moreover, these areas were not deemed to be significantly different from the areas sampled, whether in terms of agro-ecological zone, economy or market access.

3.1.10 Questionnaire design

Questionnaire design followed the six guiding principles posited by Poate & Daplyn (1993:144), namely (i) include the minimum number of topics to meet the objectives, (ii) keep the interview to a reasonable time, (iii) ensure the questionnaire is clear and easy for enumerators (i.e., field assistants) to use, (iv) make the questionnaire self-contained, with all relevant reference and identification information readily available, (v) list pre-coding alongside verbal responses to each question, (vi) ensure smart presentation, including the order of topics, clarity of presentation and adequacy of space for recording interview responses.

[13] Once the various delays associated with travelling to and from villages, meeting with village leaders and locating sample households were taken into account.

Individual questions were likewise formulated in light of recognised principles. For instance, Oppenheim (1992:128) suggests a set of rules for the wording of questionnaires, including (i) keep questions concise, (ii) avoid ambiguity or questions containing more than one key element, (iii) use simple wording, avoiding acronyms, jargon or 'loaded' words (iv) avoid leading questions, (v) do not overtax the respondents' memories. Poate & Daplyn (1993:148-54) stress similar principles, including phrasing questions in a clear and unambiguous manner, avoiding leading questions or jargon, and recognising when probing is useful and when it is counterproductive. Finally, Black (1999:201) emphasises avoiding ambiguity and inappropriate vocabulary such as jargon or emotive words.

Specifically, the study combined coded questions with short answer and open-ended questions to meet competing objectives. Notably, it sought to compromise between facilitating the survey and subsequent data processing, on the one hand, and obtaining richer, more qualitative data, on the other (Casley & Lury 1987:94; Poate & Daplyn 1993:11).

In other words, the questionnaire included a balance of open and closed questions. Open questions produce a free, spontaneous sketch of the respondents' thinking using their own categories, yet may pose various practical difficulties. Closed questions are relatively quick to answer and record and straightforward to quantify, allowing more questions to be answered and processed for a given sum of money. Disadvantages may include a loss rapport if respondents feel the choices offered do not do justice to their ideas, or a loss of spontaneity if respondents lack opportunities to express themselves in their own words (see Table 3.1). Indeed, closed questions may even introduce bias by forcing respondents to choose among alternatives or by leading them to consider alternatives that wouldn't have occurred to them. They also foreclose the opportunity to probe (Oppenheim 1992:114). Particularly important questions were typically asked in both open and closed form, to be as sure as possible of capturing household views and practices vis-à-vis these themes[14].

[14] This resulted in a situation where some categories of household responses were enunciated before the survey by the field team with guidance from the pilot study, while others were distilled from the open-ended answers of households ex-post, during the data cleaning process.

Table 3.1 Open versus closed questions

	Advantages	**Disadvantages**
Open questions	Free, spontaneous answers	Interviews time-consuming, data collection costly
	Offer opportunities to probe	Coding slow and data processing costly
	Useful to test hypotheses about awareness	
Closed questions	Require minimal writing and little time	Loss of spontaneous responses
	Relatively easy and inexpensive to process	Answer categories may be biased or crude
	Useful for testing specific hypotheses	May irritate respondants

Source: Adapted from Oppenheim, 1992:115.

The study also sought to anticipate the 'social desirability bias' inherent in certain themes. Following Oppenheim (1992:139), the field team stressed to respondents that the prime requirement of interviews was accuracy, that there were no right or wrong answers, and that no answer given would have any impact on the household. Following Bernard (1995:210), the field team began the interview by assuring informants of their anonymity and explaining that the survey's goal was to understand what they think and their farm practice. It also mentioned how they were chosen to be interviewed.

The process of questionnaire design was gradual and iterative. Initially, a rough questionnaire was drawn up on the basis of questions drawn from a range of existing questionnaires. Questions that were relevant to the study focus were copied, which often resulted in several different versions of each question. Drawing on these alternatives, a single choice was identified or distilled as the most suitable question on each particular theme. At this stage, the list of questions was inclusive to ensure that all relevant issues were considered before narrowing down its focus in light of the study priorities.

The initial list of questions was then reviewed by key personnel in the partner institutions for comment, and changes were made on the basis of these comments. Notably, certain questions were identified as relatively low priority and therefore deleted from the questionnaire. While the doctoral candidate was receptive to these comments, he also recognised his responsibility for designing the questionnaire to reflect the study focus (Casley & Lury 1987:23), and hence rejected suggestions felt to weaken it.

The end result was a draft questionnaire that reflected the study's focus and priorities. Once the doctoral candidate arrived in Shinyanga, the questionnaire was reviewed more closely by the Tanzanian partners to the study, resulting in further changes and a final English version of the questionnaire.

3.1.11 Translating and piloting

Next, several ICRAF staff helped the candidate translate the questionnaire. This involved sitting together and discussing each question in turn, to be certain that all concerned understood the gist and spirit of each question. This translation was then fine tuned together with the four field assistants. Again, this process involved discussing each question in turn, considering alternative possible ways to frame it, then selecting the best option cited.

Finally, the draft questionnaire was piloted with several farm households not included in the sample. This process was revealing. Most notably, it suggested that seeking to gather detailed data on livestock holdings and other delicate themes was counterproductive (see below). It also revealed that the questionnaire as ordered did not flow naturally. Finally, it showed that several questions remained insufficiently clear to interviewees. The questionnaire was further revised based on these findings, resulting in the final version used in the field study.

3.1.12 Sampling

The population universe

The population universe selected for random sampling included most but not all of the divisions that make up Shinyanga Rural District. As discussed above, it included the ten divisions located nearest to Shinyanga town, and excluded the four divisions located furthest from Shinyanga town. The resulting population universe is large, representing an area of approximately 10,000 square kilometres and 500,000 inhabitants. This area is entirely rural, as the only major town in the area – Shinyanga, population 100,000 – forms its own District, located in the centre of Shinyanga Rural District[15]. The sample frame includes all villages falling within this population universe.

[15] In the interest of simplicity, the present study often refers simply to 'Shinyanga District', by which it means Shinyanga Rural District, not Shinyanga Urban District.

Two-stage sampling: Stage one

Following Grosch & Munoz (1996) and Poate & Daplyn (1993), two-stage sampling was employed as a means to avoid imposing unmanageable logistical demands on the field team by concentrating households in a limited number of villages. Per standard procedure, the first-stage sampling units were villages, while the second-stage sampling units were households[16].

Stage one involved selecting twenty sample villages as primary sampling units (PSUs). These villages are government-designated administrative units (*vijiji*) that typically include from two to eight traditional villages (*vitongogi*). Henceforth, the *vijiji* are called villages, while the *vitongogi* are called sub-units. To select PSUs, a list was obtained from the local government of all the villages in the District and their current population. Villages in the four excluded divisions were deleted from the list.

Twenty villages were then selected from the villages remaining on the list using the 'probability proportional to size' technique. This technique made it more likely that villages with a large population were chosen and less likely that villages with a small population were chosen. Yet once a village was chosen, a fixed number of households located there were interviewed. Thus, it was *more* likely that any given household within a selected village was chosen if the PSU is small and *less* likely if the PSU was large. These two opposing sampling biases thus tended to cancel each other out, with the end result that each household in the population universe ultimately had an equal chance of being chosen as part of the household survey. In practical terms, this technique allowed for a fixed number of households to be selected from each sample village during the second stage of two-stage sampling, despite these sample villages being of different sizes, which facilitated project planning. It also allowed second-stage sampling to be carried out via simple random sampling, despite differences in the size of PSUs, thus facilitating sampling.

An alternative means of selecting PSUs would have been to select them randomly, i.e., by placing all the village names in a proverbial hat, then picking twenty names at random. The problem is that this would have produced a set of villages for which different numbers of households must be chosen. If a very small village were chosen, perhaps only three or four households would be required, while in a very large village as many as forty or fifty households might be required. While conceptually satisfactory, this approach would create

[16] Following Poate & Daplyn (1993:81), the household was defined as comprising those people who normally live and eat together in a dwelling or compound. It includes those who are sometimes away, as long as they spend at least three months of the past twelve in the household. In the case of multiple wives, each wife that does not normally live and eat with her co-wives may be considered to have her own household.

practical difficulties. One problem is that if a remote village were small and only required that a few households be interviewed, this would mean that the trip to this village, initial meeting with the village leaders, and sampling process would be conducted for just a few cases. More problematic, the field team may not be efficiently utilised. Since the number of households to be interviewed would differ by village, the danger is that some of the field team might be left idle for part of the day, or alternatively that they have to work very late to finish up a few last households in a village.

Instead, using probability proportional to size meant that the target number of households per village remained constant at seventeen[17]. This accorded well with the field team's work rate. Typically, each village was visited twice on consecutive days, which provided sufficient time in most cases[18] to conduct the seventeen target interviews. The first day began with a meeting with the village leaders, which included on-site statistical sampling, as discussed below.

A second advantage of two-stage sampling over simple random selection of villages follows from the fact that farmers from the same village may tend to copy one another and may also have been exposed to the same sources of outside information. Insofar as these homogenising influences apply, two-stage sampling may result in a higher degree of variability across the household survey, and hence in a more accurate picture of the breadth of practices and viewpoints across the District.

In all twenty cases, the administrative village selected was large, comprising over eighty households. This posed a logistical problem, since a large village might be difficult for members of the field team to cover on foot, particularly if it included geographically distinct sub-units (i.e., traditional villages). To address this problem, one sub-unit was selected to represent each village. In those few cases where the sub-unit selected was smaller than thirty households, a second sub-unit was selected in addition to the first sub-unit, since otherwise the households might be excessively similar[19].

To select the target sub-unit(s), the approximate size of each sub-unit was first estimated. The village roster, which lists the names of all the household heads in the village and its various sub-units, was used as a basis for

[17] While this represented a target number, actual numbers of households interviewed in each village varied slightly (minimum 15, maximum 20), depending on factors such as time spent travelling to the village and the occasional absence of a field assistant due to illness. This target is comparable to the target number of sixteen households per village interviewed as part of the LSMS studies (Grosch & Munoz 1996:67).

[18] The exceptions to this rule were a few villages where due to certain delays and difficulties, it was necessary to spend three days in the village.

this exercise. During the initial meeting between the field team and the village leaders (see below), the village roster was reviewed, and any additions or deletions to it were discussed among the village leaders and any other villagers present[20]. Next, the approximate size of each sub-unit was estimated. Finally, one (or possibly two) sub-units were selected on a probability proportional to size basis, according to the procedure outlined below.

The selection of target sub-unit(s) was conducted during the meeting with the village leaders, and was invariably a source of amusement to them. It involved estimating the size of each sub-unit to the nearest ten households, then assigning one number to each ten-household block in each sub-unit. Each number was written on a scrap of paper, and the papers were rolled into balls and placed in a hat. The village chairman was then asked to choose one paper ball out of the hat. One advantage of this process is that it seemed to convince villagers that the process of selecting a target sub-unit was truly random. This was a significant achievement, since villagers were typically envious of those who were sampled, believing that they might eventually benefit in some way from their involvement with the study[21]. In cases where households not being sampled voiced unhappiness at not being interviewed, the village leaders (who often accompanied the team leader and/or one or more field assistants around the village) often explained the selection process to the household in question, thus placating the questioner.

Two-stage sampling: Stage two

Stage two involved selecting a set of twenty households within each PSU. This selection of households within the target sub-unit(s) was likewise conducted during the meeting with the village leaders. This process simply involved determining the total number of households in the sub-unit(s), then calculating the multiple of twenty that equals that total. For instance, if the total number of households in the sub-unit(s) were sixty, then a multiple of three would be chosen. The numbers one, two and three were then written on three separate scraps of paper, rolled into balls, and placed in a hat. Again, the village chairman was asked to select one. The number selected was the starting point, and the multiple was the number of names to skip before selecting the subsequent households. Thus, if the number two were chosen, households sampled would be two, five, eight, etc.

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[19] In fact, insufficient variability among households in a given village was not found to be a problem. On the contrary, findings of household resource constraints, practices and views were found to be consistently diverse within villages. This is also reflected in the fact that the village variable was not found to be a significant determinant of specific tree management practices.

[20] This step comprises a 'supplementary inquiry' to ensure the currency and accuracy of the sample frame, as recommended by Casley & Lury (1987:56).

[21] Villagers generally seemed to believe this, despite the field team's insistence that villagers should not expect any concrete benefits from the study.

Even though only seventeen households were generally interviewed, twenty households were chosen in order to be on the safe size in case of non-response. As it happened, the field team encountered no instances of non-response, and hence did not need a contingency plan to determine replacements, but the team could not have known this in advance. To select which households out of the twenty should be interviewed first, the field team simply took the first seventeen names on the list. This practice did not damage the statistical validity of the survey, since the alphabetical ordering of the list did not represent meaningful ordering in terms of farm or household characteristics.

The only divergence from strict statistical sampling was the case of the two sample villages where ICRAF had conducted farm trials. Here, the statistical sample was supplemented by conducting a separate random selection among farm trial households to select two from each ICRAF village for inclusion in the household survey. While representing a slight compromise of the household survey's statistical validity, this was done in the interest of ensuring the survey included households with diverse views of farm trees and their potential usefulness in meeting household needs[22]. A related reason was to ensure that the study was as useful as possible to its institutional partners by shedding light on the impact of their interventions.

These households were not separated out from the others during the data analysis due to the small number of households involved, compared to the overall statistical sample. While it may slightly skew the findings in favour of tree management and any traits characterising these households (e.g., better education), this shift will be slight.

3.1.13 Meeting with village leaders

Upon arriving in a village, the field team's first task was to hold a meeting with the village leaders[23]. Typically, these meetings included the village chairman (i.e., the elected leader of the village) and the village executive officer (the government's representative at the village level), among others. This meeting began with an introduction of the field team and the field study. After responding to any questions raised, we requested their assistance for the duration of the interview process. The leaders readily agreed in all cases, and often also proved quite helpful during the interview process. In fact, they typically accompanied the team leader around the village. This was a significant help to the study, given the shyness of the Sukuma and their suspicion of

[22] Notably, it was done to ensure that the sample included some households genuinely interested in trees that were inclined to actively manage them as a means to meet diverse household needs.
[23] These meetings were pre-planned, with village leaders having been informed of them by post, complete with a copy of a letter of support from the District authorities.

outsiders. The fact that the field team had secured the co-operation and assistance of their leaders served as a powerful reassurance to villagers that we were to be trusted and assisted[24].

Only then did the field assistants head off to meet their first household and commence their first interview. This arrangement suited the team's resources, since on day one the field team typically managed seven interviews, while on day two it typically managed ten or eleven.

3.1.14 Conducting interviews

Interviews with survey households were conducted by the field assistants, sometimes with the assistance of the team leader. Following the meeting with the village leaders, each field assistant was assigned a group of households. Allocation criteria included geographical proximity and any special requirements, such as ensuring that a female assistant was sent to any female-headed household, or that a Sukuma speaking assistant was sent to a household whose members did not speak Swahili. Geographical criteria were important given the physical size of some villages, since this allowed field assistants to walk between households without difficulty rather than having to rely on the driver. Finally, special characteristics of households also sometimes influenced the allocation of households to field assistants. For instance, in one case one of the sample households was a formidable witch doctor, and the village leaders were concerned that he had been chosen. Given this special circumstance, the field assistants were questioned as to who wouldn't mind interviewing such an individual, and the household was assigned accordingly[25].

Once a field assistant arrived at a household, s/he described our work and explained the interview process, then asked whether it would be possible to hold such an interview and if so when. Typically, households agreed to conduct the interview immediately, perhaps because the survey was conducted during a season characterised by modest demands on household labour. Yet field assistants were strictly instructed to respect the wishes of the household, including their preferences as to when the interview should be held. Thus, if a household was busy when the field assistant arrived, the assistant simply scheduled a meeting for another time.

Once the interview process had begun following the meeting with village leaders, the candidate took on a supervisory role. This involved accompanying first one field assistant then another to their designated households, and sometimes involved random spot checks on field assistants, as recommended by Poate &

[24] This being said, the question of whether the chairman (or other elected official) or the VEO accompanied the team was significant, given suspicion of government representatives, with help from the latter being a mixed blessing.

Daplyn (1993:201). Key objectives of this supervisory role included ensuring consistent interview quality, minimising differences between the approaches of the different field assistants, and providing any needed assistance. The team leader also conducted a separate interview with the village leaders on a set of general points relating to the village as a whole.

Ideally, interviews should be conducted with those persons with the most direct knowledge of the subject under investigation in order to minimise inaccuracies. Yet in every survey there are cases where proxy respondents, i.e., those answering on behalf of others, have to be accepted. In the case of general knowledge about the household, however, any adult member is an acceptable respondent (Poate & Daplyn 1993:91). To ensure answers were as accurate as possible, the present study sought to interview both the household head and their spouse, along with any other adults present. Where the household head was not present, the interview was conducted with other adult household members. In most cases, several adults were present at the interview. Overall, 56% of interviews included both the household head and their spouse, 18% included the household head without their spouse, while in the remaining 24% of cases the interview was conducted with other adults. While households where the household head was not present could have been rejected and another household interviewed instead, interviewing the household head was deemed less important than adhering to the sample frame, particularly since the topics being discussed were deemed likely to be general knowledge among household members.

The only exception to the above format was the several questions asked only of adult women. This small portion of the questionnaire was conducted away from adult men, typically inside one of the huts.

3.1.15 Anticipated problems and pre-emptive solutions

One concern was that interviewees might tell interviewers 'what they want to hear' out of politeness[26]. For instance, farmers may say that particular agroforestry practices or trees generally are good, even if they do not believe this. To address this problem, interviewers were careful to avoid giving any indication of either personal beliefs or a professional agenda, thus avoiding the power of suggestion. Notably, the study team went to considerable lengths to avoid any association between themselves and trees, for instance by introducing themselves as researchers simply interested in the problems facing farmers. Also, interviewees were

[25] Incidentally, the candidate went along on this particular interview and lived to tell the story.
[26] This is reported to occur commonly during interviews with rural Africans due to their conception of politeness. These people tend to be good at detecting the interviewer's agenda, and when they do so their answers may tend to conform to their assessment. This explains the danger of being seen as associated with any particular viewpoint when conducting interviews.

encouraged to speak freely about themes raised by survey questions in order to capture the gist of their thinking about them.

A second concern was that interviewees may give strategic responses in an effort to secure unstated objectives, such as access to costly farm inputs like chemical fertilisers or ox-drawn ploughs[27]. Solutions included trying to avoid creating perverse incentives for strategic behaviour and employing direct observation to supplement interview responses. The former involved ensuring that introductory comments to both village leaders and survey households made clear that villagers must not expect any concrete benefits from participation in the study. Instead, it was emphasised that the only benefits to survey households and their villages would be an honest, open dialogue about ways to improve local livelihoods, notably in an eventual village meeting to discuss the study findings and their implications[28]. In a sense, interviewees were thus invited to not participate if they did not wish to be part of this collaborative process of seeking to address key livelihood constraints. While some initially appeared disappointed that they would not receive any handouts, all without fail ultimately accepted this challenge.

3.1.16 Contending with sensitive data

While livestock are clearly of great significance in the District (see chapter 4), the task of collecting data on livestock holdings proved problematic. In view of their centrality to households' assets, the original aim was to gather detailed data on livestock. This was to include precise numbers and types of current holdings and any recent births, deaths, sales or purchases. Unfortunately it became clear during the pilot stage of the research that these questions were overly ambitious, given the socio-cultural and historical situation in the District. In particular, it was found that many households were simply lying about their livestock holdings. This became clear when farmers who evidently owned cattle – based on observations of a livestock pen, fresh manure or actual animals around the household compound – would either claim they had no livestock at all or say they had only one or two chickens. This put the field team in a situation where by trying to get too much information, it was ending up obtaining misinformation. Meanwhile, other households would readily divulge information on their herds, leading to uneven data.

This problem of some households giving misleading responses with regard to livestock was discussed at length with the field team and the study's advisors. What became clear was that some households felt fearful and

[27] For examples of strategic responses by farmers in Shinyanga District, see Oxfam/IDS (1998).

vulnerable when faced with probing questions about livestock. Negative prior experiences with government agents were at the root of farmers' suspicion. Negative associations included that farmers had to pay taxes on cattle and ensure they were vaccinated against certain diseases, both of which imposed significant drains on household income. When this issue was subsequently discussed with village leaders during the household survey, it became clear that in the past the local government had tried briefly to assert its tax collection function in a forceful manner. Faced with widespread tax evasion, including households locking themselves in their homes and pretending not to be home or taking refuge in the bush when a tax collector arrived in their village, the local authorities had tried a policy of seizing any available assets whenever no household members could be found. As a result, moveable assets such as livestock and ploughs were sometimes simply taken away. Given these negative associations with outside interest in their livestock, it is no surprise that farmers were hesitant to divulge information on this subject.

Ultimately, the problem of misleading responses vis-à-vis livestock was addressed by radically simplifying the survey questions on livestock, in the interest of ensuring rigour and consistency across the dataset. Notably, data were only sought on *types* of livestock possessed without asking for numbers and on changes over time in livestock numbers and their principal cause. Sample households were also assured prior to the discussion about livestock that only very general information was needed, and that the interviewer would not probe. An additional check on the livestock data was provided by direct observation of the household compound. If the field assistant's observations seemed to contradict the interviewee's statements about their livestock holdings, they were asked about this apparent contradiction. In the relatively few cases where household statements remained contradictory with such indicators, the field assistant had the prerogative to revise the data on the household's livestock holdings based on his/her considered judgement. Ultimately, such revisions were only made in a handful of cases where the evidence of misleading responses seemed clear.

Although these measures seem to have been successful in securing relatively accurate and consistent livestock data[29], the end result is that the study's data on livestock and other sensitive topics such as non-farm income is sometimes quite general. Moreover, even given this strategy geared to minimise misleading responses, a small number of such responses doubtless remain.

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[28] These village meetings are provisionally planned for all twenty villages in mid-2004 as part of a collaborative research project involving Oxford University's School of Geography and Environment and various Tanzanian institutions.

[29] The fact that these data show clear and strong correlations with the other resource constraint data suggests that the resulting data, although general, is of reasonably high quality.

A comparison of the survey findings vis-à-vis livestock with those of a recent participatory study of livelihoods in the District seems to justify this conservative approach to data on sensitive topics. The study in question, conducted by Oxfam/Tanzania in conjunction with the University of Dar es Salaam's Institute of Development Studies (Oxfam/IDS 1998), found that less than twenty percent of its statistically selected sample owned *any* livestock. By contrast, the present study found that 73% of households owned cattle, a further 8% owned sheep or goats but no cattle, and a further 14% owned only chicken but no cattle, sheep or goats. Only 5% of the sample was found to own no livestock at all. Since the sample population for the two studies was similar, the only plausible explanation for this discrepancy is that one or other of these studies obtained misleading results. For the reasons listed above, it seems likely that the Oxfam/IDS study seriously underestimated the livestock holdings of District residents. This grave discrepancy between these two studies highlights the extreme delicacy of livestock data in Sukuma society.

3.1.17 Other problems encountered

A more general data problem involved inconsistencies between the work of the different field assistants and/or between the level of detail divulged by interviewees. For instance, interviewers may commit recording or coding errors, while households may either overestimate or underestimate measures of farm output. Such responses represent instances of non-sampling error[30]. Such errors are most worrisome where they are cumulative, such as the case of systematic biases in how different interviews conduct interviews or record responses, or the tendency of households to under-report sensitive data due to suspicion about the purpose of the survey (Casley & Lury 1987:62). Given this danger, the present study went to great lengths to address cumulative errors, notably through supervision of interviews and ongoing reviews of completed questionnaires, as discussed above.

Data were only useful for statistical analysis where they were consistent across survey households, as opposed to just for some subset of survey households. Nonetheless, such data were still sometimes useful qualitative indicators of field realities. Notably, qualitative comments about trees and their significance to households were useful as a means of "giving a feel" for different subsets of statistically grouped data. During the data cleaning process, the more nuanced data obtained for some households were often reduced to a broader level of generality in order to ensure that the data category in question was consistent across the dataset. The data on purchased farm inputs provide an example. While some households reported the precise types of inputs used and even the use rates and application patterns, others only gave general data about the broad category of input

used, e.g., chemical pesticide. Making these differing data amenable to statistical analysis necessitated simplifying the more detailed findings to secure the same level of detail across the dataset. To minimise such eventual problems, the team leader continually reviewed completed questionnaires during the study period and discussed inconsistencies with the relevant field assistants[31].

One logistical problem encountered involved negotiating with ICRAF and HASHI about the use of project vehicles for gathering field data. The latter proved to be an ongoing issue, primarily because these two projects each had other needs for their vehicles and drivers. A second issue was petrol, given the high petrol costs in the country and the considerable distances travelled each day by the field team (between fifteen and eighty kilometres in each direction, with an average of fifty). The solution to these problems was getting these two projects to divide up the study's transport needs by getting them to compete for partial ownership of the project. This approach worked, thanks to the inherently competitive relations between the institutions involved in this collaborative project, but required ongoing effort by the team leader.

3.1.18 Expert interviews

Twenty-two interviews were conducted with locally-based experts, including the heads of all the key public and private offices working in agriculture and resource management in Shinyanga Rural District. The aim of these interviews was to better understand the different messages being communicated to District farmers by the various resident development institutions. A secondary aim was to get an overview of how well these different agencies worked in concert with one another. Preliminary analysis of these data suggested both unexploited potential complementarities and significant conflicts between the institutional agendas and personal views expressed[32].

Expert interviews with locally-based government officials and project personnel were conducted by the candidate without the help of the field team. These involved meeting with the head of the relevant office, describing the study and requesting a meeting to conduct an expert interview. These interviews typically lasted between two and three hours. This fact demonstrates the interest taken by these offices in the study, particularly given the fact that some of them began the interview by informing the candidate that they would

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[30] Strategic responses, as discussed above, represent another type of non-sampling error.

[31] Where inconsistencies were identified during data processing, the data were simplified to a level at which they were consistent across the dataset, as discussed above.

[32] In the worst cases, different agencies were actually working in direct opposition to one another, e.g., one advocating de-stocking and reinvesting assets in other enterprises to reduce pressure on pastures while another emphasised increasing livestock holdings to bolster household assets.

not be able to meet for more than half an hour. Simply put, interviewees seemed to genuinely enjoy being interviewed. They seemed happy to be able to tell their story, to explain how they viewed the problems facing District residents and the solutions they envisaged. In particular, they seemed happy to be listened to and taken seriously by an outside expert.

The expert interviews involved an exploratory survey of certain relevant themes. Each theme was introduced with an open-ended question, while the ensuing discussion sometimes involved further clarification and encouragement of interviewees. The ten questions employed to spur this discussion as are follows:

1. What are the principal problems plaguing District farmers?
2. What are their principal causes?
3. Can you suggest any promising solutions to these problems?
4. Is environmental degradation significant in the District?
5. Can you generalise about which types of farmers tend to have 'better' knowledge and resource management?
6. Can you specify what the more successful farmers actually do differently?
7. What message does your office advocate to farmers?
8. Are farmers receptive to this message?
9. What are your personal views about the strategies advocated?
10. What is the best model for interactions between outsiders and rural people?

Most of these questions proved a success, both in terms of getting interviewees interested in the discussion and in eliciting interesting and useful data. The two exceptions were questions five and six. For one thing, interviewees were often not sure exactly what was being asked, as a result of which the question itself had to be discussed before they could answer. Even once they understood, their answers were either hesitant or predictable. Those who offered only hesitant answers seemed to sense that this was a trick question meant to get them to reveal their biases, while those who offered confident answers generally simply identified the best farmers as those who followed the recommendations of extension agents and projects. Perhaps more important than the fact that these two questions did not give useful answers was the fact that they broke up the flow and complicity of the interview. The other questions, meanwhile, almost invariably got interviewees speaking freely and with great interest about their work and the challenges faced by their office.

3.1.19 Data collected but not analysed

Several subsets of data collected were not analysed as part of the present study. Each subset is listed below, followed by the principal reason it was not included in the analysis. In most cases, this was not because the data were poor, but simply because their analysis fell beyond the scope of the present study[33], with its emphasis on assessing whether local knowledge profiles are a significant determinant of natural resource management decisions, and whether 'knowledge failure' is significant. Data not analysed include...

Production indicators — The potential of agroforestry practices to bolster farm production and meet household needs has been amply demonstrated, rendering production linkages non-essential to the present study.

Cropping patterns — Precise cropping patterns were not deemed to be directly relevant to tree management decisions.

Tree protection data — Although potentially significant to the study focus, these data were found to be poor, based on widely divergent interpretations of the term 'protect' among survey households.

Women's perspective — Although intra-household dynamics are significant to rural livelihoods, these represented an additional level of complexity that was deemed to be beyond the scope of the present study.

Expert interviews — Examining the impact of distinct information provision efforts on household decision making is a good idea in principle, but would have been unrealistic given the random nature of the study sample, as a result of which few survey households had contact with any institutions or extensionists, much less sufficient contact to allow comparisons of institutional impact.

3.2 **Data processing and analysis**

3.2.1 Data processing

The process of 'cleaning' the field data and entering them into SPSS was a challenge for a number of reasons. These include that the household survey data were in Swahili, the handwriting of the field assistants was often

[33] In such cases, these data could provide fruitful bases for future research.

difficult to read, and the data themselves were sometimes ambiguous. More simply, the data were simply voluminous, with the final SPSS file containing over 120,000 cells.

This ambiguity involved the content of long answers and sometimes also the accuracy of coded (i.e., circled) answers. It manifested itself in answers that were sometimes unclear or inconsistent and occasionally outright misleading. Ambiguous answers might reflect lack of interest in a particular topic on the part of the interviewee or careless recording by interviewers. Inconsistency may reflect a farmer's lack of formal training in analytical thinking, which could see him emphasising certain aspects of an issue while neglecting to mention others, despite being familiar with them. While the field study had prepared for the possibility of ambiguous responses by asking several questions from different angles on particularly thorny topics, the resulting data were nonetheless difficult to interpret. Misleading answers were a particularly thorny problem, as discussed above.

These concerns aside, the fact that the data showed clear trends both confirming various theoretical expectations and supporting the study hypothesis demonstrate that despite these concerns, the data resulting from this laborious process were nonetheless broadly sound.

3.2.2 Logit regressions

Following a set of basic descriptive statistics, the first part of the data analysis involved generating a set of tree management regressions and comparing their explanatory power both with and without knowledge variables. The first set of regressions included diverse resource constraints and socio-cultural factors as explanatory variables, while the second set also included knowledge variables.

Although the household survey constituted a cross-sectional snapshot of rural realities in Shinyanga District, the different tree management patterns observed may nonetheless be interpreted as evidence of differential technology adoption. This follows because those households pursuing particular tree management practices had clearly 'adopted' these practices in the past, while others had not. The fact that many of these 'technologies' were indigenous tree management patterns or endogenous adaptations to changing resource constraints does not change the fact that this is essentially a question of technology adoption. Of course, this process may operate in either direction, and hence the data may show the difference between those farmers who persist in practicing indigenous technologies or introduced technologies versus those who have abandoned

them. That is, these data may show evidence of both adoption and dis-adoption of agroforestry practices. Either way, the fact that some households continue to follow certain practices while others do not is significant, and begs the question as to why this is the case.

While the precise tree management practices followed by survey households were diverse, these were simplified into several broad categories to render them amenable to statistical analysis. The resulting models include both binomial logit and multinomial logit models, reflecting differing choices between distinct categories of tree management practice.

The analysis of technology choice typically involves dichotomous choice (i.e., logit or probit) models to compare adopters and non-adopters and to discern what characteristics of the farm, household or local environment explain adoption (Neill & Lee 2001). Other applications of these models include examining demand for veterinary services in rural Kenya (Tambi et al 1999), identifying the determinants of poverty in North West Province, South Africa (Serumaga-Zake 2002), distinguishing the characteristics of stockowners relying on private vs. commons pastures in Ciskei, South Africa (Anim & Lyne 1994), and examining the relative significance of constraints to commercial farming in KwaZulu Natal (Fenwick & Lyne 1999). Recent applications of logit or probit models to assess the determinants of agroforestry adoption by farm households include Ayuk (1997) for Burkina Faso, Adesina & Chianu (2002) for Nigeria, and Ngassam & Nkamleu (1999) for Cameroon.

While knowledge variables are sometimes included in regression equations as explanatory variables, these are typically in the form of proxy variables indicating levels of access to outside information. Typical proxies for household knowledge in studies of technology choice within African agriculture include educational level, extension contact and access to media (e.g., Abebaw 2001; Adesina & Chianu 2002; Fenwick & Lyne 1999; Nkamleu & Adesina 2000). Notably, however, these variables signify differential *access to MSK*, as opposed to differential LK. This fact reflects the received wisdom vis-à-vis MSK and LK summarised in chapter 2 as well as the assumptions about farmer efficiency and endogenous innovation highlighted in chapter 1. Simply put, it is assumed that provision of MSK can deliver powerful gains to rural producers, while LK and management of available resources are assumed to already be roughly optimal. It follows that there is no need to separate out LK as an independent factor of production or consider it as a potential explanatory factor[34].

[34] Moreover, because LK is assumed to reflect local opportunities and constraints, any eventual LK variable would be expected to show multicollinearity with key resource or socio-cultural variables, and hence have to be omitted.

By contrast, the present study sought to assess the independent explanatory power of diverse LK variables while also considering conventional MSK proxy variables. Key steps in this process included defining these LK variables, omitting any such variables found to show multicollinearity with existing factors or with each other, then factoring these variables into the existing logit models for tree management to assess their impact on overall explanatory power.

3.2.3 Associations among aspects of LK

In order to elucidate the findings of these logit regressions, which suggested that LK variables have significant independent explanatory power, the study then ran a series of correlations. These were meant to detect associations among different sets of LK variables. The premise was that if the study could demonstrate which aspects of LK tend to go together, or perhaps how these different types of LK together form distinct knowledge profiles, then perhaps the precise nature of these knowledge differences would become clear.

Correlations found indicated both the strength and directionality of association[35]. While such correlations can be used to make predictions about groups of households or to ascribe trends, there are strict limits to what can be inferred since such associations do not indicate causality. Thus, it is unclear which factor causes which, or if both are caused by a third variable or other combination of variables (Black 1999:215; Norusis 2002). As such, this part of the analysis was purely exploratory. Although the resulting findings were far from conclusive, they nonetheless provide valuable guidance to future research into LK vis-à-vis natural resource management.

In addition to conducting a full set of pairwise profiles, the study also examined these data using categorical principal components analysis (CATPCA). The rationale here was that distilling these diverse, often overlapping LK data into synthetic composite variables may indicate underlying common trends inherent in these variables (Meulman & Heiser 1999:23ff). Specifically, these trends may be represented by any synthetic variables generated.

The present study's attempt to discern distinct knowledge profiles then to assess their potential to influence on behaviour is not original, although it may be unusual within research on peasant households. Indeed, survey questionnaires often seek to assess the strength of attitudes, perceptions or views in order to assess their impact

[35] For each potential association, the study obtained a chi-squared statistic, a gamma statistic and spearman's rho, to assess statistical significance and obtain comparable measures of strength and directionality.

on behaviour. The premise is that similar views tend to be held by groups homogenous for certain traits, and that these views influence behaviour. Thus, research into attitudes or beliefs can help understand how these factors influence decisions and actions (Black 1999:215).

While 'household knowledge' may be conceptually distinct from concepts like 'attitude' or 'perception', these various concepts are clearly related. In practice, attitude and perceptions may influence knowledge or vice versa. Yet in the context of peasant communities, these concepts may be considered together, insofar as they form a complex of factors that together determines a household's understanding of a certain resource, e.g., trees and their role in securing household livelihood objectives. Taken together, such factors determine whether a household is in fact responsive to changing factor constraints and hence efficient, as assumed by existing farm household models.

3.2.4 Summarising the data analysis process

The present study examined the possibility that distinct categories of local knowledge vis-à-vis natural resources represent key causes of observed resource management practices. It formulated a theoretical model to conceptualise this possibility and ran logistical regressions to test it. By contrast, the second part of the analysis was essentially exploratory, seeking only to shed light on which patterns of knowledge vis-à-vis natural resources tend to go together. This part of the analysis does not formulate a hypothesis as to how knowledge patterns function, and hence could not begin to assess causality. Nonetheless, this exploratory analysis was able to highlight associations among knowledge variables that might help inform further research, and hence ultimately lead to attribution of causality.

The essential difference between these two parts of the analysis is that in the second case we cannot say what the underlying causal mechanism may be that leads to any observed associations. This is unsurprising, since the question of 'knowledge failure' causing some subsets of LK to be problematic vis-à-vis natural resource management is not an idea whose implications have been explored. Logically prior to this, the question of whether this problem exists to a significant extent must first be examined, which is the primary task of the present study. The research strategy chosen reflects this distinction between linkages for which causal mechanisms are hypothesised and others which are merely explored (Oppenheim 1992:18).

Chapter 4

Farming, Tree Management and Household Resources in Shinyanga District, Tanzania

The household survey was carried out in Shinyanga District[1], Tanzania in the latter part of the year 2000. This district falls in the Shinyanga Region, one of the twenty regions that make up modern-day Tanzania. Both administrative areas fall in the wider area known as 'Sukumaland', after the dominant Sukuma ethnic group. Figure 4.1 provides a map of the area.

4.1 The study context in historical perspective

4.1.1 Pre-colonial Sukumaland

Early visitors described Sukumaland as a land of plenty. One colourful description comes from Henry Morgan Stanley, who journeyed through the area in 1875. He wrote about, "the rich country of Usukuma, where the traveller, if he has resources at his disposal, need never fear starvation". Elaborating, he wrote "the products of the rich upland were here laid at our feet, and it must be conceded that the plenteous stores of grain, beans, potatoes, vetches, sesamum, millet, vegetables such as melons and various garden herbs, honey and tobacco [...] were merited by the members of the long-enduring expedition. The number of chickens and goats that were slaughtered by the people was enormous" (Stanley 1899:105).

The two major migrations into the area occurred some 400 to 500 years ago. One involved Bantu people from south of Lake Chad while the other involved Hamitic people from Abyssinia (present-day Ethiopia). Both peoples practised shifting cultivation combined with hunting. These two groups intermarried freely, and Sukuma culture is an amalgamation of their two cultures (Tomecko & Tomecko 1976:3; Meertens et al 2000).

By the eighteenth century, the Sukuma were primarily agriculturalists. Yet population pressure and the expansion of chiefdoms brought internecine warfare, and hence the need for mutual protection from outsiders. Since it was only safe to cultivate near to the village, a land-use system evolved that reflected conflict-induced land scarcity. Simply put, village lands for grazing and planting were located only in the immediate vicinity of household compounds. The danger of cultivating on one's own also led to practices of collective labour. Fears

[1] To be precise, the survey was carried out in Shinyanga Rural District, but the discussion simply refers to Shinyanga District in the interest of simplicity.

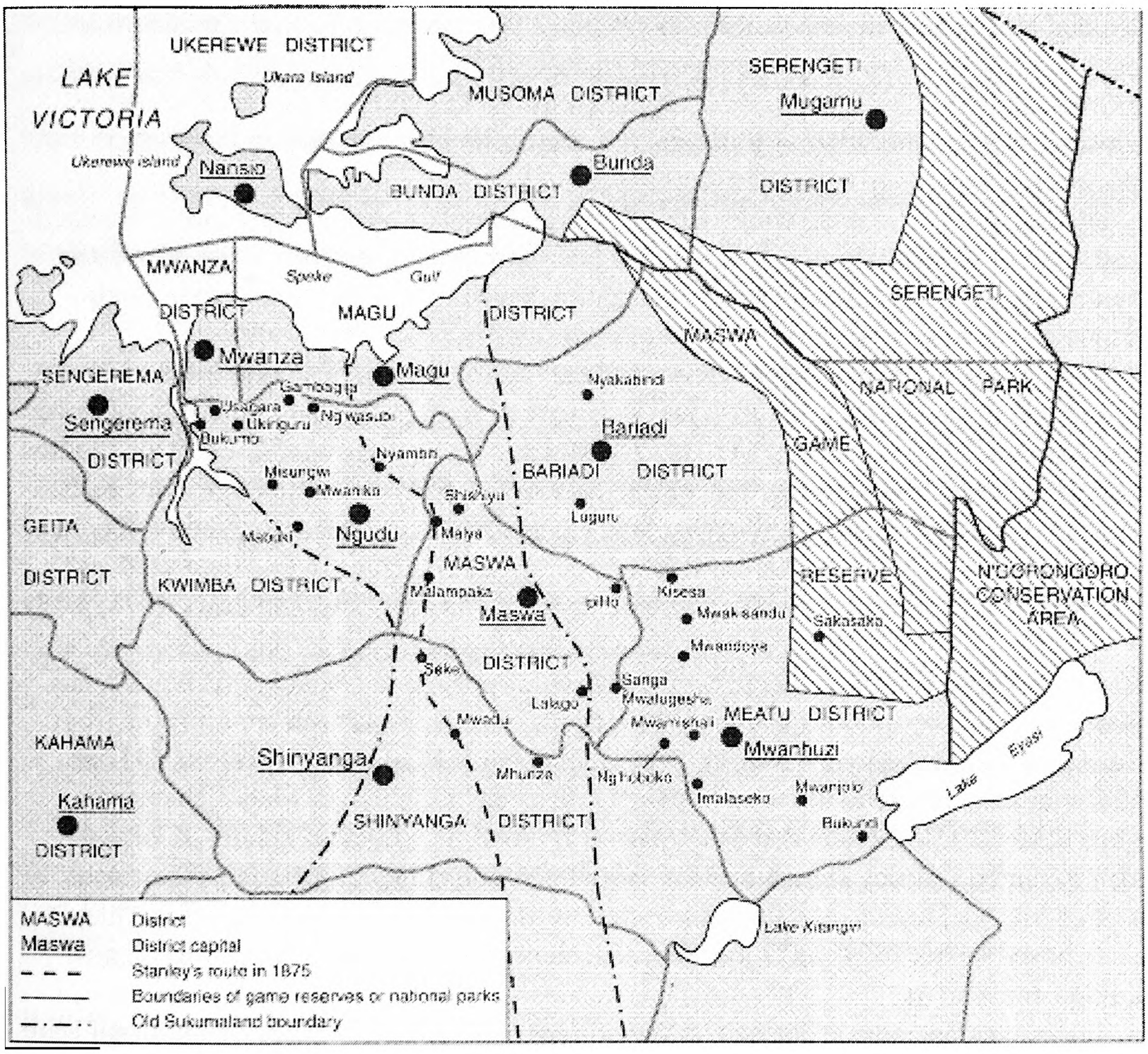


Figure 4.1 Map of Sukumaland, including the borders of modern-day Shinyanga District

Source: Meertens et al 2000

of capture increased in the early 1800s, since captives began to be sold to Arab slave traders (Tomecko & Tomecko 1976:13; Meertens et al 2000).

Besides internecine conflict, a second broad reason for relative land scarcity was the impact of tsetse fly and ticks on livestock, both of which transmit potentially fatal diseases to cattle. Given the importance of cattle to Sukuma society, the role of livestock pests was a critical determinant of Sukuma settlement and land-use patterns. These patterns were sharply restricted by the threats posed by livestock pests, particularly tsetse fly. Given the importance of these pests, it has been argued that Sukumaland has historically existed in a state of dynamic equilibrium, with cultivated farms and grazed grasslands in a dynamic equilibrium with adjoining woodlands populated by wild game and tsetse flies[2].

The several types of tsetse fly native to the area have adapted to living in a hot, dry climate by seeking refuge in cooler, shady patches, making them particularly vulnerable to habitat manipulation. To survive under semi-arid conditions, ticks likewise require a relatively humid microclimate to protect them from sunlight and wind. Ticks additionally need tall vegetation from which to colonise hosts (Yeoman 1967). Due to this intimate association between livestock pests and natural vegetation, clearing vegetation has often been viewed as a means of controlling tsetse flies by rural people and governments alike.

When the Germans arrived in 1890, they found that farmers had intensified agricultural production in response to land scarcity. This intensive cultivation necessitated various practices to ensure the ongoing viability of production, such as manuring, diverse crop husbandry skills, and an indigenous land market (Tomecko & Tomecko 1976:14).

4.1.2 Early changes brought by colonialism

Yet this rural context characterised by land scarcity changed with the arrival of the European colonists. First, the German colonial authorities imposed military rule and hence ended internecine warfare. It thus became safe to settle further away from the village centre and people began clearing new lands. Wholesale migration to new lands also became possible, with households possessing large herds particularly likely to migrate, perhaps due to their greater need for land.

[2] Notably, when woodlands invaded the grasslands they were cleared by man, while cattle that invaded the woodland were attacked by tsetse flies and ticks (Meertens et al 2000). Birley (1982) suggests however that even before the arrival of the Europeans, humans were gradually winning the battle against tsetse, both by progressively clearing the bush and because some cattle were becoming immune to infection.

A second key impact of colonial power was to progressively eradicate the tsetse fly. The tsetse eradication programmes of the 1920s and 1930s involved removing trees and shrubs from unpopulated woodlands. The Sukuma benefited directly from these efforts, which cleared vast swaths of formerly tsetse-infested land and freed up new lands for colonisation. Unlike other colonial initiatives, this effort to enlarge the tsetse-free area was highly successful, perhaps because it happened to coincide with the wishes and values of local people. Eventually, these tsetse eradication efforts coupled with intensive grazing and cultivation fundamentally transformed the local vegetation, replacing the area's native perennial grasses and scattered shrubs with annual grasses. Similarly, Milne (1947:248) argued that agriculture and the cutting down of trees had transformed the plains into a 'cultivation steppe', with the remaining woody vegetation only a vestige of what must have originally existed.

Thus, due to both the imposition of order and the progressive eradication of the tsetse fly, colonial power led to a rapid expansion of the area under cultivation and grazing[3]. One critical impact of this increase in available land was to render the skills associated with agricultural intensification unnecessary (Tomecko & Tomecko 1976:13).

4.1.3 Farm management trends

The first detailed farm management data for Sukumaland date from 1936, as reported by Rounce (1949), while other major studies include Collinson (1963 & 1972), McLoughlin (1967) and Meertens et al (1993 & 2000). Given the dramatic changes that occurred since the arrival of the German colonists, it is a pity that the systems employed during this earlier period are not well known. Nonetheless, Tomecko & Tomecko (1976) attempted to piece together a picture of the pre-colonial period based on diverse evidence. In addition to reporting on crop choice and farming systems, these studies provide details about two other factors critical to understanding agricultural development in Sukumaland, namely soils and rainfall patterns.

Soils in Sukumaland are of several broad types, including sandy loams and clay-rich soils such as hardpan and black clay. Sandy soils were easy to cultivate yet had low natural fertility, while clay-rich soils were difficult to cultivate yet more fertile (Rounce 1949). Various authors suggest that the Sukuma possess a thorough knowledge of these different soils reflected in diverse soil names that informs their management decisions vis-

[3] Indeed, Stanley's account suggests that in 1875 Sukumaland was much smaller than it is today, including only central Shinyanga District (the focus of the present study), western Maswa District and the eastern parts of Mwanza and Magu Districts.

à-vis crops and livestock. While distinct soil types may be recognised in an indigenous typology, identification of soil type is determined purely by parent material and salts (Meertens et al 2000). That is, this typology does not explicitly recognise distinctions vis-à-vis levels of organic matter content or other measures of soil 'tiredness', despite the direct relevance of such indicators to managing soil fertility.

Most of Sukumaland received an average annual rainfall of between 700 and 900 mm, with rains following a bimodal pattern. The rains in Sukumaland are highly unpredictable, posing great difficulties to farmers. Rains may begin between October and late December. While March and April are generally the wettest months, prolonged dry spells have sometimes occurred at this time. Rainfall may also be patchy, heavy in one area while marginal in a neighbouring area. On average, there are two very dry years per decade, and droughts can be so severe as to cause famine.

Crops

The two staple crops reported by Rounce (1949) were sorghum and bullrush millet. Sorghum was said to be more prominent on heavier, clayey soils, while millet was confined to lighter, sandy soils. The other two important food crops during this period were cassava and sweet potato. Cassava in particular is notable for its capacity to grow on 'exhausted' soils, i.e., those whose fertility is low due to overcultivation, and was an important crop for food security during hardship periods. All four of these food crops were drought-resistant, which fit well with a local climate characterised by low, erratic rainfall.

Maize and rice were also sometimes grown. Yet both these crops require ample water and cannot endure dry spells during certain key stages in their growth. Such characteristics arguably make these crops ill-suited to an area characterised by low, irregular rainfall. In addition, maize requires fertile soil and cannot withstand waterlogging. Despite these difficulties, maize was grown on a portion of the farm wherever possible due to the taste preferences of Sukuma people for *ugali* made from maize. Rice cultivation was made possible by constructing bunds in low-lying areas with hardpan soils, since these soils retained standing water in rice fields.

Although cotton had been grown in small quantities for centuries, this drought-resistant crop was greatly expanded during the colonial period. By the 1940s, it had replaced groundnuts as the principal cash crop of the Sukuma. This expansion began under the Germans but accelerated when the British extended the railway line from Tabora to Mwanza in 1928.

By 1945, groundnuts were the third most important cash crop after cotton and rice. They were both valued as a food and readily marketable. Moreover, as legumes they were often grown in mixed crop stands as part of intercropping strategies to maintain soil fertility.

Farming systems

Collinson (1963) reports that the Sukuma had developed a good system for crop cultivation on sandy soils. It involved the construction of ridges using a hand hoe. The same ridges were used year after year, with weeds being scraped into the furrows and buried. Mixing weeds into the soil improved the fertility, structure and water-holding capacity of soils while also decreasing weed infestation.

Yet use of this system declined after 1945, when ploughs began to widely available. Ploughs allowed farmers to expand cultivation onto formerly neglected soils such as hardpan and *mbuga*, since they made it possible to prepare these lands using animal traction. These changes rendered ridging unnecessary as well as comparatively unattractive, due to its high labour demands. The introduction of the ox plough thus represents another key factor behind the extensification of agriculture in Sukumaland (Collinson 1963).

Other aspects of the farming strategies reported by Rounce (1949) and Collinson (1963) include intercropping and crop rotation. Given the unreliability of rainfall in the area, intercropping was a commonly practised as a risk-reduction strategy. Common mixtures included grain crops with legumes, including cowpea, green gram, beans and groundnuts. While crop rotation was also practised, sequences varied between farms (Rotenham 1968), and were not generally systematised (Rounce 1949).

Rounce (1949) reports that grazing of livestock occurred mainly in uncultivated areas and on fallow fields. According to the Sukuma practice of *kutobanga*, livestock usually graze nearby the household compound until available fodder is depleted, and only then move on to more distant pastures. This strategy of intentional heavy stocking is meant to avoid long grasses favoured by ticks, producing instead a short-grass pasture (Birley 1982:5). It also minimises weeds and, if goats are present, serves to prevent the regeneration of the bush (Malcolm 1953:73).

A strategy of reserved grazing areas called *ngitiri* was also common in Sukumaland (Smith 1938). *Ngitiri* were concentrated in the older settlements, where a high concentration of cattle meant shortages of grass fodder during the dry season. To provide fodder, households began claiming the fallow of their allotted arable areas as personal grassland reserves. This process of individual claims began before in the early 20th century in some parts of Sukumaland. Eventually such pasture restrictions began posing problems for pasture boys seeking pasture for their herds, with quarrels over who had the right to graze where even leading to bloodshed. In response, some villages introduced communal grazing reserves (Malcolm 1953:73-76).

Use of agricultural inputs

Tomecko & Tomecko (1976:13) report that manuring was widely used in the nineteenth century and was considered an essential skill for farming, given the intensive cultivation practised at the time in Sukumaland. Because cultivation occurred only in a small area nearby the household compound, manure was only transported over a small distance. Meertens et al (2000) estimate that half of all households at the time had cattle, and that most of these practised manuring on their fields[4]. Yet simple percentages of households practising manuring or using fertiliser tell little about the prevalence of these practices or their application rates per hectare.

Meertens et al (2000) suggest that the Sukuma have long recognised the usefulness of manure, as reflected in the long-standing practice of growing valued crops like maize and tobacco on sites formerly used as corrals. Yet the use of manure has decreased sharply over time (see Table 4.1), only returning to and exceeding its former levels in particular cases. Similarly, Rounce (1949) reports that manuring had been practised during the period of conflict- and pest-induced land scarcity, yet was largely abandoned when households became able to extend their landholdings and migrate freely to virgin lands.

Chemical fertilisers first became available to Sukuma farmers after independence in 1961, when the new government launched a programme to encourage fertiliser use. Manuring, by contrast, was not stressed, having become associated with unpopular and punitive colonial policies. Fertiliser use slowly increased until 1986, when it began falling after currency devaluation and subsequent inflation drove up fertiliser prices. From 1991 onwards, subsidies on fertiliser were removed, further exacerbating the trend towards increased fertiliser prices and decreased use rates. Insecticide use for cotton cultivation began in the 1950s and gradually increased

[4] Because manuring is technically defined as gathering manure and transporting it to fields, even those households not classified as manuring may benefit from manure deposits on their fields due to the Sukuma practice of grazing livestock on neighbouring fields.

during the 1960s and 1970s, along with fertiliser use. By the late 1970s this trend had reversed due to the broader decline of cotton production in Tanzania and price rises associated with the same factors cited for the case of fertiliser (Meertens & Ndege 1993).

Table 4.1 Estimates of households using manure and mineral fertilisers in Sukumaland

Year estimated	**1880**	**1945**	**1955**	**1962**	**1990-91**	**2000-01**
Source	Tomecko & Tomecko (76)	Rounce(49)	McLoughlin (67)	Collinson (63)	Various[5]	Siedenburg (03)
Manuring	50%	3-5%	5-10%	3%	5-50%	45%
Chemical fertilisers	-		-	-	3-30%	1%

4.1.4 Changes to farming systems over time

One key difference between the pictures reported by Rounce (1949) and Collinson (1963, 1972) was a large increase in cotton cultivation, which represented 45 percent of cultivated land in some areas by the early 1960s. Since the total cultivated area had remained almost the same over this period, this increase in cotton cultivation was accompanied by a comparable decrease in the area of land allocated to food crop production.

Collinson (1972) suggested that this expansion in acreage devoted to cotton reflected a desire for cash earnings with which to buy more cattle. In a good year, cotton could be used to buy more cattle while in a bad year cattle could be sold to buy food. The big increase in cattle numbers during this period was thus closely linked to cotton cultivation. Other factors encouraging cotton cultivation included the high price for cotton on the international market and improved agricultural administration and marketing boards (Rotenham 1968).

A second key shift observed by Collinson involved changes in the relative importance of different cereal crops. Bullrush millet had become rare in Sukumaland by 1962, although it had been the second most important cereal crop only thirty years earlier. Sorghum cultivation also deceased sharply over this period. Both had been largely replaced by maize, which had taken over as the principal cereal crop of the Sukuma. The question is why this shift occurred, given the fact that both millet and sorghum were better adapted to the area's semi-arid environment.

[5] Sources for the 1990-91 estimates include Ahmed et al (90), Ebong et al (91), Bantje (91), and Meerten & Ndege (93).

Fuggles-Couchman (1964) attributed this shift primarily to increased wealth from cotton cultivation. This wealth created less reliance on homegrown food crops, since households could always purchase cereals if they failed to produce them. This new situation left taste as the primary determinant of crop choice, and maize was highly favoured by the Sukuma. Thus, farmers were able to grow risky but preferred maize due to the security provided by cotton cultivation and large livestock holdings. Nonetheless, sorghum remained an important secondary crop, grown largely for food security in case of poor rainfall.

Cotton prices have been stagnant now for the past decade, while during the same period the removal of agricultural subsidies has meant that the prices of purchased inputs to cotton production have risen rapidly, approximately trebling over the period in question (World Bank 2000; survey households). Such shifts raise the question of how farmers react to price fluctuations and their impact on household wealth. Namely, if households shifted their food production strategy from emphasising sorghum and millet to emphasising maize due to their newfound wealth several decades ago, will they revert to these better-adapted crops where they no longer have the wealth to ensure against the vagaries of maize production?

4.1.5 Sukuma culture and outside influences

The Sukuma are said to be a conservative people, slow to see the need for change and even slower to act (Tanner 1967:59), although this is arguably true of Bantu peoples generally. One reflection of Sukuma conservatism is the relatively high proportion of people who still adhere to the indigenous religion (Wijsen 1994:57). On the other hand, it may be more accurate to say that the Sukuma resist changes that make them the object rather than the subject of change, since they feel this diminishes their dignity and identity as independent smallholders (Hyden 1980:124). Indeed, being able to determine one's own destiny is highly valued, and some forms of modernisation are seen as alienating. Popular religion serves as both a source of identity and resistance against perceived oppression (Wijsen 1994:157).

Strong tensions exist within Sukuma society between traditions (*jadi*) and aspects of modernity (*kisasa*), with education a key vehicle of spreading modern ideas[6]. These tensions occur in diverse domains, including social relations, agriculture and health care. While people are attracted by aspects of modernism, they are also attached to their traditions. These competing ideas can breed disagreements and confusion (Wijsen 1994:59),

[6] Although the government and donors advocate education based on normative ideas about its importance, Wijsen (1994:58) reports that the Sukuma do not see much profit in education given their mainly agricultural life. This suggestion accords with the findings of the present study. Households were asked to explain how schooling had benefitted them, yet virtually the only benefit they could see was

and may cause intergenerational conflict. Traditionally, old age was identified with wisdom, but nowadays many youth see the older generation as ignorant (*Ibid.*:140). Conversely, older people sometimes complain that there are no norms or values any more. Thus, competing lifestyles and livelihood strategies are observed, each with its own ideological legitimation in competing values (*Ibid.*:156).

Within Sukuma culture, several proverbs express the idea that if a person is in trouble, he should seek help from various quarters. Examples include "my bed has four legs" and "I throw seeds in four directions". The implication is that people may freely combine elements of tradition and 'modernity'. Typically, the criterion for deciding between options in a given situation is private gain, as reflected in the often-heard question, "What profit shall I get out of it?" (*nitapata faida gani*?). (Tanner 1969b:150; 132). Despite this underlying pragmatism, Sukuma peasants may be sceptical about 'modern' solutions, since many agricultural interventions have proven disappointing (Wijsen 1994:147).

By contrast, more educated individuals such as those working for the government tend to see traditional Sukuma systems as 'bad' and 'modern' systems originating from the first world as 'good'. This view of imported systems as good stems from the belief that they promote development (*Ibid.*:134).

Interdependence is a core cultural value, with people bound together by mutual obligations and debts. People value these relationships highly, and place great importance on building and maintaining them. Isolation from the community is seen as the worst thing that can happen to someone (*Ibid.*:58). Accordingly, the two abiding fears of Sukuma people are utter failure and being highly successful. The former is believed to be caused by bewitchment, while the latter may cause one to be branded as proud and hence lead to being bewitched. Both therefore represent ways of losing social solidarity and becoming isolated (*Ibid.*:72).

4.1.6 The Sukuma indigenous religion

The Sukuma indigenous religion is closely linked with the fertility of land and cattle, which fits with the fact that its adherents are primarily agro-pastoralists living in villages for whom the fertility of land and cattle are key concerns (*Ibid.*:62,147). Many expressions of the indigenous religion are linked with the agricultural year, such as prayers or rituals associated with seed preparation, cultivation and the harvest. Other rituals focus on key phases in the life cycle, such as pregnancy, infancy and marriage (*Ibid.*:75-6).

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being able to read the occasional letter from a distant friend or relative. While it was scarcely mentioned, the capacity to better calculate market interactions must also be significant to at least some housholds.

Adherents believe that humans survive the death of the body and that the spirits of their ancestors strongly influence their lives. They also recognise the existence of a supreme being (*Ibid.*:67). While it lacks formal organisation or strict formulas, this indigenous religion is characterised by secret societies that instil social values and engage in ancestor worship and defence against witches (*Ibid.*:62).

The religion's focus is on maintaining a ritual relationship with the spirits of ancestors, to whom prayers are said and offerings are made. These spirits are believed to serve as mediums for contact with the supreme being (*Ibid.*:68). Via rituals and ceremonies, adherents maintain or restore their relationships with their ancestors. These rituals and ceremonies are seen as means of securing key objectives such as wealth (*mali*) and health (*afya*). Specifically, they are thought to neutralise the evil forces believed to prevent adherents from maintaining health and obtaining wealth in the form of wives, children, fields and cattle[7] (Tanner 1969:274; Wijsen 1994: 112, 116). Thus, religious rituals – such as visiting the graves of ancestors to obtain their blessing – are used to respond to problems or crises. For instance, consulting a rainmaker who in turn says prayers and makes offerings to ancestors is seen as an appropriate response to drought (Wijsen 1994:77).

Misfortune and disease are seen as 'not normal', and as signs of either witchcraft or disturbed relationships with ancestors (*Ibid.*:136). Notably, they may represent demands by ancestors for offerings (*Ibid.*:112). Deaths occurring for reasons other than old age are considered particularly suspect, and are typically believed to be caused by witches (*Ibid.*:115). Conversely, success in any domain is seen as evidence of good relationships with ancestors and a sign that these ancestors and the supreme being are content (Pambe 1978:121, 136).

The precise cause of a particular misfortune or disease may be determined by divination (*Ibid.*:68). The diviner is believed to use a mysterious power to diagnose the causes of peoples' troubles and identify the appropriate remedy. Witchcraft and sorcery also use such hidden powers, yet involve knowingly using them to inflict harm. They are feared by the Sukuma. Interestingly, older people say that before the colonial period witches were rare, while now they have become a major concern (*Ibid.*:113-15). The implication is that problems were comparatively few then, while now they are many.

Even among converts to Christianity or Islam, many beliefs and practices associated with the indigenous religion persist. This continued adherence to traditional beliefs is facilitated by the fact that many aspects of

the indigenous cosmology have analogues in these monotheistic religions. Thus, the spirits of ancestors are analogous to angels, mass is seen as an offering to ancestors, and wearing a cross is analogous to wearing an amulet (*Ibid.*:69).

4.2 Tree management patterns

Taken together, the present chapter and the following chapter seek to characterise and explain contemporary tree management practice by households in Shinyanga District, Tanzania. The theoretical expectation is that a household's resources place clear limits on its management options and performance possibilities, and largely determine its management practice. Thus, these resources are expected to determine both what is feasible and what is optimal for a given household, although household responses may also be affected by outside influences such as education or contact with extensionists. It follows that households will have differing farm and tree management strategies reflecting their differential resources, but that these various strategies will tend to be privately optimal.

The analysis tests this theory against a proposed alternative theoretical model. It seeks to explain observed patterns of tree management practice using different sets of explanatory variables. Specifically, it compares the explanatory power of models when only resource and outside influence variables are considered to those obtained with local knowledge variables are also integrated into the analysis.

4.2.1 Existing knowledge of trees in Shinyanga District, Tanzania

Until the early twentieth century, Shinyanga Region was extensively forested with miombo woodland[8] species, notably *Acacia, Albizia, Brachystegia, Commiphora* and *Dalbergia* (Otsyina 1992; Bradstrom 1978; Malcolm 1953). Yet in the 1920s and 1930s, large areas of land were cleared of bush and trees as part of a campaign to eradicate pests, notably the tsetse fly and quela quela bird. Deforestation and clearing of the bush have continued over the intervening decades, due both to population growth and continued pest eradication efforts (ICRAF 1988). As a result, woodland now covers only a small proportion of the region.

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[7] Thus, the Sukuma presuppose that they will prosper in life unless evil force interfere (Wijsen 1994:138).
[8] Miombo woodland is the dominant biome of Southern Africa. It is characterised by a hot, sub-humid climate and woodland interspersed by grasslands on typically well-drained soils (Miombo Network website 2002).

Shinyanga Region contains twenty-nine forest reserves[9], and 14 percent of the Region is classified as forested. The remaining land is officially classified as agricultural land (43%), grazing land (19%), game reserves (19%), and rocky hills, lakes or rivers (5%). Yet this classification of land into distinct land-use categories ignores the realities of rural life in Sub-Saharan Africa, where land-use is inherently multifunctional and conceptually distinct uses like cropping, livestock and growing trees typically cannot be strictly separated by area. Moreover, despite laws against their use, these woodland areas are often exploited by local people in search of fuel, timber and fodder, leading some to become degraded[10] (GoT[11] 2000). The household survey confirms these findings, with farmers often citing forest reserves as their preferred source of fuel and other tree products, despite the risk of incurring hefty fines. Conversely, despite not being classified as forested, cultivated areas often contain sparsely distributed trees, notably *Acacia* species (Dery et al 1999).

The region's forested areas are reported to be becoming degraded at an alarming rate due to uncontrolled harvesting and grazing[12]. Key causes include ever-rising human and livestock numbers that have placed great pressure on natural ecosystems. Associated adverse effects include soil erosion, declining soil fertility[13], shortages of fuel[14] and fodder, and water scarcity (GoT 2000). Otsyina (1995) reports that since the 1970s the effects of deforestation in the area have been pronounced, including having to travel far to find woodfuel and using crop residues and cattle dung as substitute fuels. Thus, deforestation imposes major additional labour demands on households and uses up resources that would otherwise be used as much-needed soil amendments (Ngazi et al 1997). Some authors suggest that rural people compensate for losses of off-farm resources by increasing stocks of farm-based trees (ICRAF 1996; Otsyina et al 1997). The present study examines the validity of this claim in the case of Shinyanga District.

Among the trees found in the District, exotic fruit trees represent a distinct category of tree in several senses. Most notably, they produce readily marketable fruits, making them a valuable source of cash earnings. Moreover, they do not grow naturally in the District, and therefore only occur when cultivated. Finally, while they *may* produce other products and services, fruit production is often their only clear benefit to the farm.

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[9] Forest reserves were created throughout Tanzania in 1957 to protect catchments as well as valuable ecosystems and species (World Bank 1994:28).
[10] Indeed, a majority of survey farmers cited excessive harvesting of fuelwood as the principal reason for declining incidence of off-farm trees.
[11] Henceforth, documents from the Government of Tanzania will be cited GoT.
[12] Buwalda et al (1997) suggest that deforestation rates in the miombo woodland areas are the highest in the world.
[13] Causes include virtually continuous cultivation coupled with insufficient application of soil amendments such as manure or inorganic fertiliser (ICRAF, 98; ICRAF 1988).
[14] Otsyina et al (1996) suggest that farmers in some parts of Shinyanga Region may have to walk as far as 15 kilometres in search of fuelwood.

By contrast, indigenous fruit trees and non-fruit trees occurring on farms have often grown naturally. They may have been selectively retained on the farm due to household interest in the goods and/or services they provide. Alternatively, they may simply persist due to the household's failure to remove them, which is particularly likely on large farms where management inputs per unit area are low. Where they have grown naturally, trees tend to be scattered in fields, as opposed to occurring in a specific niche within the farm. Indigenous fruit and non-fruit trees may also be cultivated[15]. In such cases, they occur in specific locations selected by the farmer, notably in the home garden, along field borders, in woodlots and scattered in fields.

Typically, non-fruit trees occurring on farms address multiple purposes, including the provision of products such as fuel, fodder, construction wood and herbal medicine, or services such as windbreak effects, shading and soil impacts. A study from nearby Kahama District (Otsyina et al 1997) shows clearly that local people only conserve naturally-occurring trees when they are expected to provide multiple products or other benefits.

Indigenous fruit trees likewise typically make diverse contributions to rural livelihoods, in addition to producing fruit. Maghembe (1994) notes the importance of indigenous fruit as a source of cash income and supplementary food, and reports that studies from Malawi, Tanzania and Zambia show that farmers greatly value and actively manage them. After years of neglecting indigenous fruit trees, researchers have recently begun examining their potential significance, and seeking to improve upon or adapt traditional technologies involving them. Notably, recent trials in Malawi have revealed that growth rates among some of these species are comparable to those of the fastest growing[16] exotic trees (Buwalda et al 1997).

A 1991 study evaluated farmers' preferences vis-à-vis trees in Shinyanga Region. It involved giving a combination of seedlings to each of twenty farmers in four different villages, then returning several months later to see what farmers had done with them and ask them about their management decisions. Two clear patterns were apparent. Most farmers planted non-fruit trees in lines along farm boundaries, either to protect or demarcate fields, while fruit trees were typically planted in the home garden or around the home compound (HASHI/ICRAF 1991). While indicative, this experiment is artificial, since it only shows what farmers do when given ready-to-plant seedlings, but not what they do under normal circumstances.

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[15] In the present study , the concept tree cultivation refers either to the case of simply planting trees or to both planting trees and providing them with ongoing care, such as watering or protection from humans and livestock. Loosely speaking, the terms cultivated and planted are thus interchangeable.

[16] Rapid growth is relevant both to fruit yields and to any other goods and services obtained from the species in question.

By contrast, the present study examines how a statistically representative sample of farm households opts to manage farm trees under 'normal' circumstances. While some survey farmers have had contact with development projects, including agroforestry projects, many have not. Moreover, the proportion of farmers who have had such contact gives a representative picture of the actual coverage of such projects in the area, and their ultimate effect on management practice.

4.2.2 Study findings of tree cover and farm trees

The trees cited by survey households as among those most significant to the household reveal local views of the contribution of trees to securing rural livelihoods. For the purposes of the present discussion, however, they provide a useful indication of some of the principal trees occurring in the District. Those species cited by at least 5 percent of survey households are listed in the Table 4.2. Given the special significance of exotic fruit trees, such trees are listed even where they were mentioned by less than 5 percent of survey households. The table lists the total number of households citing the tree as among the most significant trees to the household. It also gives the percentage of households citing the tree as the most significant tree type and the percentage citing it as among the three most significant tree types.

Five exotic fruit trees and five indigenous fruit trees met these criteria. Mango and sweet orange were the most commonly cited of the former, while tamarind and desert date were the most commonly cited of the latter. Tamarind was also found to be the most common indigenous fruit tree in a recent study of Maswa District, while it produces the indigenous fruit most frequently sold in local markets (Buwalda et al 1997). Meanwhile, both the presence of exotic species in remote villages and the size of some individual trees attest to the long presence of exotic fruit trees in the District.

Both the single tree type cited as most significant to the household and the three most significant tree types represent key indicators of a household's view of trees and their role in the farm system. The survey findings of significance are as follows: exotic fruit trees (18 percent and 20 percent), indigenous fruit trees (10 percent and 30 percent) and non-fruit trees (72 percent and 50 percent)[17].

[17] The aggregation rule for cases where more than one tree was cited is to prioritise exotic fruit trees most highly and indigenous fruit trees second most highly, since these cases were less common and hence indicative of differing views and management practices. For instance, the 20 percent of households that cited at least one exotic fruit tree as significant may also have cited other trees.

Table 4.2 Tree species cited by survey households

Botanical name (**exotic fruit tree) (*indigenous fruit tree)	Common name (English)	Common name (Swahili)	Fruit	Non-fruit tree food	Fuel	Fodder	Timber	Medicine	Soil fertility	Live fencing	Number of households citing tree	% as most significant tree	% among significant trees
Anacardium occidentale**	Cashew nut	Mkorosho	x		x	x	x	x			6	2	2
Cassia siamea**	Sweet orange	Mchongoma	x		x	x	x	x	x		51	5	14
Carica papaya**	Papaya	Mpapai	x					x			5	0	2
Mangifera indica**	Mango	Maembe	x		x		x	x	x		61	10	17
Psidium guajava**	Guava	Mpera	x		x		x	x			6	1	2
Afzelia quanzensis*	Lucky bean tree	Mkoma	x			x	x	x			17	1	5
Balanites aegyptica*	Desert date	Miyuguyu	x			x	x	x			39	2	11
Dichrostachys cinerea*	Sicklebush	Mtunduru	x		x	x	x	x	x		29	2	8
Diospyros mespiliformis*	African ebony	Msubata	x		x		x	x			15	1	5
Tamarindus indica*	Tamarind	Mkwaju	x		x	x	x	x			55	4	16
Acacia drepanolobium	-	Malula			x		x	x			49	2	14
Acacia nilotica	-	Mihale		x	x	x	x	x	x		122	21	35
Acacia polyacantha	White thorn	Nguu			x			x			47	2	14
Acacia tortilis	Umbrella thorn	Mgunga			x	x	x	x	x		101	13	29
Albizia amara	Bitter albizia	Mtangala			x	x	x	x	x	x	17	2	5
Albizia harveyi	Rain tree	Mpogolo		x	x	x	x	x	x		35	5	10
Azadiracta indica	Neem	Mwarubaini		x	x	x	x	x	x		36	4	10
Eucalyptus spp.	Eucalyptus	Mkaritusi			x		x	x			21	3	6
Euphorbia spp.	Euphorbia	Minyaa								x	35	1	10
Leucaena leucocephala	Lusina	Lusina			x	x	x		x		35	4	11
-	-	Mahushi	?	?	?	?	?	?	?	?	17	2	5

Source: Shinyanga District household survey, 2000

Some survey farmers cited euphorbia as one of the 'trees' most significant to the household. This non-woody plant is commonly used as a source of live fencing in the District to demarcate and protect household compounds. Because euphorbia's only major use is as live fencing and because it is not actually a tree, such cases were treated as missing data.

4.2.3 Historical patterns of tree management in Shinyanga District

Historically, farmers in the area have not emphasised farm trees as a land management tool. Indeed, the Sukuma are renowned in Tanzania and beyond for their dislike of trees and for viewing trees as a threat to their cattle, following the historical association of trees with tsetse fly in Shinyanga Region[18]. The Sukuma also have a reputation for clearing large areas of forest and creating a barren landscape (Mshuda 1991). Given contemporary shortages of diverse natural resource products such as fuelwood, fodder and fertile soil, the significance of local tree stocks has arguably undergone a fundamental shift, as have the incentives to retain or cultivate them. This juxtaposition of traditional antipathy and current need raises interesting questions about local peoples' adaptation to change.

In Sukumaland[19], the major exception to this rule of de-emphasising trees is a traditional system of fallow-area conservation called *ngitiri* (Otsyina et al 1992; Msangi 1995; Maro 1995; Kilahama 1994; Issae 1997). The principal function of *ngitiri* is to conserve an area of private or commons land[20] for use as dry season pasture, once fodder on farms and the surrounding bush becomes scarce. Benefits include maintaining livestock strength through to the onset of the cultivation season and prolonging milk production. *Ngitiri* also act as an accessible source of fuelwood, construction wood and thatching grass.

The principal *ngitiri* management tool is restricting grazing access[21] to foster natural regeneration. Because the primary aim of *ngitiri* is to enhance grass production, any trees suspected of competing with grasses are systematically removed. Nonetheless, trees associated with fodder production were retained in the *ngitiri* by 24

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[18] Given the powerful historical association of trees with the tsetse fly in Shinyanga Region, HASHI/ICRAF conducted a survey to assess farmers' current associations of trees with the tsetse fly. It was feared that these associations could impede farmers' recognition of the positive aspects of trees and their willingness to adopt agroforestry technologies to meet contemporary livelihood challenges. The key question asked was whether farmers believe that tree planting is likely to re-introduce the tsetse fly in the area, with detrimental consequences to both livestock and human health. In all, 16 percent thought that tsetse flies would not be likely to return even if tree densities were increased, while 80 percent feared they might. While farmers suggested they were willing to plant trees to provide essential goods and services despite these fears, they cautioned against dense tree plots with minimal management (Otsyina 1993). These fears are clearly a major factor in farmers' decisions of whether or not to adopt agroforestry technologies, or to keep farm trees generally.

[19] Tanzania's Shinyanga and Mwanza regions together make up the area traditionally called Sukumaland, after the dominant Sukuma ethnicity.

[20] *Ngitiri* initially focused on set-aside areas of private farms and only became associated with communal areas during the Villagisation period. Communal *ngitiri* remain common only in Shinyanga District, while farm *ngitiri* persist on larger farms throughout Sukumaland (Otsyina et al 1994).

percent of households in a recent study, with these households citing the importance of tree fodder once grass becomes depleted. Although they may be retained, trees are not generally cultivated in *ngitiri* (Otsyina et al 1994).

Interest in reviving the *ngitiri* tradition is widespread, but modern-day *ngitiri* are plagued by low productivity and poor forage quality in a classic 'tragedy of the commons' situation. The principle underlying cause of these problems is believed to be overutilisation by villagers[22]. One possible solution is improving the quantity and quality of *ngitiri* fodder by introducing nitrogen-fixing tree species (e.g., Acacia, Leucaena) and more nutritious and hardy grasses (Issae 1997). When questioned about this possibility, 72 percent of respondents expressed a willingness to plant such trees and grasses (Otsyina et al 1994).

The Forestry Department and others advocating tree cultivation in Shinyanga Region have shown practical interest in *ngitiris* (e.g., Otsyina 1994; Shao 1992). Because *ngitiri*s are well-regarded among the Sukuma, in contrast to their often negative associations with trees, the associated ecological concepts and management structures are seen as a useful basis on which to build contemporary tree management initiatives (Otsyina et al 1994). It has also been reported that the Sukuma have a positive view of medicinal trees, given the scarcity of health care facilities in the area and high treatment costs[23], making emphasis on medicinal trees a second useful approach for tree advocacy in the area (Dery et al 1998).

4.2.4 Current agroforestry work in the study zone: A story of untapped promise

The HASHI/ICRAF agroforestry project is a government-donor collaboration initiated in 1989 to address the challenges facing households in Shinyanga Region[24]. HASHI is the government's afforestation and soil conservation initiative for Shinyanga Region, while ICRAF[25] is an international research institute that examines means of using agroforestry technologies to address land use challenges. This collaborative project aims to develop appropriate technologies and secure their adoption. In contrast to views of different land uses as

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[21] Ownership rights have generally been well respected thanks to heavy penalties to offenders, but the effectiveness of these boundaries has declined somewhat in recent years given the problem of trespassing by herders from outside the community (Otsyina et al 1994).
[22] Specifically, Issae (1997) reports that many Sukuma pastoralists pursue a rudimentary grazing system simply involving moving animals from one area to the next once forage is removed, and cites a need for heightened awareness regarding pasture capacity and dynamics. By contrast, Otsyina et al (1994) describes the same system in positive terms, writing that it ensures optimum and uniform utilisation of fodder via controlled grazing.
[23] For instance, an individual needs TSh 250 to see a doctor and at least TSh 300 to buy a dose of choloroquin in case of malaria. Because such costs are excessive for many District residents, traditional medicine remains prominent in the zone as an accessible alternative (Oxfam/IDS 1998:84).
[24] Its aim is to alleviate the problems of natural resource degradation facing people in the Sukuma agropastoral system, notably via increased wood production, increased fodder supply and improving soil fertility for crop production. Its ultimate goal is to improve the economic and nutritional well-being of resource-poor farmers (ICRAF 1998).
[25] This institute has since changed its name to World Agroforestry Centre.

spatially distinct, this project addresses current livelihood challenges by emphasising the importance of harnessing symbioses between trees and other farm components.

Diverse farm trials conducted by HASHI/ICRAF have demonstrated the potential of agroforestry practices to address key challenges facing households in the region. One example is rotational woodlots using Acacia and Leucaena species, which are designed to improve soil fertility and provide wood while allowing maize cropping to continue. Farm trials gave the following results: (i) trees scattered in fields reduced maize yields considerably during the first three years, but yields began to rise again thereafter, (ii) the levels of grass fodder produced with and without trees was approximately the same, (iii) tree biomass provided 15.4 tons of livestock fodder per hectare after three years, (iv) wood yields totalled 88.9 tons per hectare after three years, (v) available soil nitrogen approximately doubled (Otsyina 1996; Otsyina et al 1995; HASHI/ICRAF 1999).

Despite this promise, Tanzanian government statistics call into question the project's success in meeting its goals of introducing agroforestry technologies and raising environmental awareness across Shinyanga Region. Notably, the numbers of seedlings raised over the period 1989-1999 show an erratic trend and a gradual decline over time. Yearly totals, in millions, were 2.4, 3.3, 2.8, 2.2, 4.4, 1.4, 2.5, 2.7, 1.3, 1.5. While seedling cultivation increased in Kahama District, it declined in the other districts, including Shinyanga District. These tenuous project outputs have been attributed to lack of awareness among rural communities of the importance of afforestation (GoT 2000).

The project's own findings likewise call the success of its work into question. The project conducted a farmer evaluation in 1999 to determine the social and economic factors affecting technology adoption over a range of conditions (ICRAF 2000). The 134 participating farmers were advised on a range of technologies based on eight different non-fruit tree species, then asked to choose among options and visited regularly. During these visits, farmers were asked to assess their experience with the technologies. All eight species were found to be mainly used for fuelwood, although many households also used trees for timber or building materials. Medicinal uses were cited by two-thirds of farmers, but only in relation to one species. Fodder supply was only mentioned by 18 percent of farmers in relation to one species. Finally, soil improvement was only mentioned by 8 percent of farmers in relation to two species.

The implication of these findings is that farmers view trees primarily as sources of fuelwood and construction wood[26], and do not generally see tree management as a solution to pressing problems such as fodder scarcity and infertile soil. Such findings do not inspire optimism for the potential of agroforestry practices to address the resource degradation and production challenges facing the area, particularly given the fact that these farmers had been advised about agroforestry practices prior to the evaluation. Nonetheless, if the premise of the present study is correct that basic knowledge problems and communication difficulties have not been recognised and addressed, then this could partly explain these findings.

One basic problem with HASHI/ICRAF's 1999 evaluation is that farmers were selected based on their willingness to participate, which is bound to result in selection bias. Notably, such farmers may be expected to be more educated, better-off and more sympathetic towards trees than the average farmer. Perhaps unsurprisingly then, the evaluation found that agroforestry farm trials were "appreciated by both participating farmers and their neighbours". Another danger with such evaluations, as discussed in chapter three, is that they may result in positive assessments that simply reflect farmers' politeness and hospitality while masking fundamental questions or doubts. A second recent Shinyanga-based study of farmer perceptions of agroforestry practices likewise selected households based on their willingness to participate in addition to selecting villages based on their accessibility (Ngazi et al 1997).

The underlying aim of this assessment was to help tailor technologies to farmers' needs in order to increase technology adoption. This emphasis reflects the HASHI project's assessment (and theoretical canon) that low farmer adoption rates[27] and limited interest in tree cultivation generally can be attributed to inadequate technologies that are either ineffective or fail to fit into farmers' livelihood strategies[28]. The policy implication is that more effective and/or appropriate technologies must be developed if farmer uptake is to be secured. This perspective contrasts with the premise of the present study that the key constraint on technology adoption might not be the technologies themselves but rather issues regarding their recognition.

[26] As they presumably did historically given shifting agriculture and resource abundance.
[27] Sukumaland is 'a good example of an area where tree planting efforts have not been successful' (Otsyina 1995)

4.2.5 *Tree management data used in the analysis*

The raw tree management data used in the analysis are presented in Table 4.3.

Table 4.3 Tree management data used in the analysis

Variable name	Brief description	Categories	Relative frequencies	Total cases
NUMBERS	Total number of trees on the farm	5 or less 6 – 20 21 or more	30 % 34 36	340
CULTIVATE	Whether household planted trees	Planted Did not plant	67 33	335
INTENSITY	Cultivation intensity	Planted & watered Planted only Retained trees No trees on farm	18 49 23 10	335
CULTTYPE	Broad type of tree cultivated	Exotic fruit Indigenous fruit Non-fruit None cultivated	21 16 30 33	347
CULTLOC	Location of tree cultivation	Fields Home garden only None cultivated	40 27 33	349
SELLPROD	Whether tree products sold	Sold products None sold	15 85	338

Source: Shinyanga District household survey, 2000

Data on whether or not households protected farm trees from people and/or livestock and if so how were also gathered, but were not ultimately used in the analysis. The idea was that such protection would show a degree of concern for the survival of farm trees that could be used as an additional step in a ranking of tree management intensity. Specifically, households that protected trees but did not cultivate them could be ranked between those that simply retained trees and those that planted them. Unfortunately, these data were found to be of poor quality, and hence could not be used in the analysis. The problem with the data centred around the term 'protect', which was interpreted very differently by different survey households.

4.2.6 *Identifying underlying patterns in the empirical data*

To analyse tree management, a set of distinct tree management categorisations must first be defined. A fundamental question when defining such categorisations is, 'Which patterns of tree incidence and management tend to go together in practice?' The two techniques used to identify patterns implicit in the tree management data were categorical principal components analysis (CATPCA)[29] and cross-tabulations.

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[28] E.g., the HASHI/ICRAF 1999 Annual Report states, "Nitrogen-fixing trees have the potential to restore the fertility of farmland as well as to provide fodder and wood. This potential has not been exploited due to the lack of appropriate technologies to integrate trees into the existing land-use system".

For each combination of raw variables examined, up to three synthetic factors were defined using CATPCA. The proportion of variability explained by these synthetic factors was high, ranging from 75 to 85 percent, suggesting that the data were well represented by the factors. Across the twenty different combinations of raw variables examined, only four distinct synthetic factors were identified. These indicate the clearest broad patterns of tree management occurring among survey households. Listed in order of clarity, the four broad patterns that emerged were (i) cultivating exotic fruit trees in the home garden; (ii) keeping no farm trees and relying instead on off-farm stocks of naturally-occurring trees to obtain needed tree products; (iii) retaining farm trees in fields and sometimes selling their products; (iv) cultivating non-fruit trees to meet diverse needs[30].

Running cross-tabulations of the various tree management variables (TMVs) provides a second indication of the underlying patterns vis-à-vis tree management strategies in the District. For each TMV, a table was created listing the other TMVs found to be statistically correlated with it (see Table 4.4). Because these are ordinal data, correlations were assessed using gamma statistics, which give both the strength and directionality of correlations. These statistics have a proportional reduction of error interpretation, showing how much better values of one variable can be predicted given the values of a second variable, but without assuming causality in either direction.

These data reveal the following patterns vis-à-vis tree management:

- A strong positive correlation among several variables[31] implies that tree cultivation tends to be associated with the home garden and exotic fruit trees. It may also be associated with fields, particularly when trees are planted but not watered.

- Other findings[32] suggest that trees in the home garden and trees in the fields may act as substitutes, i.e., that having trees in the home garden may be seen as particularly desirable where naturally-occurring trees in fields are scarce.

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[29] CATPCA is a useful means of simplifying data contained in ordinal categorical variables. It helps interpret complex relationships among numerous variables by reducing an original set of variables into a specified number of synthetic factors that optimally represent the variability in the data. It thus identifies and characterises the main patterns implicit in the data.

[30] Pattern one combines prioritising exotic fruit trees, tree cultivation, trees occurring in the home garden but not the bush, and selling tree products. Pattern two combines prioritising non-fruit trees, not cultivating trees, trees occurring in the bush but not the home garden, and not selling tree products. Pattern three combines trees occurring in the fields but not the home garden or the bush and selling tree products, with tree type and cultivation status indeterminate. Pattern four combines prioritising non-fruit trees and tree cultivation, with tree location and selling status indeterminate.

[31] These include *trees planted, trees planted & watered, trees cultivated in home garden only, trees occur in home garden, exotic fruit trees on farm,* and *trees occur in fields.*

[32] *Trees occur in fields* was found to be positively correlated with *trees cultivated in fields*, but inversely correlated with both *trees occur in the home garden* and *trees cultivated in home garden only.*

Table 4.4 Correlations among dichotomous tree management variables

Focus TMV	Correlating TMVs	Correlation strength	Directionality	Significance
Trees planted	Trees cultivated in HG only	99%	Positive	0%
	Trees cultivated in fields	97%	Positive	0%
	Trees occur in HG	71%	Positive	0%
	Exotic fruit trees on farm	91%	Positive	0%

Focus TMV	Correlating TMVs	Correlation strength	Directionality	Significance
Trees planted & watered	Trees cultivated in HG only	74%	Positive	0%
	Trees occur in HG	57%	Positive	0%
	Exotic fruit trees on farm	55%	Positive	0%

Focus TMV	Correlating TMVs	Correlation strength	Directionality	Significance
Trees planted in HG only	Trees planted	99%	Positive	0%
	Trees planted & watered	74%	Positive	0%
	Trees occur in HG	93%	Positive	0%
	Trees occur in fields	79%	Inverse	0%

Focus TMV	Correlating TMVs	Correlation strength	Directionality	Significance
Trees cultivated in fields	Trees planted	97%	Positive	0%
	Trees occur in fields	97%	Positive	0%
	Exotic fruit trees on farm	53%	Positive	0%

Focus TMV	Correlating TMVs	Correlation strength	Directionality	Significance
Trees occur in HG	Trees planted	71%	Positive	0%
	Trees planted & watered	57%	Positive	0%
	Trees cultivated in HG only	93%	Positive	0%
	Trees occur in fields	41%	Inverse	0%
	Exotic fruit trees on farm	64%	Positive	0%

Focus TMV	Correlating TMVs	Correlation strength	Directionality	Significance
Trees occur in fields	Trees cultivated in HG only	79%	Inverse	9%
	Trees cultivated in fields	97%	Positive	0%
	Trees occur in HG	41%	Inverse	0%

Focus TMV	Correlating TMVs	Correlation strength	Directionality	Significance
Exotic fruit trees on farm	Trees planted	91%	Positive	0%
	Trees planted & watered	55%	Positive	0%
	Trees cultivated in fields	53%	Positive	0%
	Trees occur in HG	64%	Positive	0%

Source: Shinyanga District household survey, 2000

Key: TMV signifies 'tree management variable'

HG signifies 'home garden'

- Still other findings[33] suggest that trees occurring in fields have often been planted, but were not typically watered. They also suggest that households which planted trees in fields tended to be those that grew exotic fruit trees on the farm.

Given the strong association of fruit trees with both tree cultivation and the home garden, these relationships were examined more closely. The linkage between fruit trees (whether exotic or indigenous) and tree planting is presumably due to the perceived profitability of fruit trees. Among the 230 households that planted trees, 62 percent planted only fruit trees, while among the 61 households that both planted and watered trees, 66 percent planted only fruit trees. This contrasts with the fact that of the 349 households surveyed, only 50 percent cited fruit trees only as among the tree types most significant to the household.

The linkage between exotic fruit trees and trees occurring in the home garden may be attributed either to the relative ease of protecting and caring for trees located in the home garden or to an effort to minimise competition effects with crops. Among the 44 households that cited an exotic fruit tree as the species most significant to the household, 80 percent reported that this tree occurs in the home garden. By contrast, only 48 percent of the 302 households that cited either an indigenous fruit tree or a non-fruit tree reported that these trees occurred in the home garden.

In sum, the empirical data reveal that farm households in contemporary Shinyanga District pursue diverse tree management strategies. Some remove all trees from their farm, some selectively retain certain trees on the farm, and some plant chosen trees on particular parts of the farm. Key distinctions among those who plant trees include (i) planting exotic fruit trees, indigenous fruit trees or non-fruit trees, (ii) planting in the home garden or in the fields, and (iii) simply allowing planted trees to fend for themselves or providing seedlings with ongoing care such as watering, manuring or fencing.

4.2.7 Defining distinct tree management categorisations

Drawing on these empirical patterns as well as a priori considerations and past empirical work, eight distinct tree management categorisations were defined. These categorisations comprise the eight tree management models analysed in chapter five. Five were binary distinctions (2, 3, 4, 5, 6) while the remaining four were ranked multinomial categorisations.

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[33] *Trees cultivated in fields* was found to be positively correlated with *trees planted*, *trees occur in fields* and *exotic fruit trees on farm*.

Different tree management strategies represent different ways of allocating household resources in pursuit of livelihood objectives. Given increasing pressure on natural resources, one fundamental distinction is whether households actively facilitate the regeneration of farm-based natural resources, instead of simply relying on natural regeneration. A second is the degree and nature of any such active facilitation. Given the complex role of trees in smallholder farm systems, tree management represents a case where knowledge is particularly likely to be problematic.

Model 1: Total number of farm trees

This model compares households based on the number of trees on their farms. Three categories were distinguished, namely five trees or fewer, six to twenty trees, and twenty or more trees, representing 31, 33 and 36 percent of survey households, respectively. Among the tree management models examined, this model is alone in grouping together naturally-occurring trees and cultivated trees. It also groups together trees occurring in either the home garden or the fields. While highly aggregated and hence imprecise, this model represents a useful first step to analysing observed tree management patterns.

Model 2: Sales of tree products

This model distinguishes the fifty households that sell tree products to markets from the remaining survey households. Specifically, 10 percent of survey households had sold fruit while 4 percent had sold construction wood and 2 percent had sold fuelwood. Because opportunities to sell tree products to markets are potentially accessible to households generally, this variable shows a certain type of agency vis-à-vis trees. Specifically, it shows those households that use trees as a means of meeting their needs via participation in markets.

Model 3: Neither retained nor cultivated farm trees

This tree management model examines the thirty-nine survey households that that neither planted trees nor had any trees in their fields. It distinguishes this group of households from all the remaining survey households, including both those who simply retained farm trees and those who engaged in diverse forms of tree cultivation. The model thus distinguishes this lowest category tree prioritisation from the various higher levels of prioritisation.

The fact that a farm has no trees suggests that the household removes trees from the farm, since trees tend to grow naturally if left to themselves. Alternatively, it is possible that livestock have prevented naturally-

occurring seedlings from surviving due to heavy grazing. Yet even in such cases, the fact that no large trees occur on the farm suggests that the household removed all grown trees from the farm at some point in the past, and also that it does not protect any naturally-occurring seedlings from livestock. All indications point to a grouping of households with little interest in trees that views trees as detrimental to cropping, and conforms to the stereotype of the Sukuma who doesn't like trees.

Model 4: Retained farm trees but did not cultivate them

This model examines the seventy-nine survey households that retained naturally-occurring trees but did not cultivate trees, i.e., those that had trees on their farms only because these grow naturally. It distinguishes these households from all other sample households except those analysed in regression three, i.e., those that neither cultivated trees nor retained farm trees. The model thus distinguishes those that retained naturally-occurring farm trees from those that cultivated trees, highlighting the broad differences between these two levels of tree management intensity. Although such households retained and perhaps protected farm trees as a means of meeting their needs for tree products and services, they essentially rely on natural regeneration to provide these products and services.

Model 5: Cultivated exotic fruit trees

This model examines the eighty survey households that cultivated exotic fruit trees. These households tend to associate trees with fruit production for sale to markets, since this high-value product may outweigh other aspects of trees. Thus, they value trees, yet their interest in trees may be limited to this specific function and its association with cash earnings. As such, they may de-emphasise other tree products or services, despite their interest in certain trees.

Model 6: Planted & watered indigenous fruit or non-fruit trees

This model examines the thirty-five survey households that planted and watered either indigenous fruit trees or non-fruit trees on their farms. In addition to cultivating one of these two tree types, they may also have cultivated exotic fruit trees. These households may be characterised as those with a demonstrated interest in agroforestry, since they provide ongoing care to trees whose main function is not fruit production for sale to markets. This shows clear interest in using trees as a management tool to meet household needs directly via the goods and services they provide.

The regression model distinguishes these households from all other sample households. Because this grouping represents the highest level of management intensity and the broadest view of farm trees as a tool for meeting household needs, comparing these households with all others highlights the differences between those practising intensive tree management and others.

Model 7: Tree management intensity

This model distinguishes four categories representing a ranking of tree management intensity. In order of intensity, categories include households that (i) neither retained nor cultivated farm trees, (ii) retained farm trees but did not cultivate trees, (iii) planted trees but did not water them, and (iv) both planted trees and provided them with ongoing care in the form of watering. These categories represent 10, 23, 49 and 18 percent of survey households, respectively[34]. These tree management strategies represent four broad alternative responses to the livelihood challenges facing households given intensive population pressure and resource degradation.

The relative passivity of the first two categories is reflected in the fact that such households often commented during interviews that 'trees grow by themselves'. Nonetheless, selective retention may be seen as an early form of domestication, since it involves a shift towards private provision of tree goods and services (Buwalda et al, 97).

Many households planted trees without following up this initial effort with ongoing care. Yet ongoing care such as watering[35] greatly increases the chances seedlings will survive, given the irregular and low levels of rainfall in the District[36]. This dichotomy thus represents an important indicator of the relative value of farm trees to the household. Watering seedlings suggests a certain commitment to ensuring seedling survival, while failing to do so suggests that such efforts are not seen as worthwhile[37].

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[34] Notably, three of these categories are analysed as stand-alone cases in models three, four and five.
[35] Watering trees most often involves tree seedlings, since these are particularly vulnerable during the first few months after planting until they become established. Adult trees may also be watered if a household has ready access to well-water and grows high-value trees, but this was rare in the study zone.
[36] A large proportion of survey households who simply planted trees reported that these subsequently died, which they often attributed to insufficient rain.
[37] An alternative explanation for households failing to water seedlings is that they simply do not see watering as their responsibility, and expect trees to make do with rainfall, just like off-farm trees and field crops.

Model 8: *Type of tree cultivated*

This model essentially distinguishes households based on whether they cultivated exotic fruit trees, indigenous fruit trees or non-fruit trees. The clearest distinction among tree types is between exotic fruit trees, on the one hand, and indigenous fruit trees and non-fruit trees, on the other. The former do not grow naturally, are grown primarily for production of marketable fruit, and can provide a sizeable supplementary income. By contrast, the latter may occur naturally and tend to provide diverse goods and services for household use and possibly market sale. Meanwhile, the distinction between indigenous fruit trees and non-fruit trees hinges on the fact that the former produce valuable fruit that may either be consumed or marketed. In addition to these three types of trees cultivated, the model also includes a final category representing household that did not cultivate trees. The percentage of households falling into each category is as follows: did not cultivate trees (33%), cultivated exotic fruit trees only (21%), cultivated indigenous fruit trees (16%), cultivated non-fruit trees (30%).

Because households that cultivated trees often cultivated more than one tree type, this categorisation involved an implicit ranking of tree types. Cultivating non-fruit trees was ranked higher than cultivating fruit trees, while cultivating indigenous fruit trees was ranked higher than cultivating exotic fruit trees. Thus, households categorised as cultivating indigenous fruit trees may also have cultivated exotic fruit trees, while those categorised as cultivating non-fruit trees may also have cultivated either type of fruit tree. This implicit ranking reflects decreasing significance of fruit production for market sale, and hence an increasingly broad view of tree management as a means of meeting household needs[38].

Model 9: *Location of tree cultivation*

This model essentially distinguishes households that have cultivated trees in the home garden only from those that have cultivated trees in their fields. The importance of this distinction is that trees grown in the home garden do not interact directly with field crops, while those grown in fields do. Moreover, trees grown in the home garden are more easily cared for and protected than those grown in fields. In addition to these two broad categories of where trees are cultivated, the model includes a final category grouping together those household that did not cultivate trees. The percentage of households falling into each category is as follows: did not cultivate trees (33%), cultivate in home garden only (27%), cultivate in fields (40%).

[38] Despite this rationale for ranking, in practice this regression model was better explained by nominal regression than ordinal regression.

4.3 Household resources

4.3.1 Land resources

Both quantity and quality measures of 'land' resources are included in the analysis. Quantity is measured by total farm size, while quality measures include soil type, off-farm tree stocks and soil fertility. Tenure status and market access may also be regarded as aspects of land quality. Data were gathered on all these factors.

Figure 4.2 shows a histogram of the farm size data. The figure shows that households are concentrated on smaller farms, with 18 percent on farms of 4 acres or less, 38 percent on farms of 5 to 10 acres, 29 percent on farms of 11 to 20 acres, and 12 percent on farms of 21 to 50 acres[39]. In addition, the sample is characterised by a few very large farms, including three households with over 100 acres and six households with between 50 and 100 acres, which together comprise a mere 3 percent of the sample. The mean farm size is 13.5 acres, the median is 9 acres, and the mode is 7 acres. These findings are comparable to those found by other surveys of the District[40].

Within Tanzania generally, the World Bank (1994:37) reports that 93 percent of smallholder households cultivate less than 5 acres each, highlighting the fact that farms in Shinyanga District tend to be larger than the national average[41]. There is some concentration of landholdings nationally, as 10 percent of farmers control 49 percent of the cultivated area. Although this distribution of landholdings is highly skewed, Collier et al (1990:50) report that it is less unequal than in other African countries. These authors further suggest that these differences can be largely explained by differences in household size, the implication being that land is not scarce, and hence is a poor means of differentiating among households. By contrast, another recent study (FSG 1992) found that access to land is a problem in many parts of Tanzania, including low-potential areas, while farmers in Shinyanga Region are reported to perceive access to land as 'quite difficult' to 'very difficult'. Similarly, land was identified by District residents as one of the two major determinants of wealth in a recent participatory study (UNDP 1998). Local people cited lack of land or insufficient land as a particularly significant indicator of poverty.

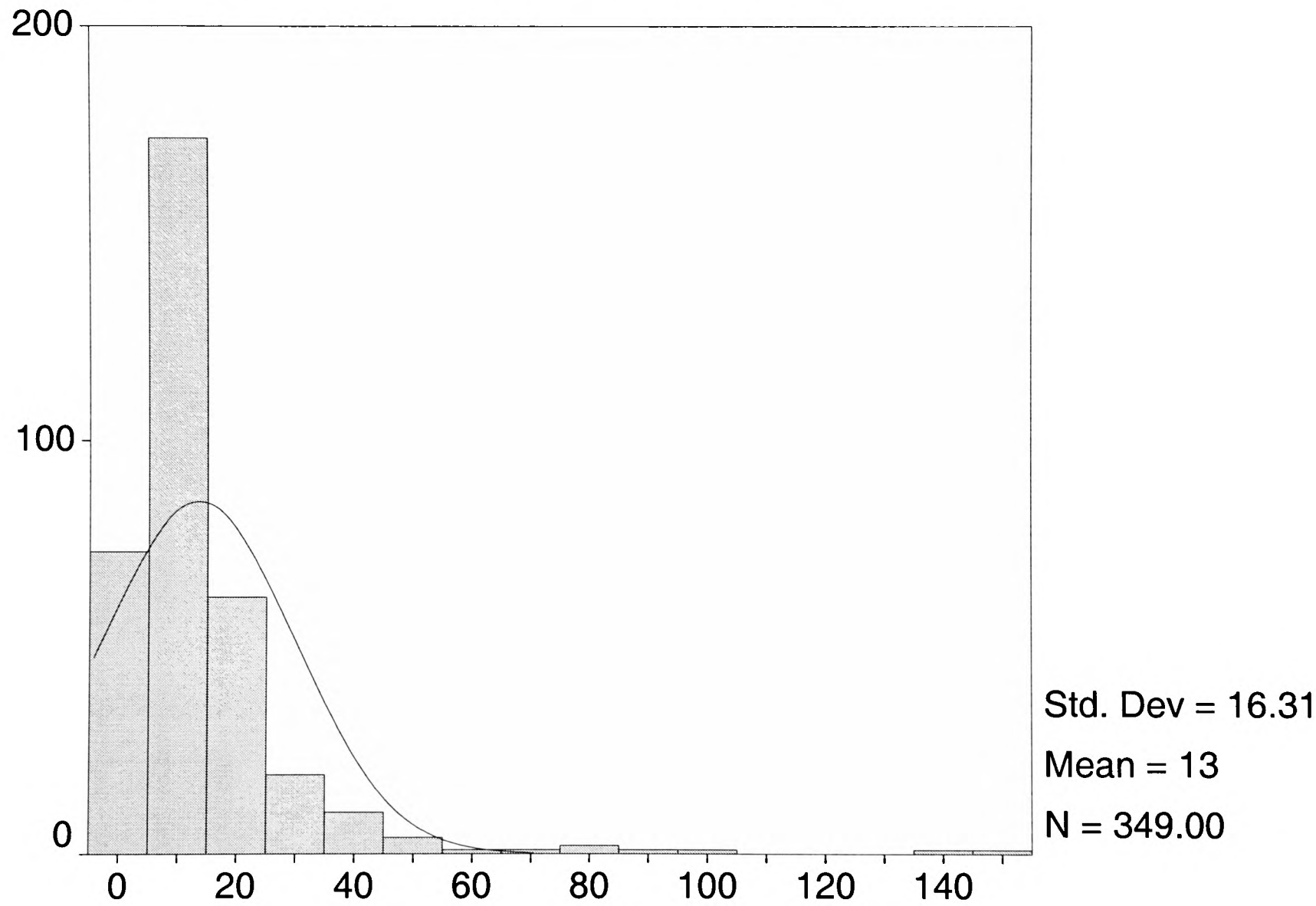
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[39] Farm size categories are rounded to the nearest integer. For instance, the category '5-10 acres' represents the interval 4.50 to 10.49 in the raw data.

[40] For instance, the Oxfam/IDS (1998:91) study found that 13% of households had 2.5 acres or less, 20% had between 3 and 5.5 acres, 30% had from 6 to 11 acres, 15% had from 11 to 20 acres, and 22% had over 21 acres.

[41] This may partly reflect the fact that smaller farms are adequate to sustain households in high-potential agricultural areas, while larger farms are needed in a semi-arid, degraded area like Shinyanga if households are to meet their subsistence needs.

Figure 4.2 Total farm size



Soils in the District are mostly clays, but with variations that generally follow the contours of the land[42], namely low hills with shallow slopes separated by extensive flat plains on a plateau some 1000 meters above sea level. The sloping lands tend to have well-drained greyish-brown sandy loams, while the low-lying lands tend to be characterised by poorly-drained black clays, or *mbuga*. The sandy upland soils are easy to work with an ox-plough even before the rains begin in November, as long as cattle are not too weak from dry-season fodder shortages. While the *mbuga* are more fertile, they are difficult to work, particularly before the onset of the rains. Once the rains come, they may soon become waterlogged due to poor drainage, leaving only a narrow time window during which cultivation is possible. Generally speaking, soils on the undulating lands are relatively low in fertility, organic matter and water-holding capacity, while those in the lowlands are more fertile, yet prone to waterlogging (ICRAF 1988; Oxfam/IDS 1998). While this breakdown is by no means strict, food crops are concentrated on the sandy loams, while cotton and rice are concentrated on black clay soils.

As elsewhere in Sub-Saharan Africa, land tenure in Sukumaland did not traditionally involve private ownership, but rather the granting of usufruct rights to particular plots of land by the village authorities. Once conferred, these rights were both indisputable and exclusive[43], and thus conferred a certain security of tenure. Following harvest, however, all cultivated lands[44] were open to free grazing by livestock. Fields of perennial crops such as cassava were an exception to this rule, since grazing might destroy these crops. Whether trees planted in fields should likewise be considered perennial crops meriting protection from grazing is unclear, given the lack of traditional rules governing this question (ICRAF 1988).

Across Tanzania generally, the land of smallholder farmers is almost entirely under customary tenure. Typically, use rights are administered within the community, and transfers to outsiders are rare. Under Villagisation, allocation was for a time controlled by the state, but by 1991 it was once again firmly in the hands of the local authorities (World Bank 1994:39). While customary tenure arrangements may be secure, the Villagisation experience had a powerful adverse impact on rural peoples' confidence in their tenure rights. Notably, it created fears of Government interference with tenure arrangements, arguably discouraging needed and advantageous investments in land quality (World Bank 1994:xvii).

[42] No detailed documentation of the area's soils has yet been conducted, however (ICRAF 1988).
[43] This remains true as long as such lands are subject to continuous use as part of a cropping cycle.
[44] All lands that were not cultivated were subject to public rights of pasture throughout the year.

Land is most commonly acquired via inheritance. While land was typically inherited by the eldest son, user rights were nonetheless retained by any other sons and daughters. Yet these traditional arrangements are coming under pressure in some areas due to population pressure, dwindling land reserves, and low productivity associated with land degradation (Oxfam/IDS 1998:91). Where such pressures exist, Mighot-Adholla et al (1991:159) report that traditional arrangements are gradually being replaced by individualisation of tenure rights. Nonetheless, land sales remain relatively rare[45]. The World Bank (1993) reports that only 7 percent of rural households in Tanzania had purchased land in the past decade, with the remaining transfers occurring either via direct allocation by the village authorities or with their sanction via inheritance or clearing unoccupied land. In Shinyanga Region, it is reported that only 18 percent of households have ever been involved in land transfers via purchase (Cornell/ERB 1991).

While often classified as a 'land' resource and inherent characteristic of land, farm trees play a different role in the present study. Here, they function instead as the outcome of past management decisions. Thus, the presence of trees on a farm reflects the farmer's past decisions either to retain naturally-occurring trees or to cultivate trees. This perspective frames management decisions as possible means of bolstering land quality and responding to land degradation and emphasises farmer agency[46].

Land degradation involves a process of declining land quality, typically caused by sustained demands on land resources not compensated for by associated remedial measures. Specific manifestations include deforestation, soil erosion, habitat loss, and desiccation. Land degradation has been cited as a key cause of the widespread declines in agricultural productivity in Sub-Saharan Africa (Scherr & Yadav 2001). The associated impacts on soils, notably nutrient losses and decreased water-holding capacity, have been blamed for the widening gap between the actual and potential yields of food crops in Sub-Saharan Africa (Dejene et al 1997:3). Lal (1995) has estimated that the resulting losses in crop yields average 6 percent per year across Sub-Saharan Africa. Moreover, these losses are concentrated on food crops and the rural poor, since it is these cases where farmers often lack access to purchased inputs with which to compensate for declining soil fertility. Because remaining expansion areas in Sukumaland are minimal, addressing land degradation a high priority in Shinyanga District

[45] One reason for this is the chilling effect of the government's policy in the 1970s of strictly restricting such transfers (Dercon 1996).
[46] This view of trees as a management tool recalls the dichotomy between 'renewable' and 'non-renewable' natural resources. How a given resource is classified depends on whether or not it regenerates naturally after being depleted. Grasses are a renewable resource, while minerals are a non-renewable resource. Soil falls between these two extremes, since it can regenerate itself, but only slowly and under favourable conditions. Given the centrality of soil to agriculture, a key management question is what role farmers can play in facilitating these conditions. Both tree cultivation and soil and water conservation represent possible means of doing so.

(Oxfam/IDS 1998). While data on land degradation were gathered, these data were not amenable to statistical analysis and hence not used in the analysis[47].

One core distinction is between nominal, ordinal and continuous variables. Of the 'land' data gathered, the only continuous variable is farm size, while data for all other land constraints are either nominal or ordinal variables. To better reveal patterns within the data during analysis, these categorical data were generally aggregated down from numerous categories in the raw data to two or three discrete categories. A second reason for aggregating data is that in some cases this was the only way to ensure that data were both rigorous and consistent, for instance when data were of uneven specificity. In still other cases, data from distinct but related variables were combined to form a composite variable, in order to give sufficiently large groupings for statistical analysis.

4.3.2 Labour resources

'Labour' inputs into farm management include agricultural tasks such as field preparation, planting, fertilisation, weeding, pest control, harvesting and herding, as well as extensive and intensive strategies of land management. Extensive land management strategies include shifting cultivation and herding or gathering fuel in the bush, while intensive strategies include cultivating farm trees and soil & water conservation (SWC) practices.

In most households the labour force is made up mainly of household members, including men, women and children. A minority of 21 percent also hired in temporary labour in the past year, generally to help with farming activities during times of peak labour demand. A further 17 percent hired out labour to neighbouring farms on a casual basis, typically at the outset of the rainy season as a means to earn some cash or secure some extra food during what may be the leanest time of the year. Some 2 percent of survey households *both* hired in and hired out farm labour. Communal labour is also sometimes practised (ICRAF 1988), whereby a group of villagers first cultivates one farm then moves to the next. Because such work is reciprocal and food is generally provided to workers, net labour gains to any given farm tend to be minimal.

Since no wages are paid to household members for their labour, the costs of household labour are assessed in terms of leisure foregone. An individual will work only as long as the marginal product of the extra effort is

[47] Specifically, virtually all survey households complained of 'tired soil', with the vast majority also citing this as a key constraint on farm production.

valued more highly than the foregone leisure. Alternatively, labour costs may be thought of in terms of opportunity costs, particularly in cases where off-farm opportunities offer either wages or self-employment earnings. Either way, these costs are real (Ellis 1993:123).

Figure 4.3 shows a histogram of total household labour. It can be seen that the sample is characterised by a relatively small number (7 percent) of households of ten members or more, with a large peak at four labour equivalents (discussed below). The mean household labour force is 5.2 labour equivalents, while both the median and mode are 4 equivalents. Nationally, rural households average 6.6 members (World Bank, 94:46), or slightly larger than in the household survey.

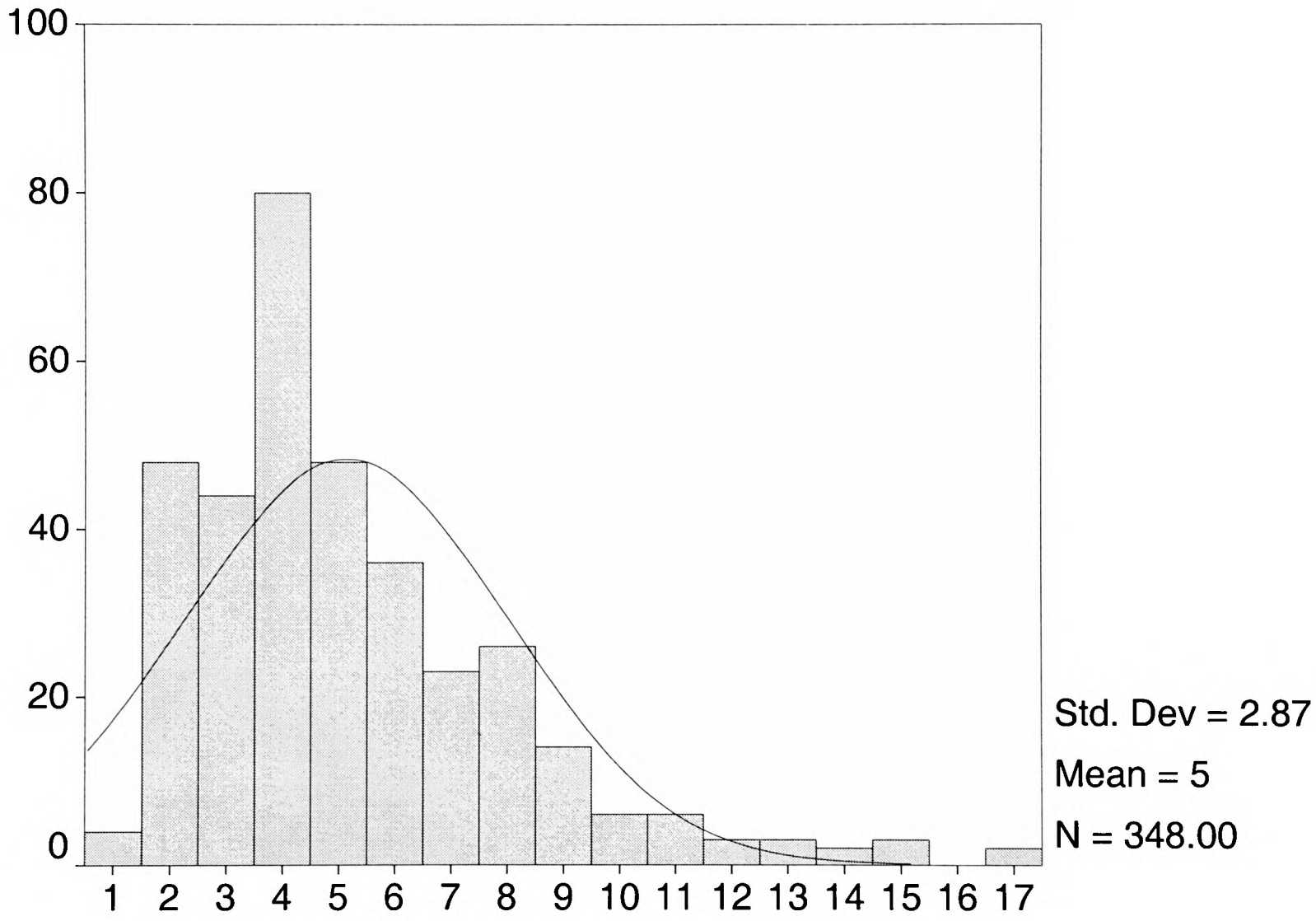
One characteristic of peasant economies is that individuals are often involved in more than one economic activity. All 349 households were involved in farming, with the vast majority citing farming as their primary occupation, of which 74 percent sometimes sell agricultural outputs to markets[48]. The other major occupation was livestock keeping, which was practised by 81 percent of households, or 95 percent if households owning only chicken are included[49]. Minor occupations included school teaching, shop-keeping, petty commerce, and various cottage industries, from pottery making to crafting ox harnesses to producing charcoal for sale to urban markets.

In a poor area like Shinyanga District, the choice between work and leisure is powerfully informed by the relative ease of producing enough to meet the household's subsistence needs. Thus, a farmer cultivating a small plot of land with many dependants may be forced to devote more time to working his land than his/her neighbours to meet the household's needs, despite diminishing returns to labour. Such considerations are relevant in Shinyanga District, given the failure of its population to meet their carbohydrate requirements in two of the past seven years and their protein requirements in all seven of these years (GoT 2000:43).

Traditionally, household tasks were apportioned by gender, with each gender having obligations and rights under customary law. Men were responsible for clearing land, perennial crops, domestic animals, housing, and hunting, while women were responsible for annual crops, food preparation, gathering wood and water, and childcare. Given this breakdown of tasks, women remain relatively busy in the dry season while men spend

[48] Many of these same farmers reported currently having insufficient food stocks, however, since the previous growing season (1999-00) had been poor. More generally, many District farmers only participate in markets in years when outputs are abundant.
[49] Given current levels of livestock and problems with fodder scarcity, labour demands associated with herding can impose a major burden on households (ICRAF 1988). Survey households repeatedly spoke about how Sukuma herders sometimes travel vast distances in search of fodder, and may remain absent from the household for weeks or even months at a time.

Figure 4.3 Household labour



Total household labour (in labour equivalents)

much of their time relaxing (Kaoneka 1997:45). Traditional factors undermining the role of women include polygamy and the payment of brideprice, which may induce households to marry off girls to secure a good 'price' (Oxfam/IDS 1998). Moreover, the position of women has been eroded by the commercialisation of agriculture, since cash crops and modern technologies are controlled by men (World Bank 1994:51).

Given these gendered roles within Sukuma society, the gender of the household head is a significant distinguishing factor among households. Yet because a women may be reluctant to identify herself as the household head, sometimes a man may be named as the household head even though he is absent and contributes little to the household. The survey finding that 11 percent of survey households are headed by women may therefore be low[50]. Significantly, female-headed households do not appear to be significantly poorer than male-headed households in Tanzania (World Bank 1994:47-51).

Ideally, one would collect data on both qualitative and quantitative aspects of household labour. Quantitative aspects include the absolute number of household members, their age and gender profiles, any hired labour, and the weighting of different types of individuals when calculating total household labour supply. Qualitative aspects of labour include acquired skills, formal education and training, involvement with projects, and health.

4.3.3 Linkage of land to labour

In their in-depth study of Tanzania's rural economy, Collier et al (1990:40) assert that labour is the main resource of poor people and of poor economies. This claim stems from an assessment of minimal capital inputs to production coupled with a perception of land as relatively abundant. Indeed, Collier et al suggests that because land is abundant, the distribution of landholdings is determined predominantly by the relative abundance of labour. In short, they argue that the opportunity cost of land is low to zero, while labour is the limiting resource.

Table 4.5 illustrates the land distribution found for Shinyanga District and its relation to this theory. Using aggregated data to highlight broad trends, it is clear that farm size increases much more dramatically than household size. While the mean household size between the smallest and largest farm size categories only varies by a factor of two, the mean farm size varies by a factor of forty. Even correcting for the incidence of outliers by using median values gives a situation where farm size varies by a factor of thirty. Thus, household

[50]Then again, this figure is broadly consistent with findings by the World Bank for rural Tanzania (1994:48).

size only accounts for a small fraction of the observed variation in farm size, suggesting that the premise of abundant land does not apply in the District.

The second criterion cited by Collier et al in support of their argument is the fact that landlessness was virtually non-existent in their sample. By contrast, the present study found that landlessness[51] accounts for six percent of survey households, suggesting that it is significant. One explanation for the difference in these two sets of findings is the changes that have taken place in the intervening fifteen years between the two studies, notably a larger labour supply coupled with increased scarcity of land quantity (given population growth) and quality (given resource degradation). A second explanation is that Collier et al examined Tanzania as a whole while the present study examined a single District.

Table 4.5 Land distribution in Shinyanga District

Farm size category	Mean / median farm size	Average household size	Number of cases
0 – 1 acres	1.0 / 1.0 acre	3.3 labour units	5
2 – 4 acres	3.3 / 3.0 acres	3.6 labour units	54
5 – 10 acres	7.7 / 8.0 acres	4.8 labour units	128
11 – 20 acres	15.0 / 15.0 acres	5.5 labour units	95
21+ acres	40.7 / 30.0 acres	7.2 labour units	53

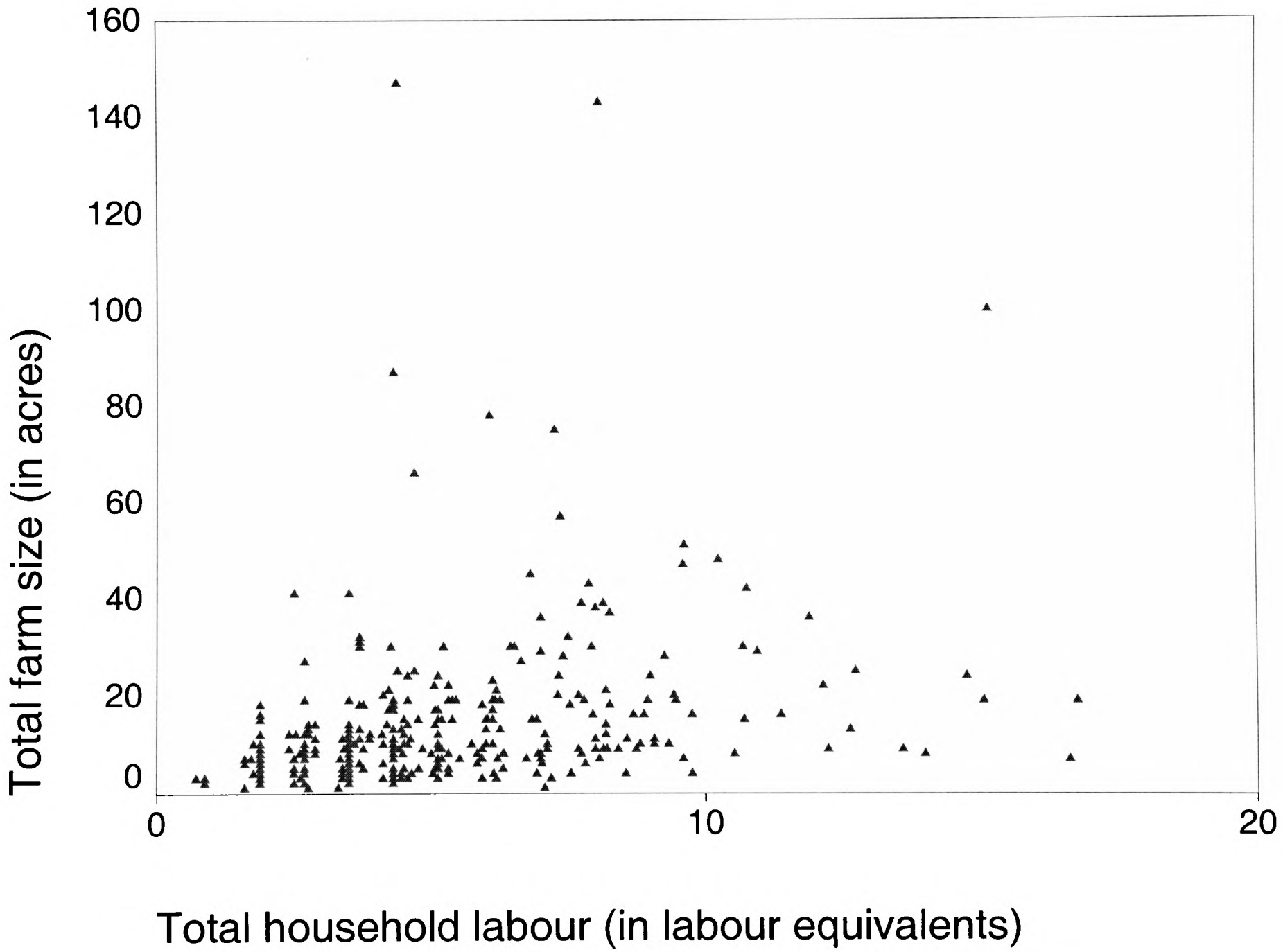
Source: Shinyanga District household survey, 2000

The land-labour ratio is implicit in any model that includes both land and labour constraints. This ratio defines both the human burden (i.e. consumption demands) on land and the available labour per unit land with which to manage it. Across the sample survey, the land-labour ratio is concentrated around a value of two acres per labour equivalent, but with a long thin tail towards larger values. Out of the 334 households for which these data were available, households could be roughly divided into four categories, one for a ratio of zero to one, a second for a ratio of one to two, a third for a ratio of two to three and a fourth for a ratio of three to five. Beyond this, twenty-eight households had a land-labour ratio between five and ten, seven had a ratio of between ten and twenty, while one had a ratio of twenty and another had a ratio of thirty-four. The scatterplot in Figure 4.4 gives an intuitive sense of the land-labour ratios prevailing among survey households.

In the past, stresses on land resources such as soils have been addressed by leaving fields fallow, while agricultural growth has often been achieved simply by expanding the area of land under cultivation. This

[51] Those households that possess only rented and/or borrowed fields are defined as landless. No survey households lacked land entirely.

Figure 4.4 Scatterplot of land-labour ratios



extensive farming strategy was suited to a context where land was abundant, since it secured relatively high returns to labour despite low-input technologies. In areas where virgin bush remains, extensive agriculture with its low labour inputs per unit area may still be economically optimal (Upton 1996; ch.8). Yet in contemporary Shinyanga District, much of the arable land has already been brought into cultivation, as reflected in the prevalence of continuous cultivation among survey households.

Once all available land is in use, increasing production depends on intensifying land use to produce more per hectare (Upton 1996:171). While there may be some scope for varying the intensity of land use within a given farming system (e.g., by weeding more frequently), bigger changes will require changing the system itself to ensure that key resources such as soil nutrients are replenished. Thus, given increasing land scarcity, farmers must change their farming system. Changing the farming system involves either adopting innovative labour-intensive technologies such as agroforestry practices or increased use of capital inputs such as chemical fertiliser. If, however, the household intensifies land use without adapting its farming system, declining soil fertility and reduced yields may result.

HASHI/ICRAF reports that the latter case is precisely the situation currently facing many households in Shinyanga Region. Specific characteristics of agriculture reported include short to non-existent fallow periods coupled with inaccessible purchased inputs, insufficient manure and a tendency towards continued reliance on traditional land management practices. Taken together, these factors explain the current reality of falling yields and scarcity of essential products in the area (Annual Report 1999).

In areas employing a farming system based on intensified labour inputs and innovative technologies, returns per hectare tend to increase, while returns per person-day of labour tend to decrease. Ukara Island in Lake Victoria is one widely-cited example of such a system (e.g., World Bank 1992), while other examples from East Africa are described in Widgren & Sutton (1999). Changing the farming system via increased use of agricultural capital might involve establishing permanent crops (e.g., coffee, mango), constructing terraces or irrigation works, or purchasing livestock or tools. The use of capital may bring about not only an increase in output per hectare, but also increased returns to labour.

Where capital is scarce, increased labour inputs are the main potential substitute for decreasing availability and/or quality of land. Land and labour have thus been called the two key inputs to agricultural production in the District (Kaoneka 1997:44). It follows that adaptation of labour allocation to changes in the rural context

such as increasing land scarcity is critical to rural people and their welfare. In Tanzania's Kondoa District[52], it is reported that rising population density creates incentives to improve land productivity, since investments in land become more attractive as the scarcity value of land increases with respect to labour (Dejene et al 1997).

In such cases of growing land scarcity, it is generally assumed that farmers adapt readily and effectively to changes via a process of 'induced innovation' (Hayami & Ruttan 1971). Yet Scherr & Hazell (1995) suggest that such adaptations may not be automatic, raising the question of how policy interventions might facilitate this process.

4.3.4 Capital resources

A household's capital stocks are expected to strongly affect its tree management strategy, since they increase its capacity to pursue diverse farming strategies. They also increase the marginal product of its labour, and hence income. Capital resources relevant to agriculture in Shinyanga District include both capital stocks and working capital. Capital stocks include livestock and agricultural tools, notably hand-hoes and ox-drawn ploughs and seeders[53]. Working (i.e., non-durable) capital includes chemical fertilisers and pesticides, high-yielding seed varieties and livestock disinfectants and medicines[54]. Beyond these forms of agricultural capital, non-agricultural capital includes non-farm income, financial assets and housing.

The traditional store of wealth in Sukumaland is livestock. Financial assets (i.e., bank deposits or cash) are reported to be virtually non-existent in rural Tanzania, which is unsurprising given the high levels of inflation that have historically prevailed in the country[55]. Food stocks are seldom used to smooth consumption across years, due partly to ineffective storage technologies (Dercon 1996). Meanwhile machinery and tools are generally confined to rudimentary items such as hand-hoes and ox-drawn ploughs (Collier et al 1990:50).

Besides livestock holdings, capital assets are thus minimal in the area. The generalised nature of this capital scarcity is reflected in the poverty of Shinyanga Region, where current estimates place per capita income at approximately US $64 per year (GoT 2000:27). Capital scarcity is also indicated by the low use rates of working agricultural capital. Low use rates are likely to have been exacerbated by the liberalisation of

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[52] Kondoa District occupies a similar agro-ecological zone and faces similar challenges to Shinyanga District.
[53] While permanent crops such as farm trees may also be classified as capital stocks, they are not so classified in the present study, due to its focus on trees as a management variable.
[54] Notably, these inputs often act as modern substitutes for goods and services historically provided by natural resources, e.g., fertilisation, pest control.
[55] Sukuma thinking about financial assets relative to alternatives such as cattle is suggested by their saying, 'Shillings do not breed' (Dercon 1996).

agricultural input supply in the early nineties, which saw working capital inputs to agriculture such as chemical fertilisers and pesticides approximately triple in price (World Bank 2000). Indeed, this sharp price rise was the factor most often cited by survey households to explain failure to use such inputs. During this same period, output prices remained largely stagnant in Shinyanga District according to survey households, a finding only partly supported by government statistics (GoT 2001).

Collier et al (1990:95-6) traced over 50 percent of income differences between the poor and non-poor in rural Tanzania to differences in endowments of human[56] and physical capital available to each family. About 21 percent of the income differential was the result of livestock holdings, while education and landholdings were the two next-most significant explanatory factors. Because access to wage employment was found to be closely linked to educational attainment, the former may be substituted for the latter. Thus, "If access to wage employment is regarded as an asset, then it is a more significant contributor to inequality than landholdings." They conclude that the poor are poor because of low returns to labour associated with low endowments of non-labour assets. That is, access to capital inputs such as fertilisers, ploughs, draught power and education affects incomes in a labour-constrained economy by increasing the marginal product of labour (World Bank 1994:53).

A recent study of rural livelihoods in Shinyanga District (Oxfam/IDS 1998) conducted a participatory wealth ranking in three statistically selected villages to determine the principal determinants of wealth in the District. Major assets listed by participating households were cattle, goats and sheep, ox-carts, bicycles and food reserves. Taken together, these assets were said to determine whether households were considered wealthy or poor. Landholdings were only mentioned as an asset in one of the three villages. An example of a wealthy household was given as one with forty or more cattle, seventy or more bags of grain following the harvest, one ox-cart, two bicycles and several good houses. A very poor household was described as one that cultivates less than one acre, depends on working on other peoples' farms for supplementary income, and has minimal grain stocks and poor clothing[57]. Of the 210 statistically selected farmers interviewed, 6 percent were considered well-off, 58 percent were considered poor, and the remaining 36 percent somewhere in between[58].

[56] Although sometimes considered a capital asset, education and human capital generally are not categorised as such for the purposes of the present study

[57] Such households are referred to locally as *Hana hata kuku*, or 'Doesn't even have a chicken', showing the centrality of livestock to perceptions of wealth.

[58] Although no wealth ranking was conducted by the present study, this breakdown represents a plausible approximation of its findings.

In Shinyanga District, both formal and informal credit markets are largely missing. In such areas, households facing income fluctuations[59] must find alternative strategies to mitigate risk and avoid potentially adverse impacts on consumption and welfare. Although other risk reduction strategies are also observed[60], the principal strategy employed by District households is liquid asset accumulation (Hankins 1974). This strategy's effectiveness depends on the liquidity of the relevant assets and their covariance with crop income. Given the decline of village-based mutual support networks over the past decades, this strategy is particularly significant in the modern context (Cory 1953). In addition to insuring farmers against adversity, liquid assets increase their capacity to undertake risky yet profitable activities, allowing them to secure higher returns and hence further accumulation (Dercon 1996).

One key advantage of livestock assets is their liquidity, given well-developed livestock markets, as a result of which they can be readily converted into cash. Moreover, cattle prices show surprisingly little variation across good and bad years[61]. Finally, livestock herds can be moved considerable distances in case of drought or other adverse local conditions, allowing households to limit any losses to the household (Dercon 1996). Cultivating farm trees, meanwhile, represents an accessible alternative means for the rural poor to build up dynamic assets and secure their livelihoods (Chambers et al 1993).

4.3.5 Livestock holdings

The livestock population of Shinyanga Rural District in 1998 was estimated at 590,000 cattle, 242,000 goats and 120,000 sheep. Cattle are thus the predominant type of livestock. Within the region generally, the livestock growth rate is estimated at 1.6 percent per annum. Livestock populations have continued this increase despite the migration of numerous livestock keepers to Tanzania's Southern Highlands in search of better fodder supplies (GoT 2000; ICRAF 1988).

Cattle have multiple functions in the farming system. When fodder is abundant, cattle produce milk that can be either consumed or sold. They provide draught power, and may be used for transport if the household has access to an ox-cart. Meat can be either consumed or sold, and manure is a natural fertiliser. Cattle also serve social functions, notably as an expression of wealth and social standing and as brideprice[62]. Finally, they are

[59] A major concern of Tanzania's rural poor is vulnerability to unpredictable events, such as famine linked to drought. Notably, Tanzania has experienced a series of adverse weather conditions since the mid-1990s that have undermined food security (PRSP 2000:9).
[60] E.g., diversifying the cropping system, hiring out labour or bullocks, remittances, non-farm income, cottage industries.
[61] Government statistics for 1977-88 show that adjusted prices for the worst years were only 10 percent below the average price over the series. This relative stability can be explained by the fact that droughts in East Africa tend to affect a limited area, allowing continued sales to unaffected areas (Dercon 1996).
[62] Wealthy households typically pay several tens of cattle, while the poor may have difficulty paying even a few cattle (Oxfam/IDS 1998).

the dominant form of savings and insurance for Sukuma villagers, as a result of which households may be reluctant to part with livestock. The value of cattle to households thus transcends their use value as assets or commodities (ICRAF 1988; Oxfam/IDS 1998).

While in theory livestock can provide goods and services or be exchanged for capital or consumption goods, in Sukuma tradition cattle and other domestic animals are generally considered stores of wealth. An animal may be slaughtered at important social functions, yet generally only sick animals are used for meat, and a farmer who slaughtered a healthy animal for home consumption would be ridiculed. Moreover, selling livestock is reported to occur only in the case of extreme difficulty, but not to fund expenditure on either consumption or capital goods[63]. Finally, cattle are rarely exchanged for food even in food deficit years, and this is done only as a last resort[64]. The idea that livestock are kept primarily as stores of wealth is supported by the observation that herd size seems to be paramount, with Sukuma households showing a tendency is to maximise livestock numbers rather than to optimise the health or productivity of the herd[65] (ICRAF 1988; Oxfam/IDS 1998).

Livestock holdings have often been used by studies of rural Africa to capture differences among households. For instance, Reardon et al (1988) used livestock holdings to gauge household capital assets in rural Burkina Faso, in light of the strong correlation of livestock with consumption security during a drought-induced hardship period. Collier et al (1990:54) suggest that livestock holdings are a critical resource in Tanzania, writing " 'livestocklessness' is the Tanzanian counterpart to landlessness in rural Asia". Finally, according to a recent participatory study of Shinyanga Region, livestock holdings and landholdings were the two key determinants of wealth in the view of local people (UNDP 1998).

4.3.6 Non-farm income

Non-farm opportunities represent alternative forms of employment and sources of income, and may fundamentally affect both household welfare and decisions vis-à-vis farming and natural resource management. Sources of rural non-farm income fall into two broad categories. On the one hand, relatively poor households may engage in diverse activities to supplement their income from farming. Examples include cottage industries

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[63] A recent participatory study of the District reports that some households that own cattle nonetheless live poorly, i.e., their children are malnourished and their clothes and houses are in poor condition. This study suggests that households can have so much faith in cattle that they keep them at the expense of their own welfare (UNDP 1998:13).

[64] An economic justification for this reluctance is that such transactions are normally conducted during the dry season when the terms of trade are disadvantageous, i.e., when cattle may have a low value due to hunger while grain prices are high due to finite supply.

[65] According to the interview data, cattle in the District typically only produce milk for several months each year, due to limited fodder and water supplies. Moreover, farmers often have to wait several weeks after the rains start for oxen to regain their strength by eating fresh grass before they can be used to plough fields, leading to problems of late cultivation. Finally, livestock were observed to be visibly skinny by the field team for the present study.

(e.g., pottery, charcoal, ox-harnesses, traditional medicine, vegetable gardening), working as a field labourer, and receiving remittances of food or cash. On the other hand, some relatively privileged households have a major source of non-farm income that may rival farming as their primary income source. Examples include being employed as a school teacher or village executive officer, running a store, livestock trading, and petty mining[66]. A third category of non-farm income involves those who leave the village in search of work[67].

According to the survey findings, the most common form of non-farm income in Shinyanga District is hiring out labour to neighbouring farms. This was done by 17 percent of survey households over the past year, with young males the most likely participants. Meanwhile, a survey of non-farm income in rural Tanzania found that between 10 percent and 12 percent of the rural population earned cash wages, primarily as agricultural labourers (Cornell/ERB 1993). Yet the latter figure underestimates the level of agricultural labour, since in poor communities such work is often paid in food rather than wages.

In the context of the District, hiring out labour is commonly seen as a sign of relative poverty and insecurity. Typically, the household hires out labour during times of peak demand for farm labour, notably at the beginning of the rainy season. As a result, it delays cultivating its own fields, which tends to lower eventual crop yields. Casual labour thus tends to be associated with poverty and food insecurity. Nonetheless, some wealthy households were also engaged in casual labour. One possible explanation involves inheritance laws, since only the eldest son of a wealthy farmer will inherit his land, while none of his children have any rights to his livestock as long as he lives[68] (Oxfam/IDS 1998:89,92).

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[66] Petty mining can be a lucrative occupation in certain parts of the District, and includes mining for diamonds and gold. It was a major occupation in one survey village, Mwigumbi.

[67] Collier et al (1990) found that 27 percent of households in rural Tanzania had a member who had left the village, primarily to seek work in the city.

[68] Besides the eldest son, a young man's only entitlement from the household head is for brideprice to be paid for his wedding (Oxford/IDS 1998:73).

Chapter 5

Analysing Observed Tree Management Patterns

Building on chapter four, this chapter seeks to identify the determinants of different tree management patterns. After defining a set of explanatory variables and discussing the analysis techniques applied, it introduces the theoretical and econometric models underlying the analysis and a range of null and alternative hypotheses. Using these foundations, the chapter employs logistic regression analysis to examine a series of nine models representing different aspects of tree management practice. The analysis of each regression model involves three stages. Stage one uses resource variables only, stage two uses both resource and 'outside influence' variables, while stage three also incorporates variables representing different aspects of farmer knowledge. These different stages examine the extent to which incorporating different variable types affects the explanatory power of the models.

5.1 Variables used in the analysis

5.1.1 Land variables

Farm size: Farm size simply totals the acreage of all the fields farmed by the household. Fields that are either hired or borrowed by the household are included in this figure. Given the importance of this variable, several alternative versions of it were integrated into the analysis. These include a continuous variable taking log values of farm size to the nearest integer and two categorical variables, one with four alternative farm sizes and one with two.

Soil type: This variable measures whether or not the farm includes *mbuga*, or black clay soil. Distinguishing features of this soil include inherent fertility and the capacity to retain water during dry spells in the rainy season[1]. Households with an area of *mbuga* soil are taken to have relatively high average land quality.

Land tenure: This variable measures whether the household owns its entire farm under customary tenure arrangements or instead rents[2] or borrows at least part of the farm. These were the main two options observed in Shinyanga District, since statutory tenure was not encountered.

[1] This significance of this soil to farming is reflected in the fact that it was the only soil type regularly singled out by farmers for comment.
[2] Rental costs are reported to be between TSh. 3,000 and TSh. 10,000 per acre per year, depending on the quality of the land (Oxfam/IDS 1998:92).

Market access: This variable measures whether the farm is located within ten kilometres of an all-weather road. Land located near markets or main roads is expected to have a high opportunity cost, given the relatively low transactions costs associated with sale to markets[3]. The fact that sample households tend to be located relatively near markets and main roads reflects a concentration of the rural population in these areas.

Off-farm trees: Trees occurring off-farm are listed as a 'land' resource, since they may be seen as a natural feature of land. This variable assesses whether off-farm trees were decreasing or roughly stable, based on judgements of survey households aggregated by village. These trees affect farmers' tree management strategy, since they may substitute for tree goods and services potentially provided by farm-based trees. The key question is whether local off-farm tree stocks are sufficient to supply needed tree products and services to households, and hence whether farm trees are needed.

Table 5.1 Land variables used in the analysis

Variable name	Brief description	Categories	Relative frequencies (%)	Total cases
FARMSIZE	Total acreage of farm	Continuous	N.a.	335
FS.CATS	Total acreage of farm	0–4 acres 5–10 " 11–20 " > 20 "	18 38 28 16	335
FS.BINRY	Total acreage of farm	1–10 acres > 11 "	56 44	349
SOILTYPE	Farm includes black clay soil	Yes No	74 26	340
TENURE	Ownership of farm	Owned in its entirety Partly rented or borrowed	82 18	348
MKT.ACC	Distance to an all-weather road	Less than 10 km. More than 10 km.	79 21	349
INCIDENCE	Changes over time in off-farm trees	Static or increasing Decreasing	65 35	349

Source: Shinyanga District household survey, 2000

5.1.2 Labour variables

Household labour: A weighted measure of household[4] size was taken to represent household labour supply. Measuring labour inputs in terms of household size assumes that households employ a substantial proportion of

[3] The primary means of transport to markets cited by District households were ox-carts (54%), head porterage (26%) and bicycles (8%). Cars, lorries and buses were restricted to the main roads due to the poor quality of feeder roads, which were often impassable during the rainy season (Oxfam/IDS 1998:90).

[4] Households were defined to include all individuals who had spent at least three months living in the household over the past year. This measure was used because three months covers the duration of the growing season. It is assumed that most family member who live in the household part of the year are present during the periods of peak agricultural demand when the household most needs them. Such a pattern was observed among students and seasonal migrant workers in the sample.

their available labour on farming activities, at least during peak periods in the farming calendar[5]. This seems a safe assumption in the context of Shinyanga District, since even those few household with substantial non-farm incomes, e.g., school teachers, store owners, indicated that they prioritised farming during times of peak agricultural labour demand[6].

Given the differing labour capacities of different household members, weighting was used to calculate total household labour supply. The weights used were adapted from Collier et al (1990:71), who provide an equivalence scale for estimating caloric requirements of households in rural Tanzania. The labour contribution of household members was estimated using the weights listed in Table 5.2. Once household size was aggregated using these weights, the resulting statistic was converted to its log value for use in the analysis, to correct for the asymptotic distribution of survey data on household size.

Table 5.2 Equivalence scale used to calculate household labour supply

· Child under 5 years	0
· Youth of 5 – 17 years, male or female	0.81
· Adult female, 18 – 60 years	0.88
· Adult male, 18 – 60 years	1.0
· Elderly female, over 60 years	0.72
· Elderly male, over 60 years	0.88

Source: Shinyanga District household survey, 2000

Ratio of youth: By gauging the proportion of youths in a household, this variable gives a sense of the household's stage in its life cycle. Three broad life stages can be distinguished: young households that have recently started their family, mature households with grown children, and older households whose children have left to start their own households. While conceptually distinct, these categories may be unclear in practice due to the tendency for households to include several generations. Across the sample survey, the ratio of youths was evenly distributed, with a mean of 49% and a median and mode of 50%.

Sex ratio: This variable measures the proportion of males in the household. Given the association of specific farm activities with gender roles in Sukuma society, the sex ratio could significantly affect household management strategy. Notably, tree cultivation is a male activity, yet women are key beneficiaries given its

[5] This assumption accords with Collier et al's (1990:49,56) findings that in rural Tanzania "virtually everyone who can work does work", and that "there is little labour surplus in the village"

[6] It is unclear whether this apparent commitment to continued farming among those possessing an alternative occupation is due to economic considerations or socio-cultural associations with farming. The latter explanation is supported by suggestions from several survey households that this was done as evidence of self-reliance or 'manliness'.

impact on women's tasks such as fuel provision. Across the sample survey, the sex ratio is very even, with a mean of 49.6% and a median and mode of 50%.

Gender of household head: This variable indicates whether the household head is female. Given the gendered nature of tree cultivation and the importance of household leadership, this factor could affect households' tree management strategy.

Table 5.3 Labour variables used in the analysis

Variable name	Brief description	Categories	Relative frequencies (%)	Total cases
LABOUR	Total labour equivalents	Continuous	N.a.	348
RATYOUTH	Ratio of youths in household	Continuous	N.a.	348
RATIOSEX	Ratio of males in household	Continuous	N.a.	348
HHH.GEN	Household head is female	Yes No	11 89	348

Source: Shinyanga District household survey, 2000

5.1.3 Capital variables

Livestock: This variable indicated the livestock holdings of survey households. Each household was categorised based on the most valuable type of livestock owned. Those listed as owning cattle may also own sheep, goats and/or chicken. Those listed as owning sheep, goats or chicken owned at least one of these, but did not own cattle. Despite the significance of livestock in the District, collecting livestock data proved problematic (see chapter three), as a result of which only general data are available.

Labour hired in: This variable indicates whether the household hired in agricultural labour over the past year. It suggests relative wealth, showing that households have disposable income during periods of peak labour demand, often at the height of the 'lean' season[7].

Labour hired out: This variable indicates whether or not any household members have worked as a fieldhand over the past year. Such labour may be paid with either cash or grain. Either way, if those hiring out labour are running low on food, a few days worth of wages might make a great difference to the household's food budget.

Both *labour hired in* and *labour hired out* were interpreted as indicating the availability of capital, given their strong association with disposable income. Although they could have been interpreted as labour variables,

[7] This follows because labour is often hired in at the beginning of the rainy season, when food supplies are at their lowest.

income effects were deemed to dominate over labour effects, since such exchanges of labour typically involve only a matter of days per year.

Non-farm income/Major: This variable indicates whether a household possesses a major source of non-farm income, such as a waged position in the formal economy, running a store, or engaging in livestock trading.

Non-farm income/Minor: This variable indicates whether a household possesses a minor source of non-farm income, such as diverse cottage industries or remittances from relatives.

Housing: Data on housing stock were also gathered, including the type of roofing and flooring materials used in constructing the household compound. These data did not prove useful, however, given the extremely small numbers (less than one percent) using 'modern' materials such as tin roofing or cement flooring.

Table 5.4 Capital variables used in the analysis

Variable name	Brief description	Categories	Relative frequencies (%)	Total cases
LIVESTCK	Livestock holdings	Cattle Goats/Sheep/Chicken Only[8] None	73 22 5	346
L.IN	Household hired in labour over past year	Yes No	21 79	338
L.OUT	Any household member worked as a farm labourer over past year	Yes No	17 83	349
NFIMAJOR	Household has a major source of non-farm income	Yes No	17 83	349
NFIMINOR	Household has a minor source of non-farm income	Yes No	32 68	349

Source: Shinyanga District household survey, 2000

5.1.4 Outside influence variables

Four 'outside influence' variables were considered as part of the tree management analysis summarised in chapter five. Three were knowledge proxy variables emphasising households' access to outside information and hence 'modern' knowledge, while the fourth was a religion variable. While the latter may not convey information that directly affects households' management decisions, it is nonetheless a powerful influence on households' thinking. Each outside influence variable is briefly described below, followed by a table summarising the data for these variables.

[8] This variable included 14% of households that owned only chicken and 8% of households that owned either goats or sheep, but not cattle. These categories were aggregated together to increase the tractability of the livestock variable.

Swahili: Proficiency in Swahili serves as a proxy for formal education, and hence for access to institutional or scientific knowledge generally. This follows from the link between Swahili language skills and formal schooling in the study area. It also follows because proficiency in Swahili may serve as a prerequisite for interfacing with knowledge-provision agents such as extensionists and development projects.

Radio: This variable determines whether or not a household listens regularly to the radio. While the information conveyed is only sometimes directly relevant to farm management, the fact that radio provides access to outside information and Western ideas may nonetheless affect households' thinking and management practices.

HASHI. This variable determines whether or not a household lives in a village where the HASHI / ICRAF Agroforestry Project has been active. The project's key goals are to introduce agroforestry technologies and to raise environmental awareness. Activities include distributing seedlings to villagers, conducting farm trials in collaboration with selected farmers, and conveying information about the significance and uses of agroforestry practices via presentations, videos, and a mime troupe. While the household in question may not have been directly involved in this institutional contact, such contact may nonetheless be relevant to it given diffusion effects within villages.

Religion: This variable indicates whether a household continues to adhere to the Sukuma indigenous religion or has instead converted to either Christianity or Islam, and may as such indicate its relative adherence to traditional ideas of farm and resource management.

Table 5.5 Outside information variables used in the analysis

Variable	Brief description	Categories	Relative frequencies (%)	Total cases
SWAHILI	Proficiency of household members in Swahili	Fluent Functional Minimal	73 10 17	333
RADIO	Frequency with which any household members listen to the radio	Daily Occasionally Never	28 28 44	349
HASHI	Whether HASHI/ICRAF project has been active in the household's village	Yes No	26 74	349
RELIGION	Whether the household has converted from the Sukuma indigenous religion to either Christianity or Islam	Yes No	46 54	347

Source: Shinyanga District household survey, 2000

5.1.5 Local knowledge variables

The premise of the present study is that integrating local knowledge variables into the analysis of observed tree management patterns could help explain these patterns, since households' knowledge may fall into distinct knowledge profiles. Based on the study hypothesis, possible distinctions among households' knowledge of trees and tree management include the following.

- How broadly are trees and their role seen, i.e., what goods and services are cited as significant?
  - * Do they only emphasise fuelwood (an obvious yet low-value product) or fruit (a high-value marketable product), or other more 'subtle' tree products also?
  - * Do they see trees only as sources of products, or also as providing services such as raising soil fertility?
- Are trees seen as providing potentially critical support services to farm enterprises, notably field crops and livestock?
- Does the household emphasise costs imposed by farm trees, and if so how are these weighed against tree benefits?
- To what degree does the household see itself as responsible for ensuring adequate stocks of needed trees?

Building on these ideas, eight 'local knowledge' variables were defined for use in the tree management analysis summarised in chapter five. These variables represent distinct aspects of local knowledge vis-à-vis trees and tree management. They reflect a broad definition of local knowledge that includes not only whether or not a household possessed a particular bit of technical knowledge, but also its relative prioritisation of different aspects of complex resources.

All eight variables represent aspects of trees cited by survey households in response to questions about the significance of trees to the household, including their significance to crop and livestock production. Such questions were central to the household survey, and were explored in considerable depth. Nonetheless, many aspects of trees were cited by some households but not by others. Such findings were taken to reflect local knowledge. While failing to cite a particular aspect of trees could conceivably reflect de-emphasis rather than lack of knowledge, this distinction was not deemed germane, since the management outcome was the same in

both cases. Thus, de-emphasis to the point of failing to cite a certain aspect of trees despite detailed discussion of their significance was deemed to be analogous to not possessing that knowledge[9].

In contrast to tree services and tree costs data, tree products data were cited by all survey households, since the role of trees in providing useful and/or marketable products was universally recognised. In the case of tree products, the key knowledge question concerned which products were prioritised by households. Specifically, the question was whether households cited any of several more 'subtle' tree products as the key product for at least one of the trees discussed by the household.

Each category of knowledge variable is briefly described below, followed by a table summarising the actual variables used in the analysis and the findings for these variables.

Key tree product: These data indicate the tree product considered most significant to the household for each priority tree type cited. As such, they reflect each household's informal valuation of the various products provided by trees. Products cited as the key tree product at least once include the following, with the total percentage of survey households citing each in brackets. Fuel (75%), fruit (26%), construction wood (26%), herbal medicine (10%), livestock fodder (8%)[10]. Because both fuelwood and fruit were considered 'obvious' choices as key product, only the final three products were taken to indicate distinct knowledge profiles, and hence treated as knowledge variables.

Soil fertilisation: This variable shows whether the household stated that trees have a positive impact on soil fertility when asked about the relationship between trees and field crops.

'Trees make rain': This variable indicates whether the household cited the widespread belief among Sukuma peasants that 'trees make rain'.

Other environmental services: This variable indicates whether the household specifically cited environmental services provided by local tree stocks.

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[9] Moreover, if the knowledge in question is so insignificant that it is not worthwhile citing, then the associated knowledge variable should likewise not be a significant determinant of tree management strategies, rendering this distinction between de-emphasis and lacking knowledge purely academic.

[10] The corresponding findings for the single tree cited as most significant to the household only are as follows: fuel (63%), fruit (16%), construction wood (12%), herbal medicine (4%), livestock fodder (4%).

Harm to crop production: These variables show whether the household cited harmful impacts of trees on crop production. The principal impacts cited were shading of crops or fodder grasses and soil desiccation or other adverse soil effects.

Table 5.6 Local knowledge variables used in the analysis

Variable name	Brief description	Categories	Relative frequencies (%)	Total cases
KEYFODD	Cited livestock fodder as key tree product	Yes No	8 92	308
KEYMEDS	Cited herbal medicine as key tree product	Yes No	10 90	308
KEYCWOOD	Cited construction wood as key tree product	Yes No	26 74	308
FERTILISE	Cited soil fertilisation capacity of trees	Yes No	28 72	346
HARMSOIL	Cited harm to crops via soil-based effects	Yes No	48 52	346
HARMSHAD	Cited harm to crops via shading	Yes No	37 63	346
MAKERAIN	Cited the view that 'trees make rain'	Yes No	32 68	273
OTHENVTL	Cited either windbreak, soil erosion or microclimate effects[11]	Yes No	52 48	273

Source: Shinyanga District household survey, 2000

In each case, the variable in question could be interpreted in either of two ways. The conventional wisdom suggests that whether or not a household cites a certain bit of knowledge is insignificant, since it is assumed that the household possesses any relevant knowledge whether or not it expresses it. The alternative possibility hypothesised by the present study is that farm households may *not* recognise certain relevant aspects of trees, particularly where the rural context has changed rapidly in recent years. In such cases, only households that explicitly cite an aspect of trees may recognise it, and local knowledge variables may be key determinants of management outcomes.

5.2 Analyses conducted

The specific models analysed reflect the key distinctions among household tree management strategies discussed in chapter four. The first model identifies the determinants of total farm tree numbers, without regard to whether trees grew naturally or were cultivated, while the second model assesses whether the household sold any tree products. Models three and four examine those households that do not cultivate trees. Model five examines households that cultivate exotic fruit trees, while model six considers the case of households that plant and water trees other than exotic fruit trees. Model seven examines the intensity of tree cultivation,

[11] Specifically, 46% of survey households cited a windbreak effect, 11% cited erosion reduction, and 14% cited microclimate effects.

model eight the types of tree deemed most significant to the household, and model nine the location of farm trees.

These various tree management models shed light on the determinants of diverse tree management patterns. Each emphasises a different aspect of tree management and provides a different window onto management strategies and their determinants. The more aggregated models show what factors distinguish one particular aspect of tree management, while the complex models show those factors that distinguish more specific tree management strategies.

These various regression models were based on the overall econometric model for tree management strategy, which in turn derives from the theoretical model. The logit regressions were used to test hypotheses vis-à-vis the various determinants of different tree management strategies.

Given categorical dependent variables, both logit and probit models represent possible tools for econometric analysis. Logit models were preferred, due both to their being more commonly used and to the diverse options for analysing logit models using SPSS. Notably, these options allow for the analysis of diverse categorical dependent variables, including dichotomous variables and both ranked and unranked polychotomous variables.

Using logistic regression, these models were analysed to identify their various determinants and overall explanatory power. Each model was initially analysed using only resource variables, after which the analysis was broadened to include knowledge variables. The integration of knowledge variables included two distinct stages. First, three outside influence variables – including two knowledge proxy variables and a religion variable – were factored into models as potential determinants. The knowledge proxy variables emphasised households' access to outside information and hence 'modern' knowledge, as commonly factored into studies of farming outcomes, while the religion variable represented outside influence on attitudes. Second, a set of variables representing aspects of farmer knowledge were factored into the model[12]. These variables characterised knowledge regarding trees and perceptions of their significance to farm management and rural livelihoods. Finally, these three distinct analyses were compared and the implications discussed.

[12] In practice, the integration of local knowledge variables itself occurred in two distinct stages. This was done because two of the eight local knowledge variables were missing significant numbers of cases. As such, they were factored into the analysis only after it had been completed using the other knowledge variables. If either of these variables was found to be significant *and* its addition increased the overall explanatory power of the model, then the final version of the model reported was the one obtained using these two variables. Otherwise, the version omitting these variables was reported.

These tree management strategies were analysed first using data on the *single* tree cited as most significant to the household and then using an aggregated measure of management vis-à-vis the *three* tree types most significant to the household. The latter set of analyses was preferred for two reasons. First, the explanatory power of the two sets of models was comparable, suggesting that the aggregation rules employed were sound[13]. Second, the aggregated data provide a more complete and balanced picture of household knowledge and practice vis-à-vis trees[14].

For each of the logistic regressions, the study employed stepwise backwards elimination as its model selection criterion to identify the best model for explaining observed patterns of the dependent variable. Independent variables were eliminated if they failed to show statistical significance at 10%. In practice, all such variables were omitted entirely from the analysis one at a time, in reverse order of their statistical significance. This was done due to the problem of missing cases affecting some study variables, as a result of which excluding insignificant variables from the analysis tended to increase the number of cases in the analysis. Following standard practice with logistic regressions, each model's goodness of fit was assessed using the Nagelkerke R^2 statistic.

During stepwise backwards elimination, alternative versions of variables were sometimes substituted for the eliminated variable to see if the alternative version was significant. This was only done in three cases. In two cases, resource variables expected to be particularly significant based on theory (farm size, livestock holdings) were presented in both more and less aggregated versions. In the final case, the different 'key product' variables were aggregated to assess their combined significance, given their centrality to the proposed theoretical model.

A fundamental distinction within multinomial logistic regression is whether nominal or ordinal regression is appropriate. The difference between these techniques is that ordinal regression assumes that the differing categories of the dependent variable are ranked, while nominal regression does not. Moreover, ordinal regression assumes that the individual comparisons within the ranking have a consistent directional relationship with various factors included in the model. For instance, it assumes that the several comparisons of smaller

[13] If using these aggregated data significantly reduced the explanatory power of the models, this would suggest the simplifying generalisations used to generate these aggregations were erroneous. Instead, the marginal differences in explanatory power suggest that the aggregation rules employed approximate actual patterns in the data. These rules emphasised tree cultivation over naturally-occurring trees, non-fruit trees over fruit trees, and trees in fields over those in the home garden.

[14] Namely, the tree cited as most significant to the household may lack certain characteristics important to the household, while other trees may also be seen as significant to the household.

with larger numbers of farm trees implicit in the tree numbers model show similar directional correlations with factors in the model, such as whether the household possesses livestock and whether it hires in labour.

Ordinal regression defines a single set of parameters for the model that apply over the entirety of the ranked sequence. Nominal regression, by contrast, cannot define a single set of parameters. This follows because the categories of the dependent variable are not ordered and the relationships between a given resource and the different logit equations cannot be assumed to have the same sign. A separate set of coefficients was therefore calculated for each logit equation in the regression model.

Out of the four multinomial models examined, two were clearly ordinal while two were more ambiguous. In one of the latter cases (logit 9), the model was found to show comparable explanatory power using ordinal and nominal regression. In such cases, the ordinal ranking used is shown to be roughly valid, despite failing to better explain observed variability. Ordinal regression was thus preferred in this case. A second reason for this choice is that ordinal regression provides clearer generalisations about observed trends[15]. In the case where nominal regression explained a significantly higher proportion of observed variability (logit 8), it was preferred. This follows because while R-square measures are an imprecise gauge of explanatory power[16], large differences in these statistics for a given dependent variable may be interpreted as evidence that the technique giving the larger value is preferable. In the latter case, while it was not possible to specify overall correlates for significant factors, observed trends between factors and the dependent variable were assessed using cross-tabulations and associated statistics.

Thus, the different logit models were assessed using different techniques, depending on the nature of the dependent variable. These included binary logistic regression (models 2 - 6), ordinal logistic regression (models 1, 7 and 9), and nominal logistic regression (model 8).

The regression findings appear in full in Appendix D. Some of these findings are complex, notably those involving multinomial regressions and/or multinomial explanatory factors (see Appendix C). While important, these complexities diverge from the focus of the present study, namely to assess the added explanatory power afforded by including diverse knowledge variables into tree management models. Instead, simplified summary

[15] For instance, if the dependent variable is ranked then the regression results may show clear directional trends with individual ranked factors, even if the overall regression is not amenable to ordinal regression.
[16] R-square values tend to increase as the number of factors increases, even if these factors are not statistically significant. Moreover, such increases reduce the efficiency of factors already in the model, since they reduce the number of degrees of freedom.

tables suited to this focus are presented below. For each regression model, the various factors found to be significant at 10% were reported along with their coefficients[17], standard errors and significance levels[18]. Where possible, the odds ratio[19] was also reported, as was the question of whether the confidence interval suggested a reliably directional relationship with the dependent variable[20]. The latter question was assessed for binary and ordinal regressions but not nominal regressions, while the odds ratio was generated for binary and nominal regression but not for ordinal regressions.

Because nominal regression generates separate coefficients for each constituent logit of the multinomial model, factors included in the model may or may not be significant to a particular logit, despite being significant to the overall model.

Diagnostic tests for the regression analysis are discussed in Appendix C. These assessed the evidence of collinearity among independent variables analysed, and considered the problems of heteroscedasticity and autocorrelation. Generally speaking, the multicollinearity diagnostics revealed only a modest level of collinearity. Several key continuous variables were transformed to minimise the danger of heteroscedasticity, while the data were not affected by autocorrelation.

5.3 Theoretical model of farm tree management

The proposed theoretical model of farm tree management includes two distinct parts, one relating farm trees to total farm production (A), and one relating farmer knowledge and perceptions to tree cultivation (B). The key question in part A is how local trees stocks – whether farm-based or off-farm, whether naturally-occurring or cultivated – affect farm production under different conditions. The key questions in part B are (i) what fraction of household labour and other household resources are allocated to investing in farm-based natural resources via tree cultivation, and (ii) how does farmer knowledge influence a household's perceptions of the value of farm trees. The focus variable in each equation is highlighted.

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[17] Where multinomial factors occurred in either binomial or ordinal regressions, the several coefficients generated for each such variable were approximated into a single coefficient by running the regression with this variable as a continuous variable.
[18] Statistical significance of regression coefficients was assessed using the Wald statistic.
[19] The odds ratio indicates the change in the probability of an event occurring given an additional unit of a factor. It thus clearly shows the relationship between a factor and an outcome.
[20] The 95% confidence interval for a given factor shows the range of plausible values for either the odds ratio (nominal logit case) or the coefficient (binary logit case). A key question is whether this interval includes the critical value for which a change in the factor has no impact on the likelihood of the outcome, since an interval including this value suggests that the factor does not reliably influence the outcome. In the case of ordinal regression this critical value was zero, while in the case of nominal regression it was one.

Although this is not explicitly noted, the theoretical model contains a time element. Ideally, each equation should therefore be represented by two equations signifying a chronological sequence, but in the interest of clarity this was not done. Instead, it should simply be understood that cultivating trees is an investment of resources towards a future outcome, and that whenever trees are cultivated, the household in question must wait before the anticipated benefits of possessing additional trees materialise. The only explicit recognition of this time element in the model is the separation of resource inputs into tree management into separate components reflecting exploitation of trees and investment in trees.

Although the theoretical model is a complex system involving dynamic feedback loops, it is presented as a multi-stage sequential system. This is done to focus on a linkage neglected by existing theory, namely, the idea that differential farmer knowledge and perceptions, referred to collectively as 'local knowledge' (LK), may significantly impact tree management patterns independently of the impact of tangible resource constraints. Yet factors such as R, T, S and Y clearly also influence LK. Indeed, it is precisely because shifts in the relative abundance of these factors may not be adequately taken into account by farmers – or knowledge providers such as extensionists – that local knowledge becomes an issue.

Equation A is a production function emphasising the role of farm trees in household production, while the three equations in part B highlight the key factors affecting this particular input into the production function. Farm production is influenced both by the specific variables included in the production function – including farm trees – and by the remaining household resources, which are collectively represented by the term 'R'. The latter are grouped together purely because they are not the focus of the present discussion.

Equation B1 highlights the key determinants of tree cultivation by households. To be precise, it signifies intensity of tree management intensity, but it is written as tree cultivation in the interest of making the model intuitive. One fundamental determinant is how labour and other household resources are allocated between exploitation and investment, i.e., the fraction of these resources allocated to investment in the form of tree cultivation. While cultivating trees involves various resources, labour inputs are emphasised as the critical input. A second fundamental determinant of tree cultivation is the perceived value of farm trees to the household. Because the resource allocation decision depends critically on this perceived value, the latter is multiplied by household resources in the equation to give the actual level of tree cultivation.

Equation B2 highlights the fact that while the perceived value of farm trees clearly depends on household resources, available tree stocks, and substitutes for tree goods and services, it may also depend on knowledge and perceptions vis-à-vis trees. For instance, it is clear that if a household owns livestock, this affects the actual value of farm trees, since they may provide dry season fodder or may make tree cultivation difficult by grazing seedlings, among other effects. Yet such factors will only affect the perceived value of farm trees if they also are recognised as significant by farmers, e.g., farm trees may only be seen as advantageous to livestock if their fodder provision function is recognised.

Equation B3 contains the essence of the theoretical model, with its focus on local knowledge informing the perceived value of trees to the household, which in turn informs the allocation of resources to tree management. Local knowledge is presented as a variable to suggest that it can display differing quality, i.e., it may be better-suited or worse-suited to the contemporary farm context[21]. The MSK-based information provided to rural communities is also presented as a variable and may likewise be better or worse suited to the farm context. It follows that if they are to accurately inform household management decisions, both local knowledge and the information provided to rural communities must first be adapted to the local, contemporary context.

The effect of the various independent variables on each dependent variable, *ceteris parabis*, is briefly described.

- Equation A: Larger amounts of the household resources L and R tend to increase farm production. Following the study's emphasis on the role of trees in bolstering rural livelihoods, trees from whatever source – cultivated trees, naturally-occurring farm trees, off-farm trees – are deemed to increase production. Finally, the various substitutes for the goods and services potentially provided by trees likewise increase farm production.

- Equation B1: Depending on the household resource in question, larger amounts of the resource may either increase or decrease tree cultivation. Null and alternative hypotheses for the various resources are listed below. The perceived value of farm trees increases tree cultivation.

- Equation B2: Like any resource, trees show diminishing marginal returns, so larger numbers of trees from whatever source tend to reduce the value of farm trees. The availability of off-farm trees is particularly

[21] While local knowledge about managing local trees is expected to be roughly optimal as long as the farm context remains static, this may cease to be true if the context changes rapidly. In such cases, local knowledge ill-suited to the contemporary context may cause sub-optimal allocation of resources to tree cultivation.

significant to determining the value of farm trees. This follows both because off-farm trees may be far more numerous than farm trees and because farm trees often function as a substitute for off-farm trees where the latter are scarce. Since purchased farm inputs act as substitutes for diverse goods and services otherwise provided by trees, higher prices for such inputs increase the value of farm trees. Labour and other household resources influence the value of farm trees by defining household need as well as its capacity to respond to that need. Finally, local knowledge affects perceived value by determining which aspects of farm trees are factored into farmers' assessments of value.

Equation B3: The 'local knowledge' with which farmers make farm management decisions is derived from two broad sources, namely indigenous knowledge and modern scientific knowledge. Either may be more or less well-suited to the contemporary farm context, and hence may need to be adapted to this context by the household in order to ensure that it accurately informs household management decisions and allows optimal management of available resources.

$$(A)\ Y = f\{ L\ ;\ R\ ;\ (T_O + T_N + T_C + S) \}$$

$$(B1)\ T_M = g\{ (L\ ;\ R)\ (P_T) \}$$

$$= g\{ [\ (L_I + L_E)\ ;\ (R_I + R_E)\ ]\ [P_T]\ \}$$

$$(B2)\ P_T = h\{ L\ ;\ R\ ;\ (T_O + T_N + T_C)\ ;\ M_S\ ;\ LK \}$$

$$(B3)\ LK = i\{ (IK)\ (A)\ ;\ (MSK)\ (A) \}$$

- **Y** signifies overall farm production, which in Shinyanga District centres on crop and livestock production, although some households also have a source of non-farm income or engage in other farm-based activities.

- **L** signifies household labour, which is allocated between $\mathbf{L_I}$ & $\mathbf{L_E}$, i.e., 'investing' in versus 'exploiting' natural resources. $\mathbf{L_I}$ involves actively facilitating natural regeneration, notably via tree cultivation, while $\mathbf{L_E}$ involves conventional labour inputs to farming, e.g., clearing fields, gathering fuel, extensive grazing.

- **R** signifies household resources other than household labour and working capital, namely land resources (farm size, soil type, land tenure, market access), labour resources (ratio of elderly, sex ratio, gender of household head) and capital resources (livestock, major and minor sources of non-farm income, labour

hired in, and farm labour hired out). These diverse factors are grouped together under the term 'R' in the theoretical model because they are peripheral to its focus. Like labour, R may also be allocated between R_I and R_E, signifying 'investing' in farm resources and 'exploiting' them.

- **S** signifies working capital, specifically purchased inputs into household production that substitute for essential goods (e.g., fuel) and services (e.g., fertilising soil) historically met by abundant natural resources, notably trees.

- $\mathbf{M_S}$ signifies the local market prices of the purchased inputs discussed above under 'S'.

- **T** signifies trees, divided into $\mathbf{T_N}$ for naturally-occurring farm trees, $\mathbf{T_C}$ for cultivated farm trees, and $\mathbf{T_O}$ for local off-farm tree stocks. In all three cases, tree variables are best interpreted as representing tree biomass rather than tree numbers.

- $\mathbf{T_M}$ signifies the intensity of tree management, which in turn determines the biomass of farm trees, whether naturally-occurring or cultivated. It represents the extent to which a household engages in tree protection and/or cultivation.

- $\mathbf{P_T}$ signifies the perceived net value of farm trees to the household, which is simply the perceived shadow price of tree products and agricultural services provided by these trees minus the perceived costs associated with them.

- **LK** signifies the knowledge, perceptions and attitudes informing household management of the farm and available natural resources. Its constituent elements are indigenous knowledge (IK) and modern scientific knowledge (MSK). IK derives from established local practice or indigenous experimentation, while MSK derives from extensionists, development projects, formal schooling or the media. To be appropriate, both IK and MSK may have to be adapted to context. Historically sound IK may need to be adapted to contemporary conditions affected by rapid population growth and resource degradation, while MSK may need to be tailored to local institutional, financial and environmental constraints.

- **A** signifies the extent to which knowledge has been adapted to the farm context. Knowledge, whether IK or MSK, may already be adapted to the farm context. When it is not, the question of the extent to which the household adapts it to the farm context becomes pertinent.

5.4 Econometric model of farm tree management

The dependent variable of a logit model, or 'logit', is defined as the log ratio of probabilities that a certain event will occur. In the case of binary logistic regression, it is a comparison between the probability of a certain event occurring and that event not occurring, while in the case of multinomial logistic regression it involves comparing the probability of each of the remaining categories with that of the reference category.

One key feature of logit models is that the dependent variable is linearly related to the various independent variables. This linear relationship is appropriate to the present analysis, since the resource variables examined represent distinct aspects of the farm system suited to being added. By contrast, it is less clear whether knowledge variables should simply be added to the tree management models alongside the resource variables. One alternative would be to multiply the knowledge variables by the resource variables to explicitly emphasise how knowledge effects interact with resource constraints. Several factors argued against emphasising interaction effects between resource and knowledge variables in this way.

- Integrating knowledge variables into the model raises the question of whether these variables are significant in their own right or rather via their interaction effects with resource variables already included in the model. To test for interaction effects, knowledge variables were explicitly linked with resource variables, and the resulting findings compared with those from a simple additive model considering only main effects. While interaction effects with some factors were significant, overall explanatory power was greatly reduced with linked models[22], suggesting that they misrepresent the impact of knowledge variables on tree management. Moreover, some resource and knowledge variables simply dropped out of the analysis, despite having been significant individually.

- More generally, it is distinctly possible that the impact of knowledge variables on tree management may be largely independent of household resources. For instance, while soil fertility and farm size may tend to be linked, such that failing to cite the soil fertilisation capacity of trees is most significant on smaller farms, this 'knowledge gap' may also be significant on larger farms, for instance if these tend to be located on inherently poorer land.

- Explicitly considering interaction effects also raises practical difficulties. In the event that a given model has either only one resource variable or only one knowledge variable, interaction effects can be highlighted

[22] For instance, explicitly emphasising these interaction effects reduced the explanatory power of the tree management intensity model by a factor of three.

by simply multiplying this one factor by the remaining factors. If, however, a particular model includes several of each type of variable, this raises the problem of which to multiply with which. If the knowledge variables lent themselves to data reduction they could perhaps be collapsed into one or two composite variables via scaling or factor analysis, but this was found to be impracticable[23], presumably because these variables represent fundamentally distinct aspects of household knowledge.

The resulting econometric model for household tree management strategy includes three versions. The first includes only resource determinants, the second integrates outside influence variables, and the third integrates local knowledge variables. These alternative versions of the generalised econometric model are labelled TMS_1, TMS_2 and TMS_3. In the interest of clarity, the factors specified in TMS_1 are not reiterated in TMS_2 or TMS_3, and the factors in specified in TMS_2 are not reiterated in TMS_3. Instead, they are simply summarised using the terms 'RVs' and 'OIVs'

Logit of TMS_1 = f {resource variables}
= f {land variables, labour variables, capital variables}
= f { (FARMSIZE + SOILTYPE + TENURE + MKTACC + INCIDENCE) +
(LABOUR + RAT.YOUTH + SEXRATIO + HHH.FEM) +
(LIVESTOCK + NFI.MAJOR + NFI.MINOR + L.IN + L.OUT) }

Logit of TMS_2 = f {resource variables, 'outside influence' variables}
= f { (RVs) + (SWAHILI + RADIO + RELIGION) }

Logit of TMS_3 = f {resource variables, 'outside influence' variables, local knowledge variables}
= f { (RVs) + (OIVs) + (KEYFODD + KEYMEDS + KEYCWOOD + FERTILISE +
HARMSOIL + HARMSHAD + MAKERAIN + OTHENVTL) }

In the case of binary logistic regression the TMS variables are of the form to the left, while in the case of multinomial regression they are of the form to the right.

$$\log\left[\frac{P(\text{event})}{1-P(\text{event})}\right] \quad ; \quad \log\left[\frac{P(\text{category}_I)}{P(\text{category}_J)}\right]$$

[23] For instance, seeking to collapse the knowledge variables into just two or three continua of variation using categorical principal components analysis was unsuccessful. With two dimensions only 40% of the observed variation was explained, while only 56% was explained with three continua of variation.

Mathematical transformation of the above equations results in the final format for the two models. Model A represents the case of binary logistic regression, and determines the probability of a sample household practising strategy 1. Model B represents the case of multinomial logistic regression, and determines the probability of a household practising either strategy 1 or strategy 2 relative to the probability of practising strategy 3[24]. In both cases, $Z = B_0 + B_1X_1 + B_2X_2 + ... + B_PX_P$ (See Appendix C for further discussion).

$$[A] \qquad \text{Prob (strategy 1)} = \frac{e^Z}{1 + e^Z}$$

$$[B] \qquad T_{Logit1} = \log \left[\frac{\text{P (strategy 1)}}{\text{P (strategy 3)}} \right] = \text{intercept} + Z \quad ; \quad T_{Logit2} = \log \left[\frac{\text{P (strategy 2)}}{\text{P (strategy 3)}} \right] = \text{intercept} + Z$$

5.5 Hypotheses relating to explanatory variables

The null hypotheses (i.e., H_0) for the independent variables included in the empirical model are listed below. Null hypotheses are based on both *a priori* considerations and past empirical work. Alternative hypotheses (i.e., H_1) are posited for seven of the fourteen resource variables[25] and one of the three 'outside influence' variables, while the case of local knowledge variables is distinct, as discussed below. In each case, the alternative hypothesis derives from the proposed theoretical model and its implications. Whether correlations are expected to be positive (+) or inverse (−) with farm tree management is also specified.

5.5.1 Resource hypotheses

In the case of each resource variable for which an alternative hypothesis was posited, this hypothesis reflects a broader, more positive view of trees and their significance to farm management and livelihood objectives. By contrast, the null hypotheses tend to emphasise the conventional view of tree management as a low-value land use, which accords well with the traditional view of trees in Sukumaland.

It follows that which hypothesis applies in any given case may be largely a function of households' perspective on tree management and its relation to livelihoods. That is, the impact of these seven resource variables on tree management patterns may depend fundamentally on household knowledge. Specifically, their impact on management may be refracted via the prism of local knowledge, such that the same resource variables cause

[24] The multinomial model is illustrated for the case of a dependent variable with only three discrete categories, and hence two discrete logits equations.
[25] None of the remaining null hypotheses are expected to be significantly affected by differential household knowledge, making alternative hypotheses irrelevant to the present study.

one management response given one knowledge prism and a different response given another knowledge prism.

Because the alternative hypotheses are associated with both a broader view of trees as a farm management tool and more intensive tree management, these hypotheses are expected to apply in situations where differential farmer knowledge was a key determinant of tree management strategy. These seven variables may thus be seen as potential indicators of situations where the knowledge of some households vis-à-vis natural resource management is problematic. Thus, where regressions are found to support these alternative hypotheses, integrating knowledge variables into the tree management models is expected to significantly increase their explanatory power.

FARM SIZE

- H_0 (+): Households with larger farms have fewer concerns about competition effects and hence are more likely to retain naturally-occurring trees. Yet they also have less need to use their land intensively and diversify their livelihood strategies, making them less likely to cultivate trees.

- H_1 (−): Households with smaller farms may have difficulty meeting their needs through cropping, and may grow farm trees to provide useful or marketable products or essential agricultural services.

HOUSEHOLD LABOUR

- H_0 (−): Larger households tend to farm land more intensively and to remove existing trees. They may also be content to rely on off-farm trees for essential tree products, even though these may be scarce given deforestation and securing needs may involve increased time gathering and herding in the bush.

- H_1 (+): Larger households are more likely to pursue intensive tree management practices such as watering seedlings and constructing protective fencing, given their capacity to meet the associated labour demands.

LABOUR HIRED IN

- H_0 (−): Given the association of hiring in labour with relative wealth, these households are expected to de-emphasise tree management due to having access to attractive alternative enterprises.

- H_1 (+): These households tend to be more educated and 'modern', and hence more likely to experiment with unconventional practices such as tree cultivation.

LABOUR HIRED OUT

- H_0 (−): Given the association of hiring out labour with relative poverty and high personal discount rates, these households are expected to de-emphasise tree management and concentrate on enterprises with shorter time horizons, e.g., cropping.

- H_1 (+): Given scarce household assets, these households may cultivate trees as a means of increasing natural capital stocks and hence improving land quality.

LIVESTOCK

- H_0 (−): Households that own livestock tend to be less inclined to grow farm trees, given historical associations of trees with livestock pests such as ticks and tsetse fly. Moreover, trees may be seen as a comparatively low-value land use, while protecting seedlings from browsing may impose labour demands as well as incurring social opprobrium.

- H_1 (+): Households with livestock may be more likely to grow farm trees if trees are seen as providing valued goods and services, notably dry season fodder.

NON-FARM INCOME / MAJOR

- H_0 (−): Households with a substantive non-farm income tend to de-emphasise tree management and other investments in land quality, since they have less available labour and have access to attractive alternatives, notably off-farm opportunities.

- H_1 (+): Households with a source of non-farm income may tend to be educated and 'modern', and may therefore be more likely to experiment with non-traditional practices such as tree cultivation.

NON-FARM INCOME / MINOR

- H_0 (−): Households possessing a minor source of non-farm income already possess a supplementary farm activity and income source, and hence have less time and need to grow farm trees.

- H_1 (+): Such households are more dynamic, proactive managers of available resources, and hence are inclined to explore alternative means of diversifying household income such as cultivating trees.

SOIL TYPE

· H_0 (–): Given its inherent fertility and capacity to retain water, households possessing an area of *mbuga* soil are not expected to cultivate trees, as they have less need to bolster land quality and may not wish to allocate valued land to trees.

LAND TENURE

· H_0 (+): Only households with private tenure to their land are confident they will reap the longer-term benefits of investments in land quality such as tree cultivation or soil and water conservation.

MARKET ACCESS

· H_0 (+): Because tree products may be marketed, ready access to markets increases the likelihood of tree cultivation. This is especially likely with exotic fruit trees, especially if their fruits are heavy and perishable.

RATIO OF YOUTH

· H_0 (–): Households with a high ratio of youth tend to manage trees less intensively, since they have more strength and energy to cultivate their fields intensively and pursue other higher-value activities.

SEX RATIO

· H_0 (+): Households with a high ratio of males tend to retain naturally-occurring farm trees, since they have fewer women to gather tree products from the bush. Also, in Sukuma society tree planting is a gendered activity practised by men.

GENDER OF HOUSEHOLD HEAD

· H_0 (+): Households headed by women are more likely to grow farm trees despite the gendered nature of tree cultivation, since these provide tree products that women would otherwise have to gather from the bush.

OFF-FARM TREE STOCKS

· H_0 (–): Off-farm tree stocks reduce tree management, since they lower the value of farm-based trees. Yet this substitution effect depends on whether the goods and services of interest are adequately supplied by off-farm tree stocks.

5.5.2 Outside influence hypotheses

Of the following three variables, two are conventional knowledge proxy variables while the third, RELIGION, may be characterised as more of an attitudinal variable. While these variables may influence household knowledge, they are largely independent of the local knowledge variables presented below, as demonstrated by the pairwise correlations conducted when testing for multicollinearity.

SWAHILI

- H_0 (+): Exogenous knowledge increases the intensity and extent of tree cultivation. It makes farmers more critically-minded, less wedded to tradition, and more aware both of emerging opportunities associated with markets and emerging challenges associated with resource degradation.
- H_1 (–): Since tree management in peasant communities typically only involves managing locally-available natural resources, it may not require exogenous knowledge in order to be efficient. Indeed, such knowledge may be inappropriate to the farm context and may encourage sub-optimal management practice.

RADIO

- H_0 (+): Because listening to the radio provides access to outside information and 'modern' ideas, it encourages dynamic responses to emerging opportunities, notably in cases where these responses challenge traditional practices and ideas.

RELIGION

- H_0 (+): Converting to either Christianity or Islam from the Sukuma indigenous religion shifts household attitudes away from traditional ideas, making people less reliant on unseen powers and more likely to act as agents of positive change. As such, they are more likely to engage in active tree management as a means of meeting livelihood challenges.

5.5.3 Local knowledge hypotheses

Following the theoretical model, 'local knowledge' of peasant households about trees and their role in the farm system may critically affect tree management independently of household resource constraints. Local knowledge is here broadly defined to include elements such as recognition of specific resource characteristics

or linkages within the farm system, understanding how best to manage these linkages, and attitudes affecting views of natural resources and human agency.

Management decisions – and the impact of resource variables on management – may depend on whether trees are seen more as competing with or symbiotic to crop and livestock production, and hence how highly they are valued. Specifically, it may depend on perceptions about the products and services they provide and the costs they impose. Ultimately, such distinctions determine whether trees are viewed as a high-value resource meriting intensive cultivation, as a low-value means of employing underutilised land with minimal effort, or as adverse to key farm enterprises and meriting removal from the farm.

As in the case of the resource hypotheses, null hypotheses are based on both *a priori* considerations and past empirical work, while alternative hypotheses are based on the proposed theoretical model and its implications. In contrast to the cases of the resource and outside influence variables, the null and alternative hypotheses are first presented as a general case for all the local knowledge variables collectively before individual hypotheses are specified.

LOCAL KNOWLEDGE: GENERAL CASE

- H_0 (none): Local knowledge closely reflects actual opportunities and needs defined by resource constraints. That is, it mirrors the incentives facing farmers. As such, it does not independently affect tree management practice. Integrating LKVs into regression models is therefore redundant. Cases where a farmer fails to cite a particular aspect of a tree indicate that this aspect is insignificant in the situation in question, not that he or she lacks recognition or understanding.

- H_1 (–): Given rapid changes to the rural context associated with population growth and resource degradation, local knowledge may fail to keep pace with changing incentives associated with changes in available resources. Such outdated knowledge may lead farmers to neglect advantageous investment in natural assets, including tree cultivation.

Individual hypotheses may be specified based on this generalised dichotomy. Null hypotheses do not appear in this listing, however, since given the nature of these variables such hypotheses would simply suggest that each variable does not have an independent impact on management practice. By contrast, specifying alternative hypotheses for these variables is useful. This follows because in cases where the knowledge of some

households diverges from their tangible incentives due to 'knowledge failure', either possessing or not possessing a specific type of knowledge may significantly impact tree management decisions. In each case, the alternative hypothesis specifies the expected impact of possessing the knowledge in question relative to cases where agents lack this knowledge.

KEY TREE PRODUCT

· H_1 (+): Households which prioritise valued tree products tend to manage trees more intensively, relative to those which prioritise low-value products such as fuelwood. Valued tree products include construction wood (useful or marketable wood), herbal medicine (affordable alternative medicines), and livestock fodder (nutrient-rich dry-season fodder).

SOIL FERTILISATION EFFECT

· H_1 (+): Farmers recognising the capacity of trees to fertilise soils tend to manage trees more intensively, since crop production is the primary activity of most survey households yet soils are reported to be degraded and infertile.

'TREES MAKE RAIN'

· H_1 (+): Households subscribing to this theory tend to manage trees more intensively, since the capacity to induce rainfall would be highly positive in this semi-arid zone. Yet this variable may be subject to density dependence.

OTHER ENVIRONMENTAL SERVICES

· H_1 (+): Households that view trees as providing windbreak, erosion control and microclimate effects tend to manage trees more intensively, given the positive impact of these environmental services on crop production.

TREES HARM CROPS

· H_1 (–): Households who view trees as harmful to crop production, whether via shading or soil effects, are expected to manage trees less intensively, all else being equal. They are especially unlikely to grow trees in their fields.

5.6 Empirical findings

The regression findings for the nine logit models are summarised in Tables 5.10 through 5.18 (see end of present chapter) and presented in full in Appendix D. Reiterating, these models examine distinct yet often overlapping categorisations of tree management practice. Because each model emphasises different aspects of tree management, these various models may be said to represent different windows onto contemporary tree management in Shinyanga District.

The following analysis emphasises variables found to be key determinants of tree management generally, i.e., those that were significant determinants of at least several different tree management models. Only a subset of the factors considered as possible determinants met this criterion. Namely, all but four of the fourteen resource variables examined were found to be significant in only a small number of cases, if at all[26]. Otherwise, two of the three outside influence variables and six of the eight local knowledge variables were found to be key determinants of tree management practice. How each of the key determinants relates to specific tree management patterns was examined based on the empirical evidence[27]. The empirical findings were then compared with theoretical expectations about the determinants of technology adoption. Finally, the various tree management models were characterised before implications of the overall analysis and alternative interpretations were discussed.

5.6.1 Key resource variables

FARMSIZE

* This variable was found to be significant to seven of the nine regression models, in five cases at the 1% (**) significance level and in a further one case at the 5% (*) significance level.
* Positive associations
  - Farm tree numbers [LOGIT 1**]
  - Retaining trees but not planting them [LOGIT 4**]
  - Cultivating non-fruit trees [LOGIT 8**]
* Inverse associations
  - Sales of tree products [LOGIT 2]
  - Cultivating exotic fruit trees [LOGIT 5**, LOGIT 8**]

[26] The one exception is INCIDENCE, which was not identified as a key variable due to its low explanatory power in the models where it was found to be significant.
[27] For instance, if livestock holdings are often found to be a significant determinant of tree management strategy, with which specific tree management patterns do they tend to be associated?

- Tree management intensity [LOGIT 7**]
- Both planting and watering trees [LOGIT 7**]

* Relation to the FARMSIZE hypotheses
  - The findings support both the null and alternative hypotheses. On the one hand, more naturally-occurring trees are retained on larger farms. On the other, households with smaller farms are more likely to cultivate trees, particularly friut trees, as a dynamic response to scarce household assets.

LABOUR HIRED IN

* This variable was found to be significant to six out of the nine regression models, in two cases at the 1% significance level and in a further three cases at the 5% significance level.
* Positive associations
  - Sales of tree products [LOGIT 2**]
  - Tree management intensity [LOGIT 7**]
  - Cultivating non-fruit trees [LOGIT 8*]
  - Cultivating trees in fields [LOGIT 9*]
* Inverse associations
  - Neither planting nor retaining farm trees [LOGIT 3*]
  - Retaining farm trees but not planting them [LOGIT 4]
* Relation to the LAB.IN hypotheses
  - The findings support the alternative hypothesis, which suggests that because these households are better-off and have broader experience, they are more likely to pursue non-traditional practices like tree cultivation.

LABOUR HIRED OUT

* This variable was found to be significant to five out of the nine regression models, in three cases at the 5% significance level.
* Positive associations
  - Sales of tree products [LOGIT 2*]
  - Tree management intensity [LOGIT 7*]
  - Cultivating exotic fruit trees [LOGIT 8]
* Inverse associations

- Farm tree numbers [LOGIT 1*]
- Neither planting nor retaining farm trees [LOGIT 3]

* Relation to the LAB.OUT hypotheses
  - The findings support the alternative hypothesis that tree cultivation may be seen by poor households as a useful aspect of their livelihood strategy. The data also partly support the null hypothesis, since those who hire out their labour tend to have fewer trees on their farm.

LIVESTOCK

* This variable was found to be significant to six out of the nine regression models, in two cases at the 1% significance level and in a further two cases at the 5% significance level.
* Positive associations
  - Sales of tree products [LOGIT 2]
  - Cultivating exotic fruit trees [LOGIT 5**]
  - Tree management intensity [LOGIT 7*]
  - Cultivating trees in fields [LOGIT 9*]
* Inverse associations
  - Neither planting nor retaining farm trees [LOGIT 3**]
* Relation to LIVESTOCK hypotheses
  - The findings support the alternative hypothesis, which suggests that households with livestock are more likely to cultivate trees due to seeing them as providing valued goods and services.

5.6.2 Key outside influence variables

RELIGION

* This variable was found to be significant to seven of the nine regression models, in four cases at the 1% significance level and in a further two cases at the 5% significance level.
* Positive associations
  - Farm tree numbers [LOGIT 1**]
  - Cultivating exotic fruit trees [LOGIT 5]
  - Cultivating indigenous fruit or exotic fruit trees [LOGIT 8**]
  - Tree management intensity [LOGIT 7**]
  - Planting trees in fields [LOGIT 9*]

* Inverse associations
    - Neither planting nor retaining farm trees [LOGIT 3**]
    - Retaining farm trees but not planting them [LOGIT 4*]
* Relation to RELIGION hypotheses
    - The findings support the proposed hypothesis that exposure to non-traditional ways of thinking encourages active tree management[28]. This seems to stem from the attitudes towards causality and cosmology associated with the Sukuma indigenous religion, as elaborated in section 4.1.5.

RADIO

* This variable was found to be significant in five of the nine regression models, in two cases at the 1% significance level and in a further two cases at the 5% significance level.
* Positive associations
    - Sales of tree products [LOGIT 2*]
    - Cultivating exotic fruit trees [LOGIT 5**, LOGIT 8*]
    - Tree management intensity [LOGIT 7**]
    - Planting trees in fields [LOGIT 9]
* Inverse associations
    - Neither retaining nor cultivating farm trees [LOGIT 7**]
    - Cultivating indigenous fruit trees [LOGIT 8*]
* Relation to RADIO hypothesis
    - Supports the null hypothesis that access to outside information and ideas has a positive impact on tree cultivation, particularly cultivation geared to market production as opposed to directly providing household products or agricultural support services.

5.6.3 Key local knowledge variables

KEYFODD

* This variable was found to be significant to five of the nine regression models, in four cases at the 1% significance level and the final case at the 5% significance level.
* Positive associations
    - Retaining trees but not planting them [LOGIT 4**]

[28] Indeed, religion was by far the strongest outside influence on tree management.

* Inverse associations
    - Cultivating exotic fruit trees [LOGIT 5*]
    - Cultivating either indigenous or exotic fruit trees [LOGIT 8**]
    - Cultivating trees generally [LOGIT 7**]
    - Planting trees in fields [LOGIT 9**]

KEYMEDS

* This variable was found to be significant to five of the nine regression models, in two cases at the 1% significance level and in a further two cases at the 5% significance level.
* Positive associations
    - Planting and watering indigenous fruit or non-fruit trees [LOGIT 6**]
    - Tree management intensity [LOGIT 7*]
    - Cultivating non-fruit trees [LOGIT 8**]
    - Tree cultivation generally [LOGIT 9]
* Inverse associations
    - Retaining trees but not planting them [LOGIT 4*]

KEYCWOOD

* This variable was found to be significant to five of the nine regression models, in three cases at the 1% significance level and in the final two cases at the 5% significance level.
* Positive associations
    - Planting and watering indigenous fruit or non-fruit trees [LOGIT 6**]
    - Tree management intensity [LOGIT 7**]
    - Cultivating exotic fruit or non-fruit fruit trees [LOGIT 8*]
    - Cultivating trees in fields [LOGIT 9**]
* Inverse associations
    - Retaining trees but not planting them [LOGIT 4*]

FERTILISE

* This variable was found to be significant to two of the nine regression models, both at the 5% significance level.

* Positive associations
    - Cultivating indigenous fruit or non-fruit trees [LOGIT 8*]
* Inverse associations
    - Cultivating exotic fruit trees [LOGIT 5*]

HARMSOIL

* This variable was found to be significant to five of the nine regression models, in two cases at the 1% significance level and in a further two cases at the 5% significance level.
* Positive associations
    - Farm tree numbers [LOGIT 1*]
    - Planting and watering indigenous fruit or non-fruit trees [LOGIT 6*]
    - Cultivating non-fruit trees [LOGIT 8**]
* Inverse associations
    - Sales of tree products [LOGIT 2]
    - Cultivating exotic fruit trees [LOGIT 5**, LOGIT 8**]

HARMSHADE

* This variable was found to be significant to three of the nine regression models, all at the 1% significance level.
* Positive associations
    - Farm tree numbers [LOGIT 1**]
    - Sales of tree products [LOGIT 2**]
    - Cultivating exotic fruit trees [LOGIT 5**]
* Inverse associations: None

5.6.4 Summarising findings vis-à-vis local knowledge

The consistently high significance of the three 'key product' variables suggests that tree products are central to households' thinking vis-à-vis trees, representing the dominant tree benefit in their view that must be weighed against tree costs. By contrast, the only tree service found to be a significant determinant of tree management patterns was soil fertilisation, and references to this factor were not nearly as strongly or consistently significant to tree management practice as references to tree products or tree costs.

Households citing either KEYCWOOD or KEYMEDS were much more likely to cultivate trees than others. Assuming that farmer knowledge is a significant cause of differential tree management – while recognising that the causality of such associations is complex – the implication is that construction wood and herbal medicine are seen as valuable products, and perhaps as valid reasons for tree cultivation. More generally, the findings imply that the importance of construction wood and herbal medicine is differentially appreciated by those who are more positively disposed towards trees, as indicated by having experimented with tree cultivation. By contrast, those more ambivalent towards trees may only emphasise the most obvious tree products, namely fuelwood and fruit, while de-emphasising their more subtle aspects.

Conversely, households citing KEYFODD were relatively unlikely to cultivate trees but relatively likely to retain trees, suggesting that this product is seen as low-value, and not as a valid basis for cultivating trees. These households are particularly unlikely to cultivate exotic fruit trees or trees in fields, suggesting that they do not tend to value trees highly. This finding has major practical implications, since it clearly suggests that the potential benefits of tree management to livestock tend to be downplayed by District households, despite the potential significance of this linkage to livelihood outcomes.

The strong positive association of HARMSHADE with cultivating exotic fruit trees and sales of tree products suggests that despite recognising this disadvantage of growing farm trees, households citing this factor concluded that tree cultivation was worthwhile. In the case of exotic fruit trees, this assessment includes both relatively dense shade and the promise of cash earnings from the sale of fruit.

The variables FERTILISE and HARMSOIL may be considered together, since both represent tree-crop interactions occurring via soil. Paradoxically, the findings vis-à-vis these two variables appear to be contradictory. Notably, the former suggests that non-fruit trees but not exotic fruit trees are associated with positive soil impacts[29], while the latter suggests the reverse.

One possible explanation is that these different trees tend to be located on different parts of the farm, with non-fruit trees more closely associated with crops and hence more likely to impact them negatively, while exotic fruit trees are unlikely to be grown near crops. As a result, positive fertilisation effects but also broader crop

[29] The positive association of soil fertilisation with non-fruit trees reflects the positive view of tree-crop interactions associated with agroforestry practices. This view reflects the scientifically-established fact that such trees tend to be more advantageous to soils and more compatible with crops than fruit trees.

harm are associated with non-farm trees[30], while exotic fruit trees fertilise soils yet are not associated with crop harm via competition for water, allelopathic effects or root strangulation.

An alternative possible explanation is that households cultivating exotic fruit trees view trees differently due to the cash benefits associated with fruit sales. These households may tend to view trees with the proverbial rose-coloured glasses, emphasising their positive attributes while downplaying their disadvantages. Conversely, those growing non-fruit trees may tend to be more critical of trees.

More generally, the fact that the data for HARMSOIL were significantly stronger than those for FERTILISE suggests that tree costs associated with negative soil effects were seen as more significant determinants of tree management decisions than perceptions of a soil fertilisation effect. It also suggests that trees' capacity to improve soil quality by minimising wind erosion was not seen as significant, despite strong winds and documented wind erosion problems in the District.

Finally, households with larger numbers of farm trees are strongly associated with harmful crop impacts via both shading and 'soil' effects, so households with more farm trees clearly recognise the negative impacts of trees on crops. These households also emphasise diverse tree products, reflecting an appreciation of more minor tree products, not just fuelwood and fruit. The capacity of trees to fertilise soils was not associated with larger tree numbers, however. A possible interpretation of this overall picture is that these findings reflect the relative prioritisation of tree functions. The question remains, however, as to whether tree characteristics like the soil fertilisation function and broader microclimate effects tend to be de-emphasised because they are less significant to rural livelihoods or due to erroneous perceptions among households stemming from 'knowledge failure'.

5.6.5 Variables not generally found to be significant

Several broad possibilities could account for the finding that various factors were insignificant to the tree management models generally. If a factor was found to be insignificant, the simplest explanation is that it simply has no clear relationship with tree management. A second possibility is that opposing impacts on tree management – such as those reflected in the null and alternative hypotheses – cancel each other out. A third

[30] This suggestion is supported by the fact that many households cultivating non-fruit trees cited both a soil fertilisation effect and crop harm via soil effects, implying that they recognise both near-term competition effects and longer-term positive impacts on soil.

possibility is that the data on resources were simply too rough to highlight subtle linkages, while a fourth is that the tree management categories examined were too general[31].

General observations aside, possible explanations for why the remaining resource variables were found to be insignificant include the following:

- Soil type: Households may remove trees from *mbuga* fields due to the legal prohibition on cultivating trees in conjunction with cotton. Yet they may also cultivate trees on *mbuga* soils due to their improved chances for survival.
- Ratio of youth: Households at an earlier stage in their life cycle have more energy to engage in diverse occupations, some of which may be preferable to tree cultivation. Yet they may also be comparatively receptive to novel practices.
- Sex ratio: Although tree cultivation is a gendered activity, households tend to be large and to include both men and women, such that households without able-bodied men are rare. Although women arguably stand to benefit most from farm trees due to gender-specific tasks such as fuel provision, they may encourage men to cultivate trees.
- Gender of household head: While household leadership may be important and tree cultivation may be a gendered task, the household head still consults with others, and can take decisions for the common good regardless of his/her gender.
- Incidence: One problem with this variable is that it is crude, showing only whether off-farm tree stocks are generally perceived to be stable or decreasing. Moreover, because any such changes are bound to be gradual, they may not be an important consideration in household decisions.
- Non-farm income: In both of the non-farm income variables, the data aggregated together are diverse, making these variables of questionable validity. Beyond this, different households may respond differently to having such income, such that the null and alternative hypotheses cancel each other out.
- Labour, tenure, market access: See section 5.7.1 below.

[31] As a result, certain resources could be insignificant due to operating in different directions for different subsets of the outcome group. For instance, diverse tree management practices may be classified together under the category 'planted and watered' trees, each of which may have distinct resource determinants. Within this one category, practices may include (i) cultivating fruit trees or non-fruit trees, (ii) growing trees to obtain marketed goods or consumption goods and agricultural support services, (iii) cultivating trees in the home garden or in fields, or (iv) watering trees occasionally or frequently.

5.7 Interpreting these findings

5.7.1 Theoretical expectations and empirical findings

In some cases, the empirical findings supported theoretical expectations based on the literature while in other cases they did not. Factors expected to be key determinants of tree cultivation include farm size, land tenure, market access, household labour and education[32]. Each of these factors is discussed below to highlight how these findings relate to the literature.

FARMSIZE — As expected, this variable is a key determinant of tree management practice, as seen above.

TENURE — Contrary to theory, land tenure was not found to be significant[33]. One possible explanation is that most households in the survey own at least part of their farm, and hence could simply concentrate tree cultivation in these areas if they feel insecure about investing in land quality on rented or hired land. An alternative possibility is that customary tenure fails to provide security, making such tenure unimportant.

MKTACC — Contrary to theory, market access was not found to be significant. One possible explanation is that transporting tree products to market may not constrain sales if the transactions costs are recompensed or if households' need for cash income is sufficiently great. Alternatively, tree products may be sold in local village markets or used to meet consumption needs.

LABOUR — Contrary to theory, household labour was not found to be significant. One possible explanation is that neither protecting naturally-occurring trees nor cultivating trees requires significant labour inputs, and hence that such decisions depend only on other factors. Another is that households are not labour- constrained at the points in the agricultural calendar at which tree management requires labour inputs.

SWAHILI — This proxy variable for education was not found to be significant, contrary to theoretical expectations. Arguably, the explanation lies in the nature of the technologies examined. Typically, technology adoption studies examine high-status, highly profitable technologies based on purchased inputs. It makes sense that such technologies are differentially pursued by better-off, more educated households. By contrast, the present study examines low-status technologies with gradual payback profiles, often in support of production for home

[32] By contrast, local knowledge variables were not expected by existing theory to be significant independent determinants of observed management practice.

[33] Tree planting can of course also be a means of conferring security of tenure, but the focus of the discussion is on explaining tree management practice. Moreover, tree planting is most likely to play this role where households are seeking to claim previously unused land rather than in cases where land is either borrowed or rented, as in Shinyanga District.

consumption. Outside information may be less relevant to such decisions, or simply less adept at informing them.

5.7.2 Characterising and discussing four key tree management models

Although the present analysis emphasises the impact of various determinant variables across different tree management strategies, four of the nine models are discussed below as individual cases. This was done to paint a picture of the four most distinct categories into which households may fall vis-à-vis tree management strategy.

Neither retained nor cultivated farm trees (Logit 3)

This strategy was found to be inversely correlated with cattle holdings and both hiring in and hiring out farm labour. The fact that households pursuing this strategy are unlikely to own cattle or to hire in farm labour suggests that they tend to be poor. Despite this fact, these households are unlikely to sell their labour to earn money or obtain food. One possible explanation is that given their strong association with the indigenous religion, such households rely on unseen powers to redress concerns. Integrating knowledge variables into the tree management model fails to increase its explanatory power, suggesting that these variables are *not* key determinants of this particular tree management practice.

Retained farm trees but did not cultivate them (Logit 4)

By far the strongest resource determinant of this strategy is farm size. This makes sense, given the large differences in farm size across the sample, as a result of which some households must cultivate their land intensively while others have ample land for diverse extensive uses, such as fallowing and retaining naturally-occurring trees. Two cases may be distinguished. One is households with abundant land, which automatically end up with farm trees unless they work hard to remove them. A second is households facing some degree of land scarcity that retain certain naturally-occurring trees. In the former case, households in this tree management category may or may not value trees, while in the latter case they are likely to do so.

Integrating knowledge variables into the model greatly increased its explanatory power. These findings suggest that this tree management strategy tends to be practised by those that view either fodder or fuel, but not herbal medicine or construction wood, as the most significant product of local trees. The implication is that

those who simply retain trees instead of cultivating them tend to view trees as a potentially useful but essentially low-value resource.

Cultivated exotic fruit trees (Logit 5)

The strongest resource determinant of this tree management strategy was farm size, with which it was inversely correlated. The implication is that households with relatively scarce land resources may compensate for this fact by cultivating valued trees to increase farm income. The positive correlation with livestock holdings may reflect reverse causality, whereby those with access to cash revenues from fruit sales are more able to purchase cattle, the standard store of wealth in the District.

Integrating knowledge variables into the model greatly increased its explanatory power. Unsurprisingly, those households favouring this strategy prioritise fruit as a key tree product (see Table 5.7) and view trees as being harmful to crops via shading. Less obvious are the inverse correlation with trees harming soil and the positive correlation with fertilising soil, which together suggest that these households view trees as having a positive impact on soils. Whether this view preceded their cultivation of trees or resulted from it is unclear, however.

Planted & watered indigenous fruit or non-fruit trees (Logit 6)

The low overall explanatory power of the resources-only model suggests that it fails to capture the key determinants of this particular tree management strategy. Integrating knowledge variables into the model greatly increased its explanatory power, albeit from a low level. The seven-fold increase obtained underlines the significance of knowledge variables to explaining this particular tree management strategy. These findings suggest that this strategy tended to be practised by those for whom the tree product of greatest interest was either construction wood or herbal medicine, but not fruit or fuel. One implication is that this strategy was associated with supplying valued products to households rather than growing fruit for market sale, while a second is that providing fuelwood was not seen as a sufficient basis for cultivating trees.

5.7.3 Implications of the regression findings

The single clearest implication of the empirical findings is that integrating local knowledge variables into regression equations can greatly increase their explanatory power under certain circumstances, notably in low-potential agricultural areas faced with a rapidly changing rural context. While integrating conventional knowledge proxy variables and other 'outside influence' variables was also significant in some cases, such

Table 5.7 Cross-tabulation of tree management models with key product data

	Livestock fodder			**Herbal medicine**			**Fruit**			**Construction wood**			**Fuelwood**		
	Dir-ection	Spearman's rho	Sig-nificance	Dir-ection	Spearman's rho	Sig-nificance	Dir-ection	Spearman's rho	Sig-nificance	Dir-ection	Spearman's rho	Sig-nificance	Dir-ection	Spearman's rho	Sig-nificance
Logit 1															
Logit 2							+	0.35	0%				–	0.23	0%
Logit 3							–	-0.17	0%						
Logit 4	+	0.19	0%	–	-0.16	1%	–	-0.22	0%	–	-0.18	0%			
Logit 5	–	-0.13	2%				+	0.65	0%				–	-0.29	0%
Logit 6				+	0.14	1%	–	-0.13	2%	+	0.13	2%			
Logit 7	–	-0.11	6%	+	0.19	0%	+	0.27	0%	+	0.02	0%			
Logit 8				+	0.18	0%				+	0.19	0%			
Logit 9	–	-0.17	0%	+	0.16	1%	+	0.26	0%	+	0.22	0%			

variables were not found to be nearly as significant as the knowledge variables. Indeed, as highlighted in Table 5.8, the explanatory power of the logit regressions incorporating only resource and outside influence variables was generally doubled by the incorporation of knowledge variables.

Household knowledge was broadly defined to include recognition and implicit valuation of diverse economically relevant aspects of farm trees. These aspects include tree products such as fruit or construction wood, tree services such as soil fertilisation or serving as a windbreak, and tree costs stemming from harm to either cropping or livestock. Such aspects of household knowledge were found to be significant determinants of the tree management models analysed, yet some were much more consistently significant to the models than others, as seen in Table 5.9[34]. Perceptions of tree products were found to be particularly significant determinants of tree management practice, while perceptions of harmful impacts on cropping were also key determinants. By comparison, perceptions of environmental services were found to be relatively insignificant.

Although the 'outside influence' variables were also sometimes significant, as a group they were less powerful than local knowledge variables at explaining tree management practice. Insofar as Swahili language skills serve as a proxy not only for education but also for contact with extensionists and development projects, the minimal significance of this variable suggests that such contacts do not strongly impact management decisions. By contrast, the high significance of the HASHI variable suggests that institutional contacts can be significant.

The generally higher explanatory power of the local knowledge variables relative to outside influence variables may be attributable to the nature of the technologies in question, namely low-status technologies with gradual payback profiles whose principal function is supporting production for home consumption. With such technologies – which may be critically important in low-potential areas – local knowledge variables appear to be more significant determinants of technology adoption than factors such as schooling or extension contact.

Another implication is that tree cultivation is not typically resource-constrained in a fundamental sense, since it may require only marginal inputs of available resources. Notably, it does not appear to be constrained by labour, in contradiction to existing theory[35]. The key question, therefore, may be whether tree cultivation is

[34] Factors not found to be significant in any cases were not included in this summary table. These factors included MKTACC, LABOUR, SEXRATIO, GENDERRAT, FEM.HHH.

[35] Indeed, tree cultivation could even reduce net resource demands if it represents an advantageous technological innovation, such as allocating a short amount of time each day to growing farm-based fuel supplies instead of spending hours searching for fuelwood in the bush.

Table 5.8 Overall explanatory power (i.e., R^2) of different versions of the logit models

Regression Model	RVs Only Case	RVs and MVs	RVs and KVs	Multiple gained
Logit 1	11.3%	14.5%	26.2%	1.8
Logit 2	12.1	17.5	21.5	1.2
Logit 3	11.5	15.5	No change	0.0
Logit 4	8.6	15.5	26.7	1.7
Logit 5	8.1	No change	30.4	3.8
Logit 6	1.8	No change	12.9	7.2
Logit 7	8.6	12.0	22.6	1.9
Logit 8	14.8	21.0	46.6	2.2
Logit 9	5.8	12.8	20.8	1.6

Source: Shinyanga District household survey, 2000

Table 5.9 Summary of factors found to be significant for the different tree management models

Factors	Logit 1	Logit 2	Logit 3	Logit 4	Logit 5	Logit 6	Logit 7	Logit 8	Logit 9	Total
FARMSIZE	+**	–		+**	–**		–**	Y**	–*	7
TENURE	+**				+*					2
SOILTYPE						+				1
LAB.IN		+**	–*	–			+**	Y*	+*	6
LAB.OUT	–*	+*	–				+*			4
NFI.MAJOR	+*						+			2
LIVESTCK		+	–**		+**		+*	Y	+	6
INCIDENCE		–**		–				Y	+*	4
RELIGION	+**		–**	–*	+		+**	Y**	+*	7
SWAHILI	–									1
RADIO		+*			+**		+**	Y*	+	5
HASHI	+	+**		–**			+**	Y**	+**	6
KEYFODD				+**	–*		–**	Y**	–**	5
KEYMEDS				–*		+**	+*	Y**	+	5
KEYCWOOD				–*		+**	+**	Y*	+**	5
KEYOTHER	+*									1
FERTILISE					–*			Y*		2
HARMSOIL	+*	–			–**	+*		Y**		5
HARMSHADE	+**	+**			+**					3
MAKERAIN	–	–					–			3
OTH.ENVTL		+								1

Source: Shinyanga District household survey, 2000

seen by households as an advantageous use of limited household resources, as determined by both tangible resource constraints and intangible factors such as farmer knowledge[36].

Thus, the data broadly support the contention of the proposed theoretical model that local knowledge variables may be key determinants of tree management practice under certain conditions. Implications include that local knowledge may fail to reflect the incentives faced by households, and that this knowledge may affect tree management practice independently of resource effects. Whether or not a household demonstrates knowledge about particular tree characteristics may therefore be relevant to understanding its management decisions, since failure to do so may mean the household lacks this knowledge.

5.7.4 Alternative interpretations of the data

While these findings appear to support the proposed theory that farmer knowledge broadly defined[37] is a key determinant of tree management practice, other interpretations of the findings are possible.

One alternative possibility is that the 'knowledge variables' found to be significant determinants of tree management practice actually reflect household resources not accounted for by the resource variables in the analysis. As noted, the resource data collected were often highly general and were only gathered on a limited number of resources. For these reasons, many subtle yet potentially significant differences in household resources inevitably remain unaccounted for in the resources-only analysis. Via unknown mechanisms, the knowledge variables may reflect such variations in resource constraints. One possible example is that whether or not a household cited the soil fertilisation function of trees may simply depend on whether or not soil fertility was a significant problem on the farm in question[38].

The possibility that these findings may *not* represent differential knowledge raises questions that are not easily answered. The underlying problem is limitations to the depth and precision of the survey data gathered[39].

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[36] As hypothesised, tree cultivation may depend on households' differing knowledge of and attitudes towards trees. Notably, given the widely reported traditional scepticism of the Sukuma vis-à-vis trees coupled with the fact that trees were historically abundant in the study area, tree cultivation may depend on the degree to which households critically question and adapt local conventional wisdom to emerging opportunities and challenges.

[37] Dimensions of local knowledge broadly defined include recognition of specific resource characteristics, understanding of how best to manage linkages between farm components, and attitudes affecting views of natural resources and human agency.

[38] This particular explanation seems unlikely in reality, since virtually all survey households complained about problems with 'tired' soil.

[39] Notably, data problems may be an issue. Reiterating, (i) data were only collected on certain key resources, given time and personnel constraints, (ii) data on resources were only approximate, sometimes leaving considerable variability between households categorised as belonging in the same category, (iii) tree data were only collected on the three species of tree cited as most significant to the household, while other species were neglected, (iv) households were sometimes evasive or misleading about key assets such as livestock due to fears about the consequences of disclosing this information, as discussed in chapter three.

While this alternative possibility cannot be ruled out, differences in household resources were controlled for insofar as possible given the study's time and financial constraints.

A second alternative possibility is that differences in knowledge variables simply reflect the different tree species emphasised by different households. This explanation relates closely to the first possibility, since certain trees may tend to be associated with certain tangible farm characteristics. Following this logic, the locus of variation is again subtle differences in resource constraints. One example is that, given the potential profitability of exotic fruit trees, whether or not a household cited these trees may depend primarily on whether it was in a position to grow them given its resource constraints[40].

Again, this criticism raises difficult questions that demand more in-depth study. Nonetheless, the findings should still represent differential knowledge to a great degree thanks to the study's emphasis on the *several* tree types most significant to each survey household. Because households were encouraged to cite several tree species, each household had ample opportunity to mention any aspects of trees it considered significant. For instance, if a farmer considered the soil fertilisation capacity of trees to be significant yet the most significant tree did not provide this service, he could still cite a tree that did.

A third alternative possibility is that differential 'knowledge' actually represents differing household preferences. Most obviously, preferences may manifest themselves in households' choice of tree type. Thus, a household may emphasise fruit trees because its members like the taste of fruit or enjoy the task of selling fruit in local markets. Similarly, a household may emphasise a tree that provides a good windbreak due to the predilection of its members for relaxing in the home garden. Alternatively, preferences may manifest themselves in households' emphasis on certain aspects of trees. Thus, two households citing the same tree may emphasise different aspects of it, one emphasising construction wood due to a penchant for large or freshly built huts and the other emphasising herbal medicine due to an interest in herbal remedies.

Again, this is a strong criticism, since preferences are fundamental determinants of human decisions. Yet in the present study the significance of preferences is arguably minimised due to the poverty of most survey households. Simply put, poor households can ill-afford the luxury of indulging in whims based on subjective preferences, given their immediate concern with securing basic needs. Because resource allocation decisions such as how to manage trees are basic strategic decisions with clear livelihood impacts, it is unlikely that poor

[40] Despite its plausibility, this statement is not supported by the findings obtained for logit model five.

households would make decisions they believed to be disadvantageous to meeting their basic needs simply because of household preferences.

A more general potential problem with the study findings is that tree planting could simply be associated with institutional tree planting initiatives. Thus, some households that have planted trees may simply have tried tree planting half-heartedly at some point, perhaps after being given seedlings by an extensionist. The fact that these households were willing to try tree planting nonetheless differentiates them from those that were not willing to do so. Moreover, the study sought to control for this effect via the HASHI variable.

5.7.5 Concluding comments

In sum, the findings show that tree management in Shinyanga District is complex, and that considering key resource constraints and outside influence variables facing households explains only a relatively modest proportion of the observed variation in tree management practice. A significant proportion of the unexplained variation may be accounted for by integrating knowledge variables into the analysis. Although there are good reasons to interpret the findings as reflecting differential knowledge independent of households resources, the degree to which this is actually the case remains an open question requiring further examination. An initial step in this direction is taken in the following chapter, which explores the distinction between tangible differences and differential knowledge using species-specific tree data.

Table 5.10 Total number of farm trees (logit 1)

Resource variables only

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	0.50	0.13	0.0%	yes
LANDTEN	0.69	0.28	1.2%	yes
NFI.MAJOR	0.67	0.28	1.7%	yes
L.OUT	-0.56	0.27	3.8%	yes

Resource and outside influence variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	0.58	0.14	0.0%	yes
LANDTEN	0.66	0.29	2.1%	yes
NFI.MAJOR	0.49	0.30	10.0%	essentially[1]
L.OUT	-0.62	0.29	3.1%	yes
RELIGION	0.58	0.23	1.1%	yes
SWAHILI	-0.26	0.15	8.6%	essentially

Resource, outside influence and knowledge variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	0.67	0.18	0.0%	yes
LANDTEN	0.75	0.35	3.0%	yes
L.OUT	-0.65	0.34	5.8%	essentially
RELIGION	0.85	0.28	0.2%	yes
SWAHILI	-0.71	0.22	0.1%	yes
KEYOTHER	0.66	0.28	1.7%	yes
HARMSOIL	0.57	0.27	3.7%	yes
HARMSHADE	0.85	0.28	0.2%	yes
MAKERAIN	-0.52	0.29	7.3%	essentially

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	11.3%	0.0%	325
RVs & OIVs	14.5%	0.0%	308
RVs & KVs	26.2%	0.0%	227

[1] In the case of those factors listed as 'essentially', the range of the relevant statistic included the cusp point for determining directionality, but only by a margin of 0.1 or less. Because the vast majority of values showed a clear directionality and the exceptions were trivial, these factors were considered to essentially show reliable directional influence on the dependent variable. In general, it makes sense that the various factors significant to the overall model would show clear or 'essentially' clear directionality, since ambiguous directionality would imply an ambiguous overall impact on the dependent variable.

Table 5.11 Sales of tree products (logit 2)

Resource variables only

Factor	Coefficient	Standard Error	Significance	Odds Ratio
FARMSIZE	-0.62	0.35	7.5%	0.54
L.IN	0.92	0.37	1.4%	2.50
L.OUT	0.86	0.40	3.2%	2.36
LIVESTOCK	0.64	0.36	7.7%	0.53
INCIDENCE	-0.98	0.34	0.3%	0.37

Resource and outside influence variables

Factor	Coefficient	Standard Error	Significance	Odds Ratio
L.IN	0.72	0.37	5.3%	2.06
L.OUT	0.77	0.40	5.3%	2.16
LIVESTOCK	0.38	0.35	7.9%	0.69
INCIDENCE	-0.95	0.34	0.5%	0.39
RADIO	0.39	0.20	2.1%	0.68

Resource, outside influence and knowledge variables

Factor	Coefficient	Standard Error	Significance	Odds Ratio
RADIO	0.67	0.24	0.5%	0.51
HARMSOIL	-0.78	0.42	6.5%	0.46
HARMSHADE	1.41	0.43	0.1%	4.08
MAKERAIN	-0.86	0.48	7.2%	0.42
ENVT.OTH	1.37	0.45	0.2%	3.94

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	12.1%	0.1%	326
RVs & OIVs	13.0%	0.1%	326
RVs & KVs	21.5%	0.0%	268

Table 5.12 Did not plant trees or retain trees on the farm (logit 3)

Resource variables only

Factor	Coefficient	Standard Error	Significance	Odds Ratio
L.IN	-1.66	0.75	2.6%	0.19
L.OUT	-1.16	0.63	6.6%	0.31
LIVESTOCK	-0.98 / 0.12	0.69 / 0.71	1.2%	0.38 / 1.13

Resource and outside influence variables

Factor	Coefficient	Standard Error	Significance	Odds Ratio
L.IN	-1.66	0.75	2.6%	0.19
L.OUT	-1.16	0.63	6.6%	0.31
LIVESTOCK	-0.98 / 0.12	0.69 / 0.71	1.2%	0.38 / 1.13
RELIGION	-1.12	0.42	0.7%	0.33

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	11.5%	0.1%	336
RVs & OIVs	15.5%	0.0%	334
RVs & KVs	No change	-	-

Table 5.13 Retained trees on the farm but did not plant trees (logit 4)

Resource variables only

Factor	Coefficient	Standard Error	Significance	Odds Ratio
FARMSIZE	0.48	0.15	0.2%	0.62
L.IN	-0.68	0.37	6.3%	0.51
INCIDENCE	-0.54	0.29	6.1%	0.59

Resource and outside influence variables

Factor	Coefficient	Standard Error	Significance	Odds Ratio
FARMSIZE	0.49	0.15	0.1%	0.61
L.IN	-0.70	0.37	6.0%	0.50
INCIDENCE	-0.64	0.29	2.9%	0.53
RELIGION	-0.61	0.29	3.7%	0.55

Resource, outside influence and knowledge variables

Factor	Coefficient	Standard Error	Significance	Odds Ratio
FARMSIZE	0.52	0.18	0.3%	0.60
L.IN	-1.07	0.46	2.0%	0.34
INCIDENCE	-0.68	0.33	4.0%	0.51
RELIGION	-0.76	0.33	2.1%	0.47
KEYFODDS	1.57	0.56	0.5%	4.82
KEYMEDS	-1.75	0.78	2.4%	0.17
KEYCWOOD	-0.98	0.41	1.6%	0.38

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	8.6%	0.4%	289
RVs & OIVs	11.0%	0.1%	288
RVs & KVs	25.6%	0.0%	255

Table 5.14 Cultivated exotic fruit trees (logit 5)

Resource variables only

Factor	Coefficient	Std. Error	Significance	Odds Ratio
FARMSIZE	-1.12	0.29	0.0%	0.33
LIVESTOCK	0.81	0.32	1.3%	2.25

Resource, outside influence and knowledge variables

Factor	Coefficient	Std. Error	Significance	Odds Ratio
FARMSIZE	-0.98	0.34	0.3%	0.37
TENURE	0.90	0.45	4.6%	2.47
RELIGION	0.57	0.32	7.9%	1.76
RADIO	0.62	0.20	0.2%	0.54
KEYFODD	-2.43	1.08	2.4%	0.09
FERTILSE	0.90	0.37	1.6%	2.45
HARMSOIL	-1.23	0.34	0.0%	0.29
HARMSHADE	0.87	0.32	0.6%	2.39

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	8.1%	0.0%	346
RVs & OIVs	No change	-	
RVs & KVs	30.4%	0.0%	302

Table 5.15 Planted & watered indigenous fruit or non-fruit trees (logit 6)

Resource variables only

Factor	Coefficient	Std. Error	Significance	Odds Ratio
SOILTYPE	0.81	0.50	7.8%	2.24

Resource, outside influence and knowledge variables

Factor	Coefficient	Std. Error	Significance	Odds Ratio
SOILTYPE	1.12	0.65	8.4%	3.05
KEYMEDS	1.45	0.52	0.5%	4.25
KEYCWOOD	1.04	0.42	1.2%	2.84
HARMSOIL	0.84	0.43	4.8%	2.33

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	1.8%	8.0%	340
RVs & OIVs	No change	-	-
RVs & KVs	12.9%	0.1%	299

Table 5.16 Tree management intensity (logit 7)

Resource variables only

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	-0.31	0.12	0.8%	yes
L.IN	0.80	0.27	0.3%	yes
L.OUT	0.68	0.28	1.6%	yes
LIVESTCK	0.38	0.20	5.4%	essentially
NFI.MAJOR	0.50	0.28	7.3%	essentially

Resource and outside influence variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	-0.33	0.12	0.5%	yes
L.IN	0.86	0.27	0.1%	yes
L.OUT	0.80	0.28	0.5%	yes
LIVESTCK	0.38	0.20	5.4%	essentially
RELIGION	0.60	0.22	0.5%	yes

Resource, outside influence and knowledge variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	-0.29	0.14	3.5%	yes
L.IN	0.65	0.34	5.8%	essentially
L.OUT	0.53	0.34	9.2%	essentially
RELIGION	0.55	0.27	4.0%	yes
RADIO	0.45	0.17	0.7%	yes
KEYFODD	-1.34	0.54	1.3%	yes
KEYMEDS	0.89	0.41	3.0%	yes
KEYCWOOD	0.77	0.30	0.9%	yes
MAKERAIN	-0.50	0.27	6.2%	essentially

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	8.6%	0.1%	322
RVs & OVIs	10.0%	0.0%	322
RVs & KVs	22.6%	0.0%	234

Table 5.17 Type of tree cultivated (logit 8)

Note: These findings are incomplete due to the fact that nominal regression was used to analyse this model. See Appendix B for regression results presented in full.

Resource variables only

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE			0.2%	
L.IN			3.4%	
LIVESTOCK			8.6%	
INCIDENCE			8.0%	

Resource and outside influence variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE			0.0%	
L.IN			2.6%	
L.OUT			9.1%	
LIVESTOCK			4.6%	
INCIDENCE			7.9%	
RELIGION			0.5%	

Resource, outside influence and knowledge variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE			0.2%	
TENURE			5.6%	
L.IN			2.5%	
RELIGION			1.3%	
RADIO			3.0%	
KEYFODD			0.1%	
KEYMEDS			0.7%	
KEYCWOOD			1.5%	
FERTILISE			5.3%	
HARMSOIL			0.0%	

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	14.8%	0.1%	320
RVs & OIVs	19.4%	0.0%	318
RVs & KVs	43.3%	0.0%	

Table 5.18 Location of tree cultivation (logit 9)

Resource variables only

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	-0.26	0.12	2.8%	yes
L.IN	0.64	0.26	1.5%	yes
LIVESTOCK	0.45	0.25	7.4%	essentially
INCIDENCE	0.47	0.22	3.3%	yes

Resource and outside influence variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	-0.25	0.12	3.6%	yes
L.IN	0.61	0.27	2.3%	yes
INCIDENCE	0.55	0.23	1.4%	yes
RELIGION	0.51	0.22	1.9%	yes
RADIO	0.22	0.14	9.8%	essentially

Resource, outside influence and knowledge variables

Factor	Coefficient	Std. Error	Significance	Directionality reliably significant?
FARMSIZE	-0.27	0.12	3.1%	yes
L.IN	0.71	0.31	2.1%	yes
INCIDENCE	0.62	0.25	1.3%	yes
RELIGION	0.43	0.24	7.4%	essentially
RADIO	0.34	0.15	2.0%	yes
KEYFODD	-1.49	0.49	0.2%	yes
KEYMEDS	0.82	0.27	0.3%	yes
KEYCWOOD	0.70	0.39	7.0%	essentially

Summary of alternative models

Version of the model	R-Square	Chi-Square	Cases in model
RVs only	5.8%	0.9%	320
RVs & OVIs	9.1%	0.1%	320
RVs & KVs	19.1%	0.0%	283

Chapter 6

Highlighting Trends Between Species-specific Tree Knowledge and Diverse Factors

The present chapter seeks to further elucidate households' thinking using species-specific knowledge data. Its goal is to identify which tangible and intangible characteristics of farm households show statistical associations with observed patterns of species-specific tree knowledge, in the interest of suggesting which types of households fall into distinct knowledge categories. Because it involves only pairwise correlations among factors unguided by specific hypotheses, this discussion is exploratory. Yet it highlights promising future angles of inquiry, both for examining causality of distinct knowledge outcomes and for suggesting possible means of addressing knowledge gaps.

6.1 Data suggesting differential thinking vis-à-vis trees

6.1.1 Qualitative comments about trees and tree management

A representative set of qualitative comments regarding tree incidence and management are cited to convey a sense of the competing perspectives animating different subsets of survey households. Given the study's focus on how knowledge informs tree management, these comments are divided up based on the broad tree management strategy followed by households. Namely, (i) have never planted trees, (ii) have planted trees, (iii) have planted and watered trees. Where a given household employed different management strategies with different tree species, the most intensive strategy employed was taken to represent the household. Thus, a household listed as having both planted and watered may have done so for one species only, yet was nonetheless categorised as having planted and watered.

These qualitative comments elucidate the thinking behind these three broad tree management strategies. Specifically, they illustrate the study's premise that different tree management strategies go together with distinct perspectives on trees and their management. The comments also provide anecdotal evidence of these competing perspectives.

Among households that have never planted trees, household comments suggest a relatively low level of interest in trees and their potential contribution to livelihoods. This is reflected in an emphasis on fuelwood, which is thought to be seen as a low-value product that can be readily substituted by non-tree products such as crop

residues or manure. Perhaps most fundamentally, these comments convey a sense that tree growth and reproduction are not the responsibility of households. Characteristic observations included:

a. Trees grow naturally
b. Trees grow by themselves, so it does not make much sense to cultivate them.
c. When people cut them back, they grow again.
d. Years ago there were many, but now there are few
e. Trees are protected by the local forestry officer
f. We have reduced use to ensure a continued fuel supply
g. We want them to be numerous to supply us with fuel
h. These trees are decreasing because we don't have any seedlings to plant
i. People enter our fields to harvest fuelwood
j. We only protect them in the home garden
k. We stop others from harvesting them so we can use them ourselves
l. Protecting against livestock is difficult, as they like it very much

Among households that planted trees but provided them with no ongoing care, household comments signal a greater interest in trees and their potential contribution to livelihoods and a greater willingness to manage them actively. Yet the agency shown by households tends to be strictly limited, with households relying on external factors to secure the survival of newly planted tree seedlings. Characteristic observations included:

a. We plant them then leave them alone
b. If you plant them in the rainy season, they grow by themselves
c. Trees grow with difficulty due to drought conditions
d. If it does not rain enough, planted seedlings die
e. We get seedlings from World Vision each year
f. Trees are decreasing because no one brings us seedlings to plant
g. Many people plant trees in their home gardens
h. Each year people plant more
i. More are cut down than planted
j. Trees increase where protected but decrease elsewhere due to extensive cutting
k. Given the shortage of fuel, it is necessary to cut trees down
l. Protecting trees is very difficult, since livestock like to eat them and people harvest them for fuel

m. If they survive, they help us with our household needs

Among households that both planted and watered trees, household comments suggest a genuine interest in the potential importance of trees to rural livelihoods as well as a willingness to manage them actively and take responsibility for ensuring their survival. Comments may also suggest a lucid assessment of the impediments to tree survival or an emphasis on tree products of potentially great significance to household welfare. Characteristic observations included:

a. After planting a tree, we water it until it is established
b. After planting seedlings I water them, since if I left them alone they would die
c. We water the seedlings when needed
d. Trees have difficulty sprouting and surviving due to drought conditions
e. When planting trees, we fertilise them with manure
f. We protect seedlings with fencing to avoid their being destroyed by livestock
g. Tree numbers are falling because people harvest them recklessly
h. Trees stocks are shrinking due to extensive harvesting from the bush, despite this being against the law
i. We help this tree because it provides dry-season fodder

6.1.2 Perceived trends in tree incidence

Roughly speaking, farmers' comments about the incidence of key tree species show what theory predicts. Namely, they suggest that incidence of farm trees tends to increase as farmers seek to compensate for falling stocks of off-farm trees. However, looking only at the single most frequently-cited species (*Acacia nilotica,* representing 17 percent of trees cited) or at acacias generally (43 percent of trees cited) suggests that these trees tend to be static on farms but decreasing in the bush.

Table 6.1 Cross-tabulation of perceived incidence changes and key tree location

	Home garden	**Fields**	**Bush**	**Totals**
Increasing	113 (40%)	131 (46%)	38 (24%)	282 (39%)
No change	70 (24%)	41 (14%)	10 (6%)	327 (45%)
Decreasing	104 (36%)	113 (40%)	110 (70%)	121 (16%)
Totals	287	285	158	730

Source: Shinyanga District household survey, 2000

These apparently contradictory findings are elucidated by a cross-tabulation of key location with key tree

product. These data show that households emphasising trees in the home garden are likely to emphasise fruit, whereas households relying on bush-based trees often emphasise fuel as key tree product. The theory that farmers increase farm tree stocks in response to falling off-farm stocks thus seems to apply only in certain cases, notably when households prioritise fruit trees. Even here, any increases may be due either to substituting farm-based trees for falling off-farm stocks or simply to taking advantage of a novel opportunity to produce a marketable product. Meanwhile, other trees appear to be becoming increasingly scarce, notably those viewed primarily as sources of fuel.

Several problems plague the data on both tree incidence and the perceived causes of changes due to uncertainty about what precisely these data represent. Most simply, they may refer either to actual changes in incidence (and their causes) or perceptions of these changes (and causes). Second, they may refer to trees in the home garden, the fields and / or the bush. Third, it is unclear over what timeframe the farmer is assessing changes in incidence. Fourth, the farmer may be speaking in the abstract for his community generally or only about his private situation. In sum, these data may lack consistency across households, since different farmers may be referring to different trees and/or different locations.

Although real, these concerns may be less grave than they at first appear. Perceptions may be isolated from actuality by dividing up the data by village. The location of the tree stocks referred to is implied in the data on key location for particular tree species. Since the survey asks about changes 'in recent years', households are likely to focus on the past ten years, particularly since poverty induces people to de-emphasise the longer-term. Finally, given the relative scarcity of trees in the study area, farmers' comments about private needs are likely to reflect the broader needs facing the community.

In light of such questions, the tree incidence data were assessed for internal consistency, i.e., whether the changes in incidence and the explanations for these changes displayed a distinct pattern. The data showed a near-perfect correlation between these two variables. Specifically, certain trends were attributed to certain factors. These trends held whether the data were looked at in aggregate or divided into specific tree types. The linkages found appear in Table 6.2.

One useful aspect of these data is that they distinguish two *types* of reason why tree stocks may increase, decrease or remain constant. Namely, trees may grow or fail to grow either through natural processes or due to human interventions. The critical distinction is how tree replacement is viewed, namely whether it is seen as

essentially reliant on natural regeneration or rather as linked to tree protection and cultivation. Thus, one view relies on nature to produce trees ('N'), while the other sees tree growth as associated with human agency ('H'). Each of the six principal reasons cited to explain recent changes in tree stocks fits neatly into one of these two categories.

Table 6.2 Perceived incidence changes and causes

Incidence trend cited	Causes of trend cited
Increasing	'they sprout naturally' (N), 'people harvest them in moderation' (N), 'people grow them' (H)
Constant	'none were planted recently' (H)
Decreasing	'people harvest their wood' (N), 'impediments to growth' (H)

Source: Shinyanga District household survey, 2000

These two categories – N and H – suggest distinct perspectives on trees and tree management. Simply put, one category suggests a low prioritisation of trees and passive management strategy, while the other suggests a higher prioritisation of trees and more activist management strategy. While suggestive of farmer views, these findings must not be taken as firm evidence, given the ambiguities in these data highlighted above.

Whether a given household falls into one category or the other is likely to be strongly influenced by the broad tree type in question, i.e., whether the tree is an exotic fruit tree, an indigenous fruit tree or a non-fruit tree, since these categories suggest both whether or not a tree is capable of reproducing itself naturally and whether or not it produces high-value fruit. Because the correlations of tree type with perceived reasons for changes in incidence were found to be similar for indigenous fruit trees and non-fruit trees, these two types were combined, leaving only the distinction between exotic fruit trees and other trees. Overall, 84 percent of households citing an exotic fruit tree saw trees as associated with human agency, while only 35 percent of those citing other trees subscribed to this view. The sharp distinction between these cases suggests that households prioritising exotic fruit trees tend to view trees differently than others, perhaps because they associate tree cultivation with securing marketable products.

A second type of analysis seeks to separate out perceptions in incidence and their causes from actual changes by controlling for tree species and village. The idea is that if one household from a given village perceives local stocks of a certain tree to be increasing while another household perceives them to be decreasing, this difference could be attributed to differing perceptions of a common reality.

This exercise was conducted for the case of *Acacia nilotica*, the most commonly cited species in the household survey[1]. On the surface, it seems to reveal that farmers within villages made contradictory statements about this species, strongly suggesting that knowledge gaps plagued some households. For instance, three households in Idukilo cited an increase while five cited a decrease, in Mwaweja ten cited an increase while six cited a decrease, and in Masagala three cited an increase while four cited a decrease. Across the sample survey, 58 percent of households cited an increase in this species, 10 percent cited no change and 32 percent cited a decrease. These contradictions seem to be most common in villages where at least several households cited decreasing incidence, suggesting that this apparent confusion among households ensues in areas where resource degradation is pronounced, as hypothesised.

Yet before such data can be taken as indicative of knowledge gaps, all alternative possibilities must first be exhausted insofar as the data allow. Notably, the question of whether the trees in question are concentrated in the home garden, fields or bush must first be considered. Specifically, these data could only safely be interpreted as evidence of data gaps if they emphasised trees of a particular species occurring *primarily* in the bush surrounding a given village, since only then is it clear that the households in question are referring to a common physical reality. While logical, this suggestion is impracticable, since it greatly narrows down the available data points.

Even if these data points are aggregated across the twenty survey villages, the number of data points for the same tree occurring primarily in the bush is still excessively small for statistical analysis. Those species most often cited as being located primarily in the bush are three acacias, namely *A. nilotica, A. tortilis* and *A. polyacantha*. These species fulfil these criteria 11, 13 and 16 times each, respectively. The largest number of cases occurring in a specific village is as follows:

* *Acacia nilotica*: 4 in Mwigumbi (3↑, 1↓)[2], 3 in Masagala (3↓)
* *Acacia tortilis*: 3 in Manyada (2↑, 1↓), 3 in Mwigumbi (1↑, 2↓), 3 in Mwanulu (1↑, 2↓)
* *Acacia polyacantha*: 4 in Masagala (1↑, 3↓)

While the fact that these data appear to be fairly contradictory suggests the existence of knowledge gaps, the

[1] Specifically, *Acacia nilotica* was cited by 121 of the 349 survey households.

current dataset is insufficiently large to reach such an assessment. Once again, these findings are merely indicative of knowledge gaps vis-à-vis trees, but do not provide clear evidence of them. Moreover, even where direct contradictions are identified, it is impossible to say which households are plagued by a knowledge gap and which are not in the absence of additional data on trends in tree incidence.

In an effort to extract more substantive evidence of knowledge gaps out of the present dataset, the data for the four key acacia species cited by survey households were aggregated. While these species are distinct, they nonetheless display significant similarities, partially justifying this aggregation. Taken together, a total of 43 households cited either one of the three acacia species considered above or *A. drepanolobium* as being primarily located in the bush. The villages for which the largest number of households meet these criteria are as follows:

* Ibingo 3 households (1↑, 2↓)[3]
* Manyada 5 households (2↑, 3↓)
* Masagala 9 households (1↑, 8↓)
* Mwanulu 4 households (1↑, 2↓, 1=)
* Mwigumbi 8 households (5↑, 3↓)
* Shilabela 3 households (1↑, 2↓)

Once again, the fact that these data appear to be contradictory suggests the existence of knowledge gaps. Yet in addition to these data remaining thin despite the aggregation, they have the problem of representing four distinct tree species. As such, these findings remain purely suggestive.

A still more general assessment involves considering whether distinct categories of tree, namely indigenous fruit trees or non-fruit trees[4], are seen to be increasing or decreasing in the bush surrounding different villages. Because the findings for these two tree categories were similar, these data were aggregated. Taken together those indigenous fruit trees and non-fruit trees for which the bush was cited as the key location (121 cases) were seen to be increasing 20 percent of the time, decreasing 75 percent of the time and not changing 5 percent of the time. The implication is that bush-based tree stocks are generally but not always seen to be decreasing. Given the generality of this finding both across villages and different tree types, it does not make sense to try to

[2] This formulation signifies that three of these four households reported the incidence of this tree in the local bush to be increasing, while one reported it to be decreasing.

disentangle whether this represents the actual dynamics of bush-based tree stocks or rather the differential perceptions and attitudes vis-à-vis trees.

6.2 Comparing local and scientific knowledge regarding particular tree characteristics

Another way in which species-specific tree data can be used to critically examine farmer knowledge is by considering the goods and services associated with commonly cited trees. For each of the five species discussed by at least fifteen percent of survey households, the goods and services cited were compared with those identified by scientists, as listed in the World Agroforestry Center's (WAC) agroforestry database[5]. Beyond highlighting specific gaps in the knowledge of some survey households, this exercise may also highlight ways in which the scientific canon is incomplete or otherwise problematic[6].

6.2.1 Comparative data

As seen in Table 6.3, household comments and the WAC database give roughly equivalent answers for many functions associated with these five tree species. For those goods and services where this rough equivalence holds, the implication is that the farmers in the study area and the scientific canon generally agree on these aspects of the species in question. Because either body of knowledge can be viewed as a measuring stick and source of authority, either may be seen as confirming the findings of the other on these points. Those goods and services for which these bodies of data broadly agree are indicated by a 'yes' in the final column[7].

Even in such cases, it remains possible that *both* of these groups may be mistaken about an aspect of a particular tree, and hence that both may be plagued by a knowledge gap. The only circumstance in which such an eventuality might occur is one where the factor in question is obscured by the conceptual models informing both LK and MSK. One possible example of such a case is the broad issue of responses to resource degradation, since the conceptual models underlying both MSK and LK tend to take natural resources for granted.

From the viewpoint of the present study, the more interesting cases are where these two bodies of knowledge at

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[3] The number before the upwards arrow signifies cases citing 'increasing', while that before the downwards arrow signifies cases citing 'decreasing'

[4] The third broad tree type, exotic fruit trees, were not cited by households as predominantly based in the bush

[5] While the WAC database cited more different categories of tree characteristics than those considered, such as windbreak and erosion control, this comparative analysis was constrained by the data limitations of the present study, since data on some factors were only gathered at the household level but not at the level of particular tree species.

[6] These data also represent a means of comparing different households within a target community.

[7] The decision criteria for asserting agreement is whether over 70 percent of households cite this characteristic when it is cited by WAC or when under 10 percent of housholds cite it when it is not cited by WAC. In all other cases these bodies of data are deemed to disagree.

Table 6.3 Comparison of scientific knowledge with household knowledge

Acacia nilotica		WAC recognises?	Survey HHs citing it	WAC & HHs agree?
Tree products	Fruit	-	2%	Yes
	Fuelwood	Y	95	Yes
	Construction wood	Y	78	Yes
	Fodder	Y	92	Yes
	Herbal medicine	Y	58	No
	Fencing	Y	31	No
Tree services	Fertilises soil	Y	3	No
	Shade for HH / livestock	-	13	No
Tree costs	Dries / degrades soil	Y	74	Yes
	Shade harms crops	-	28	No

Acacia tortilis		WAC recognises?	Survey HHs citing it	WAC & HHs agree?
Tree products	Fruit	-	1%	Yes
	Fuelwood	Y	98	Yes
	Construction wood	Y	65	No
	Fodder	Y	80	Yes
	Herbal medicine	Y	21	No
	Fencing	Y	44	No
Tree services	Fertilises soil	Y	17	No
	Shade for HH / livestock	Y	30	No
Tree costs	Dries / degrades soil	Y	26	No
	Shade harms crops	-	36	No

Mangifera indica		WAC recognises?	Survey HHs citing it	WAC & HHs agree?
Tree products	Fruit	Y	93%	Yes
	Fuelwood	Y	84	Yes
	Construction wood	Y	5	No
	Fodder	Y	66	No
	Herbal medicine	Y	25	No
	Fencing	-	0	Yes
Tree services	Fertilises soil	Y	16	No
	Shade for HH / livestock	Y	37	No
Tree costs	Dries / degrades soil	-	5	Yes
	Shade harms crops	-	58	No

Cassia siamea		WAC recognises?	Survey HHs citing it	WAC & HHs agree?
Tree products	Fruit	-	0%	Yes
	Fuelwood	Y	96	Yes
	Construction wood	Y	88	Yes
	Fodder	Y	49	No
	Herbal medicine	Y	41	No
	Fencing	-	12	No
Tree services	Fertilises soil	Y	26	No
	Shade for HH / livestock	Y	21	No
Tree costs	Dries / degrades soil	-	19	No
	Shade harms crops		25	No

Tamarindus indica		WAC recognises?	Survey HHs citing it	WAC & HHs agree?
Tree products	Fruit	Y	88%	Yes
	Fuelwood	Y	64	No
	Construction wood	Y	36	No
	Fodder	Y	62	No
	Herbal medicine	Y	50	No
	Fencing	-	2	Yes
Tree services	Fertilises soil	-	19	No
	Shade for HH / livestock	Y	43	No
Tree costs	Dries / degrades soil	Y	0	No
	Shade harms crops	Y	57	No

Source: Shinyanga District household survey, 2000

least partly contradict one another. Such goods and services are indicated by a 'no' in the final column. These cases suggest either that (i) a significant proportion of households ignore a factor noted by WAC or (ii) households cite a factor ignored by WAC. Taking the case of *Acacia nilotica*, examples of the former include herbal medicine and fertilising soil, while examples of the latter include fencing and harmful shade effects. In cases where these two bodies of data disagree, the question of which to prioritise is problematic, and suggests an area where further study is needed.

6.2.2 Interpreting discrepancies between local and scientific knowledge

Where WAC fails to note a factor cited by significant numbers of survey households, this may be seen as evidence that scientists are ignoring aspects of trees that are important to rural people and their tree management decisions. These factors represent a challenge to scientists and development practitioners. One possible response is to design technologies to address these concerns, while an alternative possibility is that these concerns may be misplaced due to problems with the informal cost-benefit calculus that determines rural peoples' choices. Either way, it is essential that outsiders respond to such local concerns – whether by adapting technologies to fit them or by convincing locals that their concerns are misplaced – since ignoring them is to invite problems with technology adoption.

Where WAC cites a factor yet some or all households fail to cite it, this provides evidence of a different type of disconnect between these two groups. Here, a characteristic of a certain tree species has been substantiated by scientific observation or experimentation, yet is either not recognised or not seen as significant by local people. In cases where farmers cite their need for the good or service in question yet fail to recognise the capacity of trees to provide it, this may be interpreted as evidence of a knowledge gap. Following this rule of thumb, instances where farmers complain about low soil fertility yet fail to recognise the capacity of trees[8] to respond to this need represent knowledge gaps. The fact that this gap affects only some households but not others strengthens this finding, since it shows that some local people have demonstrated the significance of this good or service in the local context.

While differences between WAC and local knowledge and differences among the tree characteristics cited by different households both suggest the existence of knowledge gaps, clearly demonstrating specific knowledge gaps is difficult. This is due to the existence of alternative possible explanations for the views expressed (or

[8] As documented in the World Agroforestry Center agroforestry database.

not expressed) by households. Thus, various explanations may account for the failure of households to cite a particular tree product or service. For each of the key products and services associated with farm trees, the alternative possible reasons besides knowledge failure why the product or service in question may be de-emphasised are listed in Table 6.4.

Table 6.4 Alternative possible reasons why particular tree characteristics may be de-emphasised

Product / service	**Possible reasons besides knowledge failure for de-emphasis**
Construction wood	* Household (HH) prefers to get its construction wood from another species * HH can afford to purchase its wood from others, and hence does not need to gather it
Fuel	* HH has alternative fuel sources, such as ample manure or compressed gas * HH has low fuel needs, e.g., due to having no elders who need to keep warm
Fruit	* HH lacks access to markets, and fruit is of interest primarily for sale to markets
Fodder	* HH lacks livestock
Fencing	* HH has minimal need for fencing, e.g., if does not cultivate vegetables or trees * HH is located in an area where there are minimal livestock to protect against
Herbal medicine	* HH can afford modern medicines, and hence does not need herbal remedies
Fertilises soil	* HH can afford chemical fertilisers * HH has ample land for lengthy fallow periods that keep soil from growing 'tired' * HH sees the tree's impact on crops as dominated by an opposing effect, such as competing with crops for sunlight or drying the soil.

More generally, a household would normally be expected to cite a useful product or service characterising a particular tree species. Yet such a product or service may not be cited if a household has access to viable substitutes, since these may render redundant the tree's capacity to provide this good or service. Under these circumstances, the household may no longer need the good or service in question, and hence may neglect to cite it during the interview. Another alternative is that the good or service in question is not actually important to the household, such that it prefers to do without it rather than going to difficulty to secure it.

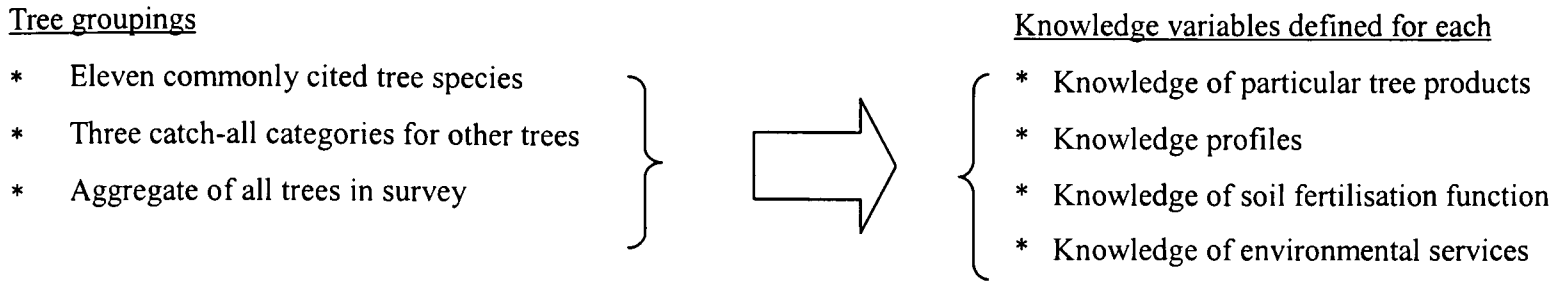
6.3 Defining species-specific knowledge variables

In preparation for the associations analysis summarised below, a set of knowledge variables was defined for each of fifteen distinct tree groupings. Eleven of these groupings relate to particular tree species, specifically to those eleven species cited by at least ten percent of survey households. Three groupings constitute catch-all categories for the remaining trees cited by less than ten percent of survey households[9]. The final grouping

[9] While ideally these remaining trees would have been aggregated together into a single variable, this was not possible given how the data were gathered. The resulting variables represent 102 cases, 129 cases and 132 cases, respectively.

includes the entire sample of trees aggregated together. The knowledge variables defined for these tree groupings are loosely referred to as 'species-specific knowledge variables' (SSKVs), to distinguish them from the knowledge variables examined in chapter five[10].

For each of these groupings, a number of distinct knowledge variables are defined. Potentially, a total of fourteen different knowledge variables are defined for each tree grouping, including (i) six variables on particular tree products, (ii) three knowledge profile variables, (iii) two variables on the soil fertilisation function of trees, and (iv) three environmental variables about households' recognition of other tree services.



In practice, however, some of these potential variables were not defined for each tree grouping. Most basically, due to data limitations only ten knowledge variables were defined for the three 'catch-all' groupings while only eleven variables were defined for the overall grouping. Beyond this, various other knowledge variables were not defined despite data on the factors in question having been collected because they were deemed unsuitable for assessing differential household knowledge vis-à-vis this grouping.

The end result is a distinct set of knowledge variables defined for each tree grouping. These variables represent means of distinguishing among survey households based on differential tree knowledge. Section 6.4 discusses how these variables were used to assess distinct knowledge categories.

6.3.1 Knowledge variables for particular products and services

Knowledge variables for particular tree products and services[11] were defined for all cases except where either of two exclusion criteria applied. The most fundamental basis for not defining such a variable is because the product or service does not appear to be provided by the tree in question. For instance, if a certain tree does not provide fruit, it would be nonsensical to use knowledge of its fruit provision function as a means of comparing household knowledge. In theory, whether or not a given tree provides particular products and services can

[10] Nonetheless, the text occasionally refers to 'knowledge variabes' or 'knowledge data', in which cases it means species-specific knowledge variables and data in the context of the present chapter.

simply be read from the scientific canon. Beyond this, however, tree characteristics that were cited by a significant minority (i.e., >10%) of households discussing the tree in question despite being neglected by WAC were also considered to characterise this tree.

The other reason why knowledge variables for particular products and services were sometimes not defined was because households did not display statistically significant differences vis-à-vis this characteristic. The criterion applied is whether at least 10 percent of households citing the tree type in question differ from the majority in their view of the characteristic. The point is that variables which do not differentiate among households are not useful to the present study, given its emphasis on distinguishing between different trends observed among survey households.

The extreme case where either all or no households cite a given aspect of a tree is uncontroversial, since in such cases the variable conveys no information about differential patterns among households. Cases of variables where just a few households (i.e., < ten percent) cite a given aspect of a certain tree or fail to do so are more complicated. While such findings may provide valuable insight into households' thinking, they may nonetheless fail to show statistically significant relationships with other factors, given the one sided nature of these data.

Due to this statistical criterion, whether or not a knowledge variable is defined for particular tree characteristic may have little to do with the importance to the household of the product, service or cost in question. Indeed, if a certain good or service is highly valued, then it may be cited by virtually all households and hence prove a poor means of differentiating among households. An example is fruit provision by the mango tree, which for this reason was not used to distinguish among households' knowledge of this tree, despite the high value of mango fruit and its centrality to this tree's role on the farm.

[11] This section only defines variables for products and services cited as specifically associated with the tree type in question. The second of the two soil fertilisation variables and the three environmental services variables do not meet this criterion, since these variables simply show whether households citing a particular tree type cited the tree service in question, as provided by *any* tree.

Table 6.5 Species-specific knowledge variables defined for particular tree products and services

Species	*Factors excluded*	*Total number defined*
A. nilotica	Fruit, soil fertilisation	12
A. tortilis	Fruit, fuel	12
M. indica	Fruit, construction wood, fencing	11
C. siamea	Fruit, fuel	12
T. indica	Fencing	13
A. drepanolobium	Fruit, fuel, medicine	11
A. polyacantha	Fruit, fuel	12
B. aegyptica	-	14
L. leucocephala	Fruit, fuel, fencing, fodder	10
A. indica	Fruit, fencing, medicine	11
A. harveyi	Fruit, fuel, fencing, soil fertilisation	10

6.3.2 Defining knowledge profiles

Tree-specific knowledge data such as those considered above may also be aggregated into distinct knowledge profiles. Aggregation is attractive in principle, since it holds promise that composite variables will capture linkages between different aspects of farmer knowledge. Three alternative possible approaches to aggregation were considered.

- Defining inclusive knowledge profiles: All the various knowledge variables could simply be combined into an inclusive knowledge profile for each commonly cited tree species. While it fully captures any linkages between different aspects of household knowledge, this approach is problematic. For one thing, integrating all thirteen knowledge variables into a single knowledge profile is cumbersome, raising difficult issues about which factors to prioritise when diverse elements fail to fall neatly into distinct groupings. More fundamentally, such an approach would imply that all these variables defined only a single continuum of variation vis-à-vis tree knowledge, whereas they arguably define several distinct dimensions.

- Using principal components analysis (CATPCA) to define synthetic factors of variation: As a statistical means of defining distinct continua of variation implicit within a set of related variables, CATPCA could arguably be used to define distinct groupings of knowledge patterns. Yet using CATPCA with these tree knowledge data is problematic, due to the fact that it treats all input variables equally, when some are arguably critical while others are peripheral. Moreover, given complex data, CATPCA may fail to explain a significant fraction of the observed variation.

- Manually defining distinct continua of variation: The clearest continua of variation vis-à-vis knowledge of trees correspond to the two broad uses of trees within farm systems: the provision of products and agricultural support services. Arguably, products may be further broken down into high-value, potentially

marketable products such as fruit and low-value, easily substituted products such as fuel. Agricultural support services may be broken down into crop linkages and livestock linkages. Costs associated with trees such as competition between crops and trees for water or sunlight fall readily into these categories.

Of these three approaches, the final approach was deemed most suitable to analysing species-specific knowledge vis-à-vis trees. In contrast to the other approaches, it involves defining distinct groupings manually by combining elements into categories that fit observed patterns in the data while also heeding theory and common sense.

Following this approach, the species-specific tree data were used to define three distinct knowledge variables for each commonly cited tree species. Each of these variables defines a continuum of variation vis-à-vis household knowledge of the tree in question. Specifically, these variables characterise alternative household perspectives on (i) the various products provided by the tree, (ii) the tree's interactions with field crops, and (iii) the tree's interactions with livestock. In each case, the variables define a continuum of knowledge profiles, from less to more inclusive.

For each of these three continua of variation, the data for a given tree species are divided into two or three categories that identify the key alternative knowledge profiles vis-à-vis a particular tree characteristic. The idea is that if the data falling along each distinct continuum of variation can be divided into just a few alternative categories, this could clarify contrasting household views. The challenge is to identify those distinctions that represent natural breaks between fundamentally distinct viewpoints of the tree in question.

Ideally, this analysis would be conducted for each of the various tree species cited by survey households. In practice, however, it only includes data relating to the eleven species cited by at least five percent of the survey households. All told, these eleven species provide data for 92.3 percent of the households surveyed, although they account for only 61.4 percent of the trees cited by households. The remaining species were not included in the analysis due to the relatively small number of cases involved, which made them unsuitable for statistical analysis.

As discussed in chapter five, it is difficult to know whether the various tree characteristics cited indicate what households know or just what they emphasise and see fit to say. Conceivably, a household may recognise that

a certain tree provides fuelwood yet not opt to say so, perhaps because fuel is a comparatively low-value product relative to other products provided by the tree. The household may also not *want* to use the tree as a source of fuel, preferring instead to save it for higher-value uses. The tree's association with fuelwood may also be obscured if alternative sources of fuel are readily available. As in the case of fuel, a household may recognise the tree's role in providing livestock fodder or fertilising soil, yet fail to mention it.

Although the distinction between lack of knowledge and de-emphasis is real, it may make little difference in terms of its impact on tree and farm management. Notably, the tree products data were elicited by asking what products were obtained from the tree in question, with a list of possible products read out to the interviewee. If a given product was recognised by a household yet of so little interest that it was not cited under these conditions, then from a management perspective this deprioritisation may be similar to lacking this knowledge entirely. In both instances, this characteristic of the tree in question is unlikely to sway households in their tree management decisions.

Knowledge profiles of tree products

Defining knowledge profiles vis-à-vis the products of a given tree involves determining which combinations of 'indicator' products indicate critical breaks in household knowledge. The first question is which products act as 'indicator' products for a given species of tree, while the second is how to prioritise these 'indicator' products. While these two questions are conceptually distinct, in practice they overlap. Taken together, they define the key alternative knowledge profiles vis-à-vis products provided by a particular tree. Specifically, they define categories of household deemed to have either more or less complete knowledge of the products provided by a given tree.

A first step towards determining which tree products to use as 'indicator' products for a given tree is to observe the proportion of households which cited the product in question among those citing the tree. Unless there are strong a priori reasons to emphasise them, products cited by either a very low or a very high proportion of households are best not used as 'indicator' products[12], since such variables are not readily amenable to statistical analysis[13]. Ideally, each category should represent a clear-cut viewpoint held by a significant fraction of survey households.

[12] In the extreme case where either all households or no households cite the product in question, then knowledge of this product is meaningless for distinguishing among households.
[13] This emphasis on numbers of cases must not be overstated, however. The most important thing is whether a given tree characteristic is deemed a critical determinant of the household's view of this tree, not how many households recognise it.

Otherwise, two tree products may be ruled out of consideration on *a priori* grounds, namely fuelwood and fencing. Both are relatively low-value products, in comparison to products such as fruit, construction wood and herbal medicine[14], and data on them is likely to be unreliable. Fuelwood in particular is an obvious product of almost any tree, and households may view it as easily substituted by crop residues or manure. As such, households that fail to cite it may simply not have bothered to do so. Indeed, citing fuel may sometimes indicate that a household has nothing else to say about the tree, and views it as a low-value resource not worthy of being cultivated or perhaps even retained on the farm. Thus, when either fuelwood or fencing is not cited but some higher-value tree product is, the former should not be taken as a significant determinant of the household's knowledge profile.

A second reason references to fuelwood are not a good means of differentiating among farm households is that fuel provision is a gendered task in Sukuma society. Specifically, meeting the household's fuel needs is the responsibility of women. As such, there is some danger that interviews conducted primarily with a male household head may fail to reflect the role of trees in providing fuel. Simply put, male interviewees may fail to cite fuel since this resource is not their concern. Once again, the fuelwood data emerges as unreliable.

The four remaining tree products are fruit, construction wood, herbal medicine and livestock fodder. How best to combine these variables to define distinct knowledge profiles depends on the relative significance of the product in the eyes of survey households. Products significant to household welfare – and hence to the household's implicit valuation of trees and their management – must first be identified. Those products which may be considered critical or dominant must then be determined. Criteria used to assess which factors are significant to household welfare include both whether the product in question was cited by a significant number of survey households and the received wisdom regarding the role of trees on smallholder farms[15]. Criteria used to assess the relative value of different products deemed significant to households include (i) products cited as the tree's 'key product' by some survey households, (ii) products often associated with tree cultivation rather than relying on natural regeneration, and (iii) products often associated with trees being located on the farm as opposed to the commons or bush.

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[14] Given the cash constraints on households, this distinction is especially sharp in cases such as mango where tree products are marketable.
[15] Whether or not a given product is recognised by the theoretical canon is not a strong criterion, since if significant numbers of households cite a factor, the fact that it is not recorded in the canon would not stop it from being used to differentiate among households. Yet if a factor were only cited by a few households, whether or not it was also cited by the canon – and hence has been demonstrated via the scientific method – might make the difference between whether or not it was treated as an 'indicator' product.

The resulting categorisations of knowledge include either two or three distinct categories. In all the variables characterising competing knowledge profiles vis-à-vis tree products, the most inclusive category is comprised of households that cited all of the 'indicator' products for the species in question. This strict definition of the category representing 'no knowledge gaps' follows from the fact that each of these tree products is clearly valuable to farm households, making each such oversight an important gap with clear welfare implications. While some of the resulting categories involve minor variation in terms of the tree products cited, taken together they highlight the key distinctions between households' knowledge of the products provided by a particular tree.

Knowledge profiles of tree livestock linkages

Of the various tree products cited by survey households, livestock fodder has particular significance in Shinyanga District and similar areas. While in theory fodder is low-value and easily substituted, in practice it is often critically scarce, particularly during the latter stages of the dry season. Moreover, herds that eat well throughout the year are likely to be stronger and healthier. Notably, they are more likely to survive and reproduce, better able to draw a plough, and likely to produce more milk. In contrast to the other tree products cited by survey households, citing livestock fodder implies an explicit integration of farm components, notably their tree and livestock components. Given species-specific tree data, citing fodder highlights the household's recognition of a positive linkage between the tree in question and livestock.

While provision of livestock fodder by trees was cited by a large proportion of survey households (89 percent), the fact that fodder was seldom cited as the key product of trees (8 percent)[16] raises the question of whether tree fodder's importance is only partly recognised by most households. Given the importance of livestock to household welfare and security and the potentially critical significance of tree fodder to livestock health and vigour, it does not make sense that this aspect of trees is seldom prioritised by survey households. Following the study hypothesis, households' appreciation of tree fodder's significance may be constrained by deeply-rooted historical and cultural biases against trees.

As noted, knowledge of both this linkage and the linkage between trees and field crops are deemed to represent distinct continua of variation from knowledge of tree products, due to their potential significance in poor smallholder systems facing resource degradation. Such variables reflect households' relative appreciation of the role of trees in supporting key farm enterprises such as crop and livestock production. To use Boulding's

(1965) colourful metaphor, emphasis of these linkages may be said to signify a shift from thinking in terms of a 'cowboy economy' characterised by vast expanses of ample resources to thinking in terms of a 'spaceman economy' characterised by limited resources. In a 'spaceman economy', maximising symbiotic linkages between systems may be key to survival, such as utilising the wastes of one system (i.e., farm component) as inputs to another. By contrast, such linkages are insignificant in a 'cowboy economy'.

Comparing the knowledge profiles for tree products with those reflecting tree – livestock linkages shows that these different knowledge profiles may not be mutually exclusive, but may simply represent different aspects of a common reality, or different points of emphasis. As defined, these two sets of knowledge profiles overlap to a significant degree, since in both cases the final knowledge category is identical. These knowledge profiles emphasise different aspects of trees, however, with one emphasising households' recognition of tree products while the other emphasises their recognition of tree fodder. Variables emphasising fodder while also considering other tree products were deemed preferable to simply assessing whether or not fodder was cited, since their integrated view of the role of trees on farms was thought to better represent households' thinking.

Knowledge profiles of tree - crops linkages

These variables show household views of the relationship between trees and annual crops in the 80 percent of cases where survey households cited such interactions. Defining knowledge profiles vis-à-vis a tree's interactions with field crops involves identifying the key breaks in views of this linkage.

Given the widespread and often grave problems of soil fertility in Shinyanga District, the potential role for trees in helping to fertilise soils is clear, and has been a key motivation of the various tree advocacy initiatives that have worked in the area. Yet farm trees may also have adverse impacts on annual crops, notably via competition for scarce water or shading. Whether a household cited both positive and negative crop impacts or negative impacts only was taken as an indication of its view of trees' impact on crops as either purely negative or potentially positive. Given the centrality of the soil fertilisation function to this linkage, these knowledge profiles have only two categories, namely 'fertilises yet may also harm' and 'harms only'.

On the surface it would appear that knowledge gaps facing households vis-à-vis the soil fertilisation function of certain trees may be read directly from the tables of species-specific data. Yet before any such discrepancy can be interpreted as a knowledge gap, one key alternative explanation must be considered. Namely, households

[16] Or associated with tree cultivation.

failing to cite trees' soil fertilisation function must be compared with those that complain of soil fertility problems affecting farm production. Only in cases where households cited soil fertility as an issue yet failed to recognise this aspect of trees can this discrepancy be interpreted as a knowledge gap.

The remaining households that did not cite soil fertility as a problem may nonetheless face grave soil fertility problems, but simply not view the associated difficulties in this light[17]. Arguably, such farmers could likewise be categorised as demonstrating a knowledge gap vis-à-vis trees, if it seems apparent from other data that they are experiencing soil fertility problems. Alternatively, those households that did not report soil fertility problems may simply not experience such problems, as a result of which any soil fertilisation function of trees may be irrelevant to them.

To assess whether farmers fall into one category or the other, two further measures were employed to assess whether households have access to a viable alternative means of securing soil fertility, besides farm trees. These include assessing whether households are able to practice fallowing at least one year in two and whether they have regular access to chemical fertilisers. If a household both lacks these alternative means of securing soil fertility and experiences production difficulties, the household in question may be deemed to be experiencing soil fertility problems. Any such household that fails to recognise the fertilisation function of a tree possessing such a function may be deemed to be facing a knowledge gap.

While knowledge profiles vis-à-vis crop linkages were defined, these variables were *not* used in the correlations analysis below. This followed because the resulting variable closely resembled the 'perspective' variable *trees' role vis-à-vis crops*. Moreover, these data were deemed to be better suited to being categorised as a perspective variable than a knowledge variable (see section 6.4.2).

6.3.3 The resulting variables and data

The resulting knowledge profiles appear in Table 6.6 while the remaining species-specific knowledge variables appear in Table 6.7. Reiterating, these variables are defined for a range of different tree characteristics across a range of tree groupings. While not all potential combinations of the former with the latter are listed, as

[17] Households that experience soil fertility problems yet do not state this may instead characterise their production problems as linked to other production constraints, most often 'insufficient rainfall' While rainfall that is erratic and/or insufficient certainly affects crop production, the way these vagaries impact crops depends critically on soil. This follows because soils with higher levels of organic matter have greater water-holding capacity, allowing crops to cope more effectively with erratic rainfall. Moreover, various farm management practices raise soil organic matter levels, including applying manure or compost to fields, refraining from burning weeds and crop residues, and growing farm trees. Soil organic matter levels and hence soil water-holding capacity are thus partly a function of farm management strategy.

Table 6.6 Knowledge profiles defined and relative frequencies

Tree product profiles	%	Livestock linkage profiles	%	Crop linkage profiles	%
Acacia nilotica					
· CW, MED, FOD	46	" "	46	Fertilises yet harms	24
· CW, lack FOD or MED	49	FOD, lack CW, MED	65	Harms only	76
· Not CW	26	Lack FOD	10		
Acacia tortilis					
· CW, MED, FOD	19	" "	19	Fertilises yet harms	33
· CW, lack FOD or MED	47	FOD, lack CW, MED	62	Harms only	67
· Not CW	35	Lack FOD	20		
Mangifera indica					
· MED, FOD	10			Fertilises yet harms	26
· Lack either FOD or MED	35			Harms only	74
· Not MED, FOD	16				
Cassia siamea					
· CW, MED, FOD	12	" "	12	Fertilises yet harms	42
· CW, lack MED or FOD	33	FOD, lack CW or MED	13	Harms only	58
· Not CW	6	Lack FOD	26		
Tamarindus indica					
· FR, CW, MED, FO	18	" "	18	Fertilises yet harms	42
· FR, lack CW, ME or FO	26	FO, lack FR, CW or ME	13	Harms only	58
· Lack FR	6	Lack FOD	19		
Acacia drepanolobium					
· CW, MED, FOD	4	" "	4	Fertilises yet harms	25
· CW, lack MED or FOD	13	FOD, lack CW or MED	21	Harms only	75
· Not CW	31	Lack FOD	23		
Acacia polyacantha					
· CW, MED, FOD	6	" "	6	Fertilises yet harms	44
· CW, lack MED or FOD	28	FOD, lack CW or MED	20	Harms only	56
· Not CW	11	Lack FOD	19		
Balanites aegyptica					
· CW, ME, FO	7	" "	7	Fertilises yet harms	41
· CW, lack ME or FO	28	FO, lack CW or ME	13	Harms only	59
· Not CW	3	Not FO	18		
Leucaena leucocephala					
· CW, FOD	26	" "	26	Fertilises yet harms	60
· CW, lack FOD	2	FOD, lack CW	6	Harms only	40
· Lack CW	8	Lack FOD	4		
Azardirichta indica					
· CW, FO	5	" "	5	Fertilises yet harms	61
· CW, lack FO	16	FO, lack CW	5	Harms only	39
· Not CW	14	Not FOD	25		
Albizia harveyi					
· CW, ME, FO	6	" "	6	Fertilises yet harms	31
· CW, lack ME or FO	20	FO, lack CW or ME	12	Harms only	69
· Not CW	6	Not FOD	14		

Source: Shinyanga District household survey, 2000

Table 6.7: Species-specific tree knowledge variables and frequency statistics

Tree grouping	Total # of cases	Fruit	Construction wood	Fuelwood	Livestock fodder	Herbal medicine	Fencing	Fertilises soil	Fertilises / any tree	'Makes rain'	Micro-climate	Wind-break
Acacia nilotica	121	98%	22%	95%	92%	58%	31%	3%	21%	34%	26%	49%
Acacia tortilis	101	1	65	98	80	21	44	17	27	28	19	47
Mangifera indica	61	93	5	84	66	25	0	16	20	28	15	44
Cassia siamea	51	0	88	96	49	41	12	26	29	36	30	53
Tamarindus indica	55	88	36	64	62	50	2	19	32	29	12	44
Acacia drepanolobium	49	6	35	94	52	13	38	21	21	32	32	45
Acacia polyacantha	47	0	76	91	58	13	16	28	36	39	23	46
Balanites aegyptica	39	13	92	74	53	24	16	32	34	13	17	27
Lucaena leucocephala	35	0	78	100	89	11	3	41	50	36	13	48
Azadirachta indica	36	0	60	74	29	100	3	42	49	25	32	41
Albizia harveyi	35	0	81	94	56	34	13	8	25	50	26	41
Other spp. 1	102	-	59	91	59	28	-	21	33	31	28	49
Other spp. 2	129	-	53	87	62	25	-	13	29	30	21	43
Other spp. 3	132	-	51	84	52	21	-	25	25	36	22	53
All trees together	922	32	84	98	89	51	40	28	28	32	23	46

Source: Shinyanga District household survey, 2000

Table 6.8 Species-specific management and key product data

Tree grouping	Key product		Key location		Tree cultivation	
Acacia nilotica	High-value Low-value	4% 96	Home garden Fields Bush	46% 38 16	PW PL NP	15% 45 40
Acacia tortilis	High-value Low-value	7 93	Home garden Fields Bush	29 49 22	PW PL NP	3 27 70
Mangifera indica	High-value Low-value	88 12	Home garden Fields Bush	68 32 0	PW PL NP	27 71 2
Cassia siamea	High-value Low-value	14 86	Home garden Fields Bush	53 40 7	PW PL NP	20 73 7
Tamarindus indica	High-value Low-value	72 28	Home garden Fields Bush	37 37 26	PW PL NP	11 40 49
Acacia drepanolobium	High-value Low-value	6 94	Home garden Fields Bush	15 46 39	PW PL NP	0 13 87
Acacia polyacantha	High-value Low-value	7 93	Home garden Fields Bush	32 26 42	PW PL NP	0 65 35
Balanites aegyptica	High-value Low-value	29 71	Home garden Fields Bush	40 35 25	PW PL NP	0 21 79
Lucaena leucocephala	High-value Low-value	11 89	Home garden Fields Bush	58 32 10	PW PL NP	28 66 6
Azadirachta indica	High-value Low-value	74 26	Home garden Fields Bush	55 29 16	PW PL NP	36 61 3
Albizia harveyi	High-value Low-value	0 100	Home garden Fields Bush	17 70 13	PW PL NP	0 19 81
Other spp. 1	High-value Low-value	30 70	Home garden Fields Bush	35 39 26	PW PL NP	9 39 52
Other spp. 2	High-value Low-value	34 66	Home garden Fields Bush	35 34 31	PW PL NP	6 29 65
Other spp. 3	High-value Low-value	43 57	Home garden Fields Bush	33 40 27	PW PL NP	9 27 64
All trees together	High-value Low-value	43 57	Home garden Fields Bush	40 38 22	PW PL NP	12 43 45

Source: Shinyanga District household survey, 2000

discussed above, the vast majority are defined. Finally, Table 6.8 gives some statistics on the management and key product data corresponding to distinct tree groupings.

The tree groupings in question include the eleven tree species most commonly cited by survey households, three catch-all categories for other tree types mentioned, and an aggregate category. The tree characteristics for which household knowledge is assessed include six tree products, three knowledge profiles, two fertilisation variables, and three environmental service variables.

The products are fruit, construction wood, livestock fodder, herbal medicine, fuelwood and fencing, while the knowledge profiles are as defined above. One soil fertilisation variable reflects whether households citing a particular tree cited soil fertilisation by this tree, while the other reflects whether these same households cited fertilisation by any tree. Finally, the environmental variables considered are 'trees make rain', improved microclimate and windbreak.

6.4 Exploratory associations with species-specific knowledge variables

To elucidate variations within households' knowledge of trees, the present chapter runs correlations of species-specific knowledge variables (SSKVs) with a set of thirty-eight variables representing various aspects of survey households. These variables include 13 resource variables[18], 4 'outside influence' variables, 12 farm management variables, and 8 'perspective' variables. These variables are collectively referred to as 'associative variables' (AVs), in reference to their role within the analysis. The resulting associations are arranged by associative variable, with each of 38 variables being correlated in turn with the full range of species-specific tree knowledge variables.

These correlations identify instances where households citing a particular tree product or service show a clear tendency of one sort or another represented by the variable in question. The analysis examines each of these thirty-eight variables in turn, assessing how each relates to species-specific tree knowledge generally and knowledge of certain tree characteristics in particular[19]. The fifteen distinct tree groupings thus function as fifteen different sets of data points with which to assess the factor's relationship with tree knowledge (see section 6.5). The question addressed is whether each of the associative variables examined is significantly

[18] Although knowledge variables were used to explain residual variation left by resource variables in chapter five, using these same variables to help elucidate species-specific knowledge variables in this chapter does not represent circular logic. In the first place, knowledge variables were not used to explain resource variables. Moreover, in the present analysis resource variables are simply considered as among the possible correlations with particular patterns of species-specific knowledge.

associated with species-specific tree knowledge, and if so how. Thus, while the knowledge variables characterise patterns of household knowledge vis-à-vis trees[20], the correlations highlight diverse factors associated with observed knowledge patterns.

These correlations fall into two broad categories with distinct interpretations. Correlations with resource and outside influence variables provide insight into factors that may contribute to households possessing differential knowledge vis-à-vis trees. That is, they provide suggestive evidence of factors which may be among the causes of particular knowledge outcomes. Correlations with management and perspective variables, meanwhile, suggest how intangible factors tend to be linked in the minds of survey households, and hence provide a holistic view of competing household perspectives. Specifically, they suggest whether different factors move together, move in opposing directions, or define distinct continua of variation[21]. In sum, correlations with resource and outside influence variables highlight potential causal factors while correlations with management and perceptual variables elucidate intangible characteristics that tend to go together. In both cases, these findings highlight promising future angles of inquiry, whether for examining causality or suggesting possible means of addressing knowledge gaps.

Issues of causality are not formally addressed in this analysis due to the likely complexity of interactions among these diverse factors, notably the difficulty of disentangling causes from consequences. Because they do not address causality, these statistical associations are merely indicative and exploratory.

The association findings provide insight into the knowledge characteristics of survey households, notably why some households in a community have better, more complete knowledge of available natural resources than others. Such differences are likely to be attributable to diverse factors, such as those represented by the thirty-eight variables examined. Inevitably, they are also partly attributable to differences in the personality type and intelligence of individuals, yet such factors lie beyond the scope of the present study. Innovators are particularly likely to show inherent differences, given the demands associated with adopting views or practices unfamiliar to the community. Rather than seek to understand what makes these unusually bold and dynamic people the way they are, the more useful question – and focus of the present study – is why the more 'normal'

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[19] One exception is the few cases where perspective variables were partly defined using knoweldge data. Any such associations were omitted from the analysis, since they would be spurious.

[20] Reiterating, the knowledge data do not indicate the most valuable products and services of local trees. Instead, the focus is on differential knowledge among households, as a result of which species-specific knowledge variables emphasise tree factors that are recognised by some households but not others, or for which knowledge is partial.

[21] For instance, if adherence to Christianity tends to be associated with certain knowledge gaps, the potential origin of these gaps within Christian teachings or rites may be explored in a future study, and could potentially be addressed via surgical changes to religious teaching.

households do not adopt a given viewpoint or practice when it already exists within the community and addresses pressing needs.

6.4.1 Aggregating knowledge data to strengthen associations between factors

These associations with household knowledge could be assessed purely on the basis of species-specific, function-specific data, e.g., how different households citing *A. nilotica* speak about fuelwood. The advantage of such an approach is that it would not depend on simplifying assumptions regarding the knowledge data, which are needed if these data are to be aggregated. While such data already represent a reasonable number of data points[22], these data were aggregated in order to strengthen association findings by enlarging the body of data considered. Although aggregation may reduce the precision of correlation findings, it was deemed to increase their clarity and reliability.

The two possible means of aggregating the species-specific knowledge data are aggregating the different tree functions within a given tree type and aggregating the findings for a particular tree function across tree types. That is, knowledge data may be grouped either by species (i.e., assuming that each tree function tends to be seen similarly across species) or by tree function (i.e., assuming that knowledge of different characteristics of a particular tree tend to correspond). Given these choices, the latter alternative was preferred. The principal reason was the study's focus on household views of trees and their various functions generally rather than on differences between tree types.

Tree functions may be divided into at least two broad categories, namely those that have been of clear significance over time[23], such as fuelwood and fruit, and those that were comparatively insignificant historically, such as livestock fodder and soil fertilisation. Based on the study hypothesis, the former are expected to be widely recognised, while the latter may only be recognised by the more innovative households. Given such differences between tree functions, knowledge vis-à-vis different tree functions may need to be interpreted differently. For instance, failure to cite fuelwood may signal its de-emphasis due to status considerations, citing herbal medicine may indicate interest in trees via attention to their minor products, and citing trees' capacity to fertilise soils may indicate adaptation to a contemporary context characterised by infertile soil.

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[22] For instance, 121 households cited *A. nilotica*, representing 121 distinct data points for each characteristic of this species.
[23] Notably, even when local natural resource stocks were formerly plentiful, such as the case of trees in Shinyanga District.

By contrast with these differences between tree functions, differences across species in households' knowledge of a particular tree function are expected to be small. For instance, households are believed to view trees' fuelwood provision function similarly across different species, as they are their fruit provision or soil fertilisation functions. Although this assumption is bound to be at least somewhat problematic due to differences between tree types, it seems a reasonable approximation. Thus, relationships between factors were assessed not just on the strength of one association for a particular tree grouping but rather on the basis of correlations across the range of tree groupings. Only associations which showed a clear and consistent correlation across a significant minority of groupings were cited as statistical linkages.

6.4.2 Different types of 'associative variable'

The distinction between the 'knowledge variables' examined in chapter five and the 'perspective variables' considered in the present chapter is subtle, and represents a differing emphasis more than actual differences. By contrast, the difference between the species-specific knowledge variables and the perspective variables is clearer.

The species-specific knowledge variables show whether or not different survey households possess specific types of technical knowledge. Each such variable identifies an aspect of knowledge about trees believed to be of economic significance to households in the study area, while the species-specific knowledge data show which households recognise this aspect of the tree in question[24]. Where they are economically significant, it might be said that households 'should' recognise these factors, since it is in their interest to do so. While how best to manage a certain tree may be a complex, context-dependent question, recognising its various aspects is a fundamental matter.

By contrast, the perspective variables characterise differing views of and attitudes about farm production and the role of trees on farms. They are less formally rigorous, not showing the presence or absence of a specific bit of technical knowledge, but rather suggesting a particular perception, view or attitude. Some perspective variables convey differing household prioritisations as informed by perceptions of trees, such as which product of a given tree is most significant to the household or which tree location is most significant to its role in helping meet household needs. Others relate to knowledge of a particular phenomenon, yet concern complex issues critically informed by household perceptions. As such, they suggest a certain perspective on an issue

rather than a concrete, falsifiable piece of knowledge. Examples include the overall impact of trees on annual crop production, whether tree impacts are density-dependent, and whether rainfall alone critically constrains farm production or rather the combination of erratic rainfall and poor soil fertility[25]. What all these factors have in common is that they are arguably readily amenable to change[26], in contrast to physical resource constraints such as land, labour or capital assets.

A second category of variables examined may also be readily amenable to change, namely the outside influence variables. These variables represent socio-cultural or institutional factors that may have affected household attitudes, values and knowledge, such as education and religion. While a factor such as religion may not itself be readily amenable to change, its impacts on household management may be, for instance via surgical adjustments to religious teachings or practice.

Correlations of species-specific knowledge with two additional categories of factors were also assessed. These include the tangible resources considered in chapter five and diverse farm management variables, which may function either as complements or substitutes to particular tree management strategies. Any correlations with these factors are expected to give useful insights into the types of households possessing different knowledge profiles.

6.4.3 Determining the significance of associations between factors

The associations data determine which relationships between a particular knowledge category and a particular AV are significant based on statistical criteria. Each relationship between a particular knowledge category (e.g., trees' provision of livestock fodder) and a particular AV (e.g., household Swahili skills) was characterised by a total number of potential correlations or data points. The total number of such potential correlations is given by the number of SSKVs defined for the knowledge category in question, or the number of tree groupings for which the SSKV category is defined.

Assessing the significance of such relationships involves two stages, namely determining (i) how many of the potential correlations corresponding to a given relationship are significant, and (ii) whether these aggregated findings signify that the overall relationship between these factors is significant. The first stage was

[24] As noted above, cases where households fail to cite a certain tree characteristic cannot simply be interpreted as knowledge gaps, since they may simply reflect the household's de-emphasis of this characteristic. Nonetheless, this distinction is unlikely to significantly affect the management decisions of households, as discussed above.

straightforward, with individual correlations considered significant if they were found to be statistically significant at 10%. The second stage involved assessing the overall relationship between the factors in question. This relationship was considered significant if either of two conditions was met: at least fifty percent of potential correlations was significant or at least four correlations for particular tree groupings were significant. In either case, the final determination of significance also depends on the individual correlations showing the same directionality of association, or on any exceptions to the prevailing directionality being explicable by unusual characteristics of the tree grouping in question. Thus, relationships between a given knowledge category and a given AV were found to be significant only in cases where a clear statistical trend was discernable between the two factors based on data drawn from distinct tree groupings.

One problem with applying a statistical criterion of 10% for inclusion of particular correlations in the analysis is that where the data for a given variable are strongly skewed to one side of its distribution, even strong associations between factors may not be statistically significant. One possibility is that the SSKV may be problematic. For instance, while recognition of *A. nilotica*'s soil fertilisation function was found to be perfectly correlated with various AVs, these associations were generally not statistically significant at 10% due to the fact that only three households cited this tree's soil fertilisation function. The AV data may likewise be problematic. For instance, all or nearly all of the households in a particular tree grouping may speak Swahili well. Conversely, very few or none may speak Swahili well. In either case, even perfect correlations with SSKVs[27] may not be significant at 10%.

6.4.4 Perspective variables used in the analysis

Each of the 'perspective variables' used in the analysis is discussed briefly below, while frequency statistics for these variables are listed in Table 6.9.

KEY TREE PRODUCT

That product cited as the "key product" of a given tree species tells much about the household's view of this tree and perhaps of trees generally. The most fundamental distinction is between comparatively high-value, potentially marketable products and comparatively low-value products typically obtained from the bush. Based

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[25] More generally, households' view of the relationship between erratic rainfall and 'tired' soil sheds light on how they analyse production constraints and weigh up competing factors, conveying a certain perspective on resource management and production challenges.
[26] Via targetted, effective information provision campaigns.
[27] Given their inherent interest, perfect correlations that were found to be insignificant were nonetheless noted along with the statistically significant associations between factors. While they were used to help interpret findings, these data were not used to define significance ratios or to determine the overall significance of relationships between factors.

Table 6.9 Management and perspective variables used in the exploratory analysis

Variable group	Variable	Categories	Frequencies	Cases
Management variables	Kitchen waste	Yes No	15% 85	347
	Manure	Yes No	54 46	348
	Micro-irrigation	Yes No	39 61	284
	Intercropping	Yes No	86 14	346
	Crop rotation	Yes No	52 48	336
	Fallowing	Yes No	34 66	347
	Ratio of fallowing to use	> 1:1 < 1:1 No fallowing	11 21 68	347
	Purchased hybrid crop seeds	Yes No	32 68	349
	Purchased agricultural inputs	Yes No	40 60	349
	Drought-resistant crops	Yes No	84 16	349
	Cash crops	Yes No	72 28	348
	Leguminous crops	Two or more Just one None	43 41 16	348
	Vegetable cultivation	Yes No	45 55	347
Perspective variables	Key tree product	High-value product Low-value product	32 68	308
	Key tree location	Home garden Fields Commons / bush	40 38 22	347
	Harm crops via soil effects	Yes No	48 52	346
	Harm crops via shading	Yes No	37 63	346
	Density-dependent adverse impacts	Yes No	9 91	349
	Trees' role vis-a-vis crops	Fertilises yet harms Harms only	35 65	297
	Diagnosis of production difficulties	'Tired' soil is a factor Cite rainfall but not soil	35 65	297
	Poor rainfall as key constraint	Yes No	87 13	309
	Poor rainfall as sole constraint	Yes No	41 59	309

Source: Shinyanga District Household Survey, 2000

on deductions from the data of how households tended to view different tree products, fruit, construction wood and herbal medicine were categorised as high-value products while livestock fodder, fencing and fuelwood were categorised as low-value products.

KEY TREE LOCATION

The principal location of those trees considered most significant to the household's livelihood tells much about its view of these trees and perhaps of trees generally. The three commonly cited categories were the home garden, the fields, and the commons / bush / nature reserve. Households citing either the home garden or fields as the key location of a given tree are expected to value the tree in question more highly than those citing the commons or bush as key location. Perhaps the most fundamental distinction is between farm-based trees and off-farm trees, yet the distinction between the home garden and the farm fields is arguably also important.

HARMSOIL & HARMSHADE

The two principal tree costs cited by survey households both involve harmful impacts on annual crops. HARMSOIL indicates household perceptions of competition effects between a tree and field crops vis-à-vis soil moisture and/or nutrients, while HARMSHADE indicates household perceptions that this tree competes with annual crops for sunlight. In both cases, such competition may impede crop growth.

Where households cite these tree costs, this could have any of several meanings. It could suggest either a subtle understanding of the tree and its diverse impacts or a negative disposition towards trees and tendency to emphasise tree costs rather than benefits. Two further possibilities are not supported by the data. One is the idea that whether or not tree costs are cited simply depends on the tree type in question, while the other is that the tree cost data simply reflect whether or not a given tree occurs on the farm. In sum, whether or not either tree cost is cited by a given household may be seen as depending on intangible factors, notably the household's familiarity with diverse aspects of particular trees and its attitudes towards trees generally.

DENSITY DEPENDENCE OF ADVERSE IMPACTS ON CROPS

This variable distinguishes households that explicitly cited the density-dependence of any harmful impacts of trees on crops. The fact that these households qualified their comments about harmful crop impacts is meaningful, since it suggests that this qualification is central to their understanding of tree-crop linkages. What is less clear is whether those households that failed to mention this qualification nonetheless subscribe to it.

VIEW OF TREES' ROLE VIS-À-VIS CROPS

This variable distinguishes whether households cited only negative impacts of trees on crops or whether they also cited positive impacts, with the latter narrowly defined as trees providing a soil fertilisation function. Although these data were aggregated across tree types, they nonetheless convey a fundamental distinction among households as to their view of trees in relation to farming. Because most trees grown in the study area have both beneficial and detrimental impacts on annual crops, all survey households may be assumed to have experienced or at least observed both types of impacts, however subtle and gradual. The question of which aspects they emphasise may therefore be said to be a question of farmer views of and attitudes towards trees.

Given the centrality of this variable to household perceptions of trees and the degree to which they are viewed as useful tools for addressing farm management challenges, two alternative versions of the variable were examined. One distinguished households citing harm to crops but not soil fertilisation from any citing fertilisation while the other distinguished households citing either harm to crops or no crop impacts from any citing fertilisation[28].

DIAGNOSIS OF KEY PRODUCTION DIFFICULTIES

Among the various factors cited by survey households as key constraints to farm production, the two most commonly cited factors were insufficient rainfall and 'tired' soil. Both factors plague farmers throughout the study zone, and are deemed to be functionally related. Namely, ample, consistent rainfall can secure moderately successful production despite poor soils, while fertile soils can compensate for poor or erratic rainfall via their greater water-holding capacity.

Given this backdrop, these factors were brought together to define a composite variable, since they are deemed to be indicative of differing household attitudes to dealing with production constraints. That is, which factors households emphasised suggested distinct viewpoints on a common question. Moreover, this dichotomy highlights a fundamental distinction vis-à-vis the potential for agency. Namely, farmers in the District lack clear irrigation opportunities and hence cannot address the problem of insufficient rainfall directly, while the

[28] In the latter version of this variable, the seventy-three households that did not cite crop impacts were categorised as emphasising negative crop impacts. The fact that no crop impacts are mentioned is not a meaningless finding, but conveys definite information about the relationship between trees and crops. Namely, it may be seen as evidence that trees are kept away from crops, ostensibly due to a negative assessment of their impact on crops, whether based on their own experience or observations or on ideas gleaned from others.

problem of 'tired soil' can be addressed via diverse 'sustainable agriculture' technologies that ensure more efficient water use via greater retention of water within the farm system.

Given that it reflects two competing assessments of an overarching problem, this variable is expected to divide households into distinct groups with fundamentally different approaches to dealing with perceived production challenges. Households citing insufficient rainfall but not 'tired' soil are expected to have only a partial view of production constraints and a passive view of addressing these constraints. By contrast, those citing 'tired soil' are expected to have a more lucid view of production constraints and a more active attitude towards addressing these constraints.

OTHER 'DIAGNOSIS' VARIABLES

Given the centrality of the diagnosis variable to assessing competing views of trees as a means of addressing livelihood challenges, several alternative diagnosis variables were also examined. These included variables distinguishing (i) households that cited 'tired' soil as a key production constraint, (ii) households that cited inadequate rainfall as a key production constraint, and (iii) households that cited inadequate rainfall as the sole production constraint.

6.4.5 Associations with species-specific knowledge variables

In the following discussion, association findings are grouped by associative variable to emphasise the overall significance of each of these variables to understanding patterns of tree knowledge. For each associative variable, association findings are listed by tree function, in keeping with the study's focus on tracing knowledge vis-à-vis particular tree functions across different tree species. The correlation findings are summarised in Table 6.10.

6.4.6 Associations with resource variables

The associations with resource variables are distinct from the other associations in that these variables identify tangible characteristics of farm households and the local context that determine the incentives (i.e., the combination of opportunities and constraints) faced by households. If patterns of resource management and the local knowledge relevant to it are determined by incentives, as suggested by existing theory, then the associations between key resource variables and knowledge patterns should be strong. Specifically,

Table 6.10 Summary of associations findings[1]

Variables associated w/ SSKVs	Positive associations	Inverse associations	Additional associations
Resource variables			
Farm size	Fruit, construction wood, livestock fodder, soil fertilisation	-	-
Land tenure	-	-	-
Soil type	Construction wood		-
Market access	-	-	-
Household labour	Livestock fodder, SOIL FERTILISATION	-	-
Land-labour ratio	-	-	-
Ratio of elderly			
Sex ratio	-		
Female household head	Fuelwood	SOIL FERTILISATION	-
Livestock holdings	FRUIT, construction wood, FENCING, SOIL FERTILISATION		Windbreak (+)
Non-farm income / major source	Herbal medicine, FUELWOOD, soil fertilisation		-
Non-farm income / minor source	CONSTRUCTION WOOD, herbal medicine		Windbreak (+), 'trees make rain' (+)
Hired out labour as 'fieldhand'	Fruit, CONSTRUCTION WOOD, LIVESTOCK FODDER	Soil fertilisation	
'Outside influence' variables			
Listens to the radio	Fruit, HERBAL MEDICINE, SOIL FERTILISATION	Fuelwood	
Contacts with farming agents		-	'Trees make rain' (+), improved microclimate (+), windbreak (+)
Swahili language skills	Fruit, HERBAL MEDICINE, LIVESTOCK FODDER, fuelwood, fencing, SOIL FERTILISATION		Windbreak (–), improved microclimate (–)
Religion	HERBAL MEDICINE, livestock fodder, SOIL FERTILISATION		-
Management variables			
Kitchen waste		HERBAL MEDICINE, fencing, products generally, soil fertilisation	Windbreak (+)
Manure	Fencing		'Trees make rain' (+)
Micro-irrigation	Construction wood, fruit	Soil fertilisation	'Trees make rain' (+), improved microclimate (+)
Intercropping	Herbal medicine	Construction wood, fuelwood	Windbreak (+), improved microclimate (+)
Crop rotation	Livestock fodder, fencing, products generally, soil fertilisation		Improved microclimate (+), 'trees make rain' (–)
Fallowing	Livestock fodder		Windbreak (+)
Purchased agricultural inputs	Herbal medicine, soil fertilisation		-
Purchased crop seeds	HERBAL MEDICINE, soil fertilisation		Windbreak (–)
Drought-resistant crops	Herbal medicine	-	-
Cash crops	-		
Leguminous crops	Herbal medicine, soil fertilisation		
Vegetable cultivation	Fruit, HERBAL MEDICINE, soil fertilisation		
Perspective variables			
High-value tree product	Fruit, construction wood, herbal medicine	Soil fertilisation, fuelwood	
Farm-based trees	Fruit, CONSTRUCTION WOOD, diverse products		'TREES MAKE RAIN' (–), IMPROVEDMICROCLIMATE (–), WINDBREAK (–)
Harm crops via soil effects	Construction wood	Soil fertilisation	
Harm crops via shading effects	Construction wood, livestock fodder, herbal medicine	Soil fertilisation	'Trees make rain' (–), IMPROVEDMICROCLIMATE (–), WINDBREAK (–)
Density-dependence of adverse impact	Livestock fodder	Soil fertilisation	'Trees make rain' (+), improved microclimate (+)
Trees' role vis-à-vis crops	Livestock fodder, herbal medicine		Improved microclimate (+), windbreak (–)
Diagnosis of production difficulties	Soil fertilisation		-
Rainfall a key constraint	Fencing	Livestock fodder	'TREES MAKE RAIN' (+), IMPROVEDMICROCLIMATE (+), WINDBREAK (+)
Rainfall the sole key constraint		Livestock fodder, construction wood	'Trees make rain' (–), improved microclimate (–), windbreak (–)

Source: Shinyanga District household survey, 2000

[1] Factors listed in all capitals were generally significant at 1%, while the remainder were generally significant at 5%.

management of trees is expected to be more intensive and knowledge of them expressed more fully where the tangible resources available to household are more constrained[29].

While these associations are expected to reflect the incentives facing rural actors, they may also suggest instances where rural actors fail to respond to private incentives or where their responses to incentives are only partial or halting. To the degree that such associations are found to be weak, non-existent, or in reverse of the direction expected, they suggest neglect of existing incentives. Specifically, such findings support the study hypothesis that knowledge of available resources and associated opportunities may fail to keep pace with a rapidly changing rural context and associated management incentives.

Given the study focus, the central question is whether or not associations with resource variables are clear and in the expected direction. Where associations are in the reverse direction, they typically suggest that households with more assets tend to have better knowledge. Cases where the associations found fail to support a priori expectations are followed by a single asterisk, while those where the association is found to operate in the reverse direction are followed by a double asterisk[30].

FARM SIZE (**)

Farm size was found to be positively correlated with fruit, construction wood, livestock fodder and soil fertilisation. These associations suggest that households with larger farms are more likely to recognise diverse tree functions and appreciate the potential role of trees on farms.

One possible explanation is that households with larger farms are more likely to have farm trees by default, i.e., because they do not remove all naturally-occurring trees, and hence may be more likely to learn about them via direct experience and observation. A second possible explanation is that this linkage simply reflects mutual association with a third factor such as relative wealth or greater dynamism that tends to be associated both with larger farms and better knowledge of trees. Either way, these findings contradict a priori expectations that local actors tend to show greater appreciation of trees' diverse functions – and to intensify tree management – in response to growing resource scarcity.

[29] Notably, trees may be used to close feedback loops within farming systems.

LAND TENURE (*)

No clear correlations found. One possible explanation is the fact that the vast majority of survey households own at least part of their farm, as discussed in chapter five.

SOIL TYPE (**)

Farms with richer soil (i.e., those that included an area of black clay) were found to be positively correlated with recognition of construction wood. Again, this finding fails to support a priori expectations that those with more constrained resources tend to show more complete knowledge of trees. Instead, recognition of diverse tree functions corresponds to relative wealth rather than relative neediness.

MARKET ACCESS (*)

No clear correlations found. One possible explanation is that those with better or worse market access may face similarly strong incentives to harness tree products and services, since such aspects of trees will tend to be relevant to both types of households. Another possible explanation is that village-based markets may be dynamic.

HOUSEHOLD LABOUR (**)

Household labour was found to be positively correlated with citing both livestock fodder and soil fertilisation. These two knowledge variables are particularly significant, as they represent the two key means of employing trees to support existing farm enterprises and better integrate farm components. That is, these are the two key means of employing trees in agricultural support functions to bolster farm production, given stresses to the environmental basis of farming systems associated with resource degradation.

These associations suggest that households with greater labour supplies are more likely to recognise – and hence better able to harness – these opportunities. Specifically, they suggest that such households better appreciate the advantages of closing feedback loops among farm components. Potential explanations for this finding include having more person-hours with which to explore alternative means of working the land and having greater household needs that oblige them to explore alternative means of meeting these needs.

[30] Instead of seeing better tree knowledge associated with stronger incentives, such findings show it as associated with greater household assets, and hence suggest the existence of knowledge gaps.

This finding contradicts a priori expectations, yet is of dubious value when examined independently of farm size. This follows because larger households only indicate increased pressure on land resources and hence increased need where they imply a lower land-labour ratio. As such, these findings may simply be due to mutual association with farm size. Labour effects are better examined using the land-labour ratio.

LAND-LABOUR RATIO (*)

The land-labour ratio showed no clear correlations with the various tree knowledge variables. The absence of correlations with this variable argues against the a priori expectation that households begin managing trees and other available resources more intensively once they begin growing scarce, since this variable directly assesses farm size per unit labour. Specifically, the absence of significant correlations with this variable suggests that household knowledge does not readily adapt to growing resource scarcity. Moreover, because it assesses farm size controlled for labour units, the variable *land-labour ratio* is more appropriate for assessing household responses to growing land scarcity than either *farm size* or *household labour*, making the absence of any statistical correlations particularly significant.

RATIO OF ELDERLY IN HOUSEHOLD (*)

No clear correlations found. As discussed in chapter five, the explanation may be that households tend to include several generations of members, making distinctions between the 'life stage' of households non-critical.

RATIO OF MALES IN HOUSEHOLD (*)

No clear correlations found. As in the case of the ratio of elderly in the household, one possible explanation is that the vast majority of households include both adult males and adult females, making this distinction non-critical.

FEMALE HOUSEHOLD HEAD (* , -)

Households headed by women were found to be positively correlated with citing the fuelwood provision function of trees and inversely correlated with citing their soil fertilisation function. The correlation with citing fuelwood is unsurprising, given women's responsibility for meeting household fuel needs in Sukuma society. The overwhelming inverse correlation with citing soil fertilisation may be due to women being less educated and hence less likely to entertain non-traditional ideas about the role of trees on farms. Alternatively, it may

reflect the fact that tree cultivation is a gendered role allocated to men, to the extent that recognising trees' capacity to fertilise soil is concentrated among those involved in tree cultivation.

LIVESTOCK HOLDINGS (*)

Possessing livestock was found to be positively correlated with fruit, construction wood, fencing, soil fertilisation and the windbreak function. These findings suggest that possessing livestock tends to be associated with better knowledge of diverse tree products and services. Two notable surprises are the lack of correlation with citing livestock fodder and the strong positive correlation with citing soil fertilisation, even though manure represents a potential substitute for the fertilisation effect of trees. Taken together, these findings suggest no discernable correlation of tree knowledge with incentives but a strong correlation with greater household assets, implying a linkage of better tree knowledge with households' education and dynamism.

NON-FARM INCOME (*)

Having a major source of non-farm income such as running a store, working as a schoolteacher or being a livestock trader was found to be positively correlated with recognition of herbal medicine, fuelwood and soil fertilisation. Having a minor source of non-farm income such as those associated with cottage industries was found to be positively associated with recognition of construction wood, herbal medicine and the windbreak function of trees. These various correlations suggest that households with a source of non-farm income tend to have better knowledge of diverse tree functions, implying a linkage of better tree knowledge with households' education and dynamism.

LABOUR HIRED OUT

Having hired out labour was positively correlated with knowledge of fruit, construction wood and livestock fodder as well as being inversely correlated with knowledge of soil fertilisation. These findings suggest that households that have members who work as fieldhands tend to have better knowledge of diverse tree products as well as the soil fertilisation function of trees. Whether this is because these households have more experience of alternative farming strategies or are simply more needy is impossible to judge from this association, yet running correlations of the fieldhand variable with diverse indicator variables suggests that both interpretations apply.

6.4.7 Associations with outside influence variables

The following correlations seek to identify associations between how different households view trees and different outside influences on farm households. The underlying premise is that outside influences may have a profound impact on both the attitudes and specific views of households.

LISTENS TO THE RADIO

The associations findings for *listens to the radio* closely resemble those for the two Green Revolution variables considered above. The principal difference is that RADIO shows a positive correlation with fruit provision in addition to positive correlations with both herbal medicine and soil fertilisation. Because listening to the radio involves information provision and requires familiarity with Swahili, this variable indicates some level of both formal education and exposure to non-traditional ideas. It may also indicate households that are comparatively well-off, since the costs of both the radio itself and the batteries needed to keep it running are likely to be prohibitive to poorer households. These associations thus imply that knowledge of diverse tree functions is higher among those with greater education and / or household assets.

CONTACTS W/ EXTENSIONISTS, PROJECTS OR INPUTS PROVIDERS

The only clear findings were positive associations with the different environmental variables, notably 'trees make rain', improved microclimate and windbreak function. The implication is that recognition of environmental benefits deriving from local tree stocks tended to be linked to contact with outside organisations. One possibility is that these ideas originated with these organisations and were transferred to households via contacts with them, while a second possibility is that these outside ideas simply reinforce existing ideas or perceptions while providing a convenient format for expressing them. The relative lack of correlations with this variable may be due to the fact that data on this variable were missing for a majority of survey households, making these findings statistically tenuous.

SWAHILI

Better Swahili language skills were found to be positively correlated with households' recognition of various tree products as well as trees' soil fertilisation function. Swahili was also inversely correlated with the two environmental service variables. These findings imply a rough breakdown of households into a more traditional grouping relatively uninterested in trees and a more educated grouping more interested in trees. Supporting this finding, households citing either of the two environmental services variables were likely to

emphasise trees located in the bush, suggesting a de-prioritisation of trees and a passive management strategy relying on natural regeneration and off-farm tree stocks. The implication is that households traditionally tend to view environmental services as provided by off-farm trees, while greater appreciation of diverse tree products and services depends partly on access to outside information.

RELIGION

Adherence to a modern religion was found to be positively associated with both diverse tree products and the soil fertilisation function of trees. These findings support the expectation based on the study hypothesis that outside (i.e., non-traditional) influences tend to be associated with better knowledge of trees and their potential significance to the farm. The principal exception to this among the tree knowledge variables were the four environmental variables, none of which showed a clear, consistent correlation with the religion of households. The implication is that these variables represent an older form of knowledge that is not dependent on the influx of outside ideas and influences, but rather persists within the population independent of the play of outside influences.

6.4.8 Associations with management variables

The following section seeks to identify statistical associations between patterns of tree knowledge and farm management. Management decisions considered include diverse soil and water conserving practices and aspects of crop choice. The aim is to determine how patterns of tree knowledge relate to farm and natural resource management decisions by households.

Like tree management decisions, decisions vis-à-vis soil and water conservation and crop choice arguably depend critically on household knowledge and perceptions, since the physical resources in question tend to be available at minimal cost to households. Moreover, these various management decisions form part of an overall farm management strategy that is based on perceptions of how different resources interact and how they may be combined to meet household needs. The question addressed is whether these various resource management decisions and the perceptions underlying them are related to knowledge about trees and if so how.

Because households with differing knowledge profiles (i.e., those either with more or less exhaustive knowledge about trees) are combined in these assessments, the associations detected simply show the tendencies vis-à-vis tree knowledge among those households following the management practice in question,

taken as a group. In other words, they show which tree views are comparatively likely among those households following this particular practice. They may also suggest how these factors are seen to interact by survey households.

KITCHEN WASTE

Using kitchen waste to fertilise crops was found to be inversely correlated with recognition both of diverse tree products and the soil fertilisation function of trees. It was also found to be positively correlated with *provides windbreak*. The implication is that the 15 percent of survey households using kitchen waste tend to have relatively poor knowledge of trees, or to de-emphasise the role of trees in meeting household needs. While recognition of the windbreak function of trees is an exception, this function is commonly associated with off-farm trees. The net picture is that households using kitchen waste tend to have a passive attitude towards tree management, relying on nature to provide trees rather than protecting or cultivating them.

MANURE

Using manure to fertilise crops was found to be positively correlated with both citing fencing and the observation that 'trees make rain'. The implication is that the 54 percent of survey households using manure have only minimal linkages with patterns vis-à-vis tree knowledge. Notably, despite the fact that manure is a key natural fertiliser, no linkage was found with greater recognition of soil fertilisation and other agricultural support services provided by trees. One possible explanation is that sometimes manure is seen as an alternative means of fertilising soils that renders trees' soil fertilisation function redundant, while sometimes these two options are seen as complementary means of addressing acute fertility problems.

MICROIRRIGATION

Employing micro-level water management was found to be positively correlated with recognition of construction wood and fruit and inversely correlated with the soil fertilisation function of trees. It also showed clear positive correlations with the environmental services variables *'trees make rain'* and *improved microclimate*. Although discernable, the linkages between this factor and most of the tree knowledge variables are tenuous, perhaps due to the fact that the micro-irrigation variable combines divergent types of water management. The only clear implication is that the 39 percent of survey households engaging in water management are more likely to recognise environmental services provided by trees, perhaps because these often involve concerns with rainfall and managing water flows to reduce erosion.

INTERCROPPING

Practising intercropping was found to be inversely correlated with citing diverse tree products, notably construction wood and fuelwood, and positively correlated with citing herbal medicine and the environmental services variables *improving the microclimate* and *windbreak function*. The implication is that the 86 percent of survey households following this practice tend to be less aware than others of certain products provided by trees, yet more likely to view trees as providing environmental services or herbal medicines. The mixed picture painted by these correlations is difficult to interpret. It could however be taken to suggest that households practising intercropping have comparatively poor knowledge of trees, except of environmental services typically associated with off-farm tree stocks.

CROP ROTATION

Practising crop rotation was found to be positively correlated with diverse tree products as well as *improved local environment* and the fertilisation function of trees. It was also found to be inversely correlated with *'trees make rain'*. The implication is that these 52 percent of survey households tend to have comparatively exhaustive knowledge of the products and services provided by local tree species. The linkages with tree services make sense, since failure to practice crop rotation suggests that households disregard the need to balance crop needs imposed on soils with their capacity to regenerate. Similarly, it stands to reason that households that better appreciate subtle tree services would also better appreciate more obvious tree products.

FALLOWING

Practising fallowing was found to be positively associated with livestock fodder and *provides windbreak*, but not with any other tree products or services. The 34 percent of survey households that continue to rely on fallowing to regenerate their soils tend to be either relatively traditional households with a more passive view of farm management or simply those households with farms large enough to render fallowing viable. These associations suggest that trees' capacity to provide livestock fodder is associated with either large farms or traditional management. Either way, these associations suggest passive management of local environmental resources.

PURCHASED CROP SEEDS / PURCHASED AGRICULTURAL INPUTS (**)

Purchased crop seeds was found to be positively correlated with recognising trees' capacity to provide both herbal medicine and soil fertilisation. It was also inversely correlated with *provides windbreak*. Similarly, *purchased agricultural inputs* was found to be positively correlated with herbal medicine and soil fertilisation to farm households. Given the similarity of these findings and the natural linkages between these variables, these two sets of associations were discussed jointly.

Both variables may be interpreted as indicating households employing elements of a Green Revolution agricultural strategy. *Purchased crop seeds* identifies households that purchased hybrid or at least carefully selected seeds[31], while *purchased agricultural inputs* identifies households that bought either crop inputs (e.g., chemical fertilisers or pesticides) or livestock medicines (e.g., disinfectants or vaccinations).

Given this backdrop, the associations data show that households pursuing a Green Revolution strategy – including both the 32 percent purchasing hybrid seeds and the 40 percent using some other purchased input to either cropping or livestock – tend to have relatively good knowledge of trees and their diverse functions. The broader question is why some households pursue this strategy – and tend to recognise diverse tree functions – while others do not. One possible explanation is that these households possess opportunities associated greater household assets, while others simply cannot afford to purchase seeds or other marketed agricultural inputs due to sheer poverty couple with lack of credit. Again, better knowledge of tree characteristics emerges as associated with greater household assets rather than greater need for innovative or intensive resource management.

DROUGHT-RESISTANT CROPS

Growing drought-resistant crops was found to be positively correlated with knowledge of herbal medicine but showed no clear correlation to any other tree functions. The implication is that while these 84 percent of survey households may be somewhat more aware of tree products than other households, no clear linkage between tree knowledge and opting to grow drought-resistant crops may be deduced.

[31] Hybrid seeds represent the highest category, selected seeds represent the intermediate category, while others represent the final category.

CASH CROPS

No clear correlations found. The implication is that the choice to grow cash crops is unrelated to knowledge about trees.

LEGUMINOUS CROPS

Growing leguminous crops was found to be positively correlated with recognition of herbal medicine and soil fertilisation. The implication is that the 41 percent of survey households growing just one leguminous crop and the 43 percent growing two or more such crops tend to have more complete tree knowledge than others. Given the established linkage between leguminous crops and soil fertility, the positive linkage with the soil fertilisation function of trees is unsurprising.

VEGETABLE CULTIVATION

Vegetable cultivation was found to be positively correlated with citing trees' capacity to provide fruit, herbal medicine and soil fertilisation. It represents a means for households to supplement their income from crop cultivation and livestock herding by exploring alternative ways to work the land. The associations suggest that better knowledge of trees is concentrated among households that explore such alternative possibilities, including the 45 percent of survey households that cultivated vegetables.

6.4.9 Associations with perspective variables

The following correlations seek to identify patterns between observed tree knowledge and underlying perceptions of production constraints and the role of trees in the farm system. The premise is that differing views and perceptions vis-à-vis trees may impact tree management decisions, an idea strongly supported by the regression findings in chapter four.

KEY TREE PRODUCT

Prioritisation of high-value tree products instead of low-value tree products showed clear associations with the species-specific knowledge variables. It was found to be positively associated with fruit, construction wood and herbal medicine, suggesting that where these products were cited by households they were often also prioritised. It also showed strong inverse correlations with citing either soil fertilisation or fuelwood. These

findings suggest that explicit recognition of tree services and low-value tree products tends to be inversely correlated with prioritisation of high-value tree products.

One possible interpretation of these findings is that interviewees wished to say something about trees out of politeness, yet preferred to not say more once they had conveyed what they deemed the necessary minimum. While even such comments would be revealing, the principal implication would be that farmer comments about tree characteristics did not reflect their views. This interpretation may be plausible, but it is dismissed as excessively skeptical, particularly in light of the qualitative comments by survey farmers elaborating their thinking vis-à-vis trees.

The other possible interpretation is that trees tend to be viewed *either* as the source of high-value products or as multifaceted farm components providing diverse products and services, but not both. The implications of this possibility are profound, as it suggests sharply divergent perceptions of particular local trees with inescapable consequences for tree management decisions.

KEY TREE LOCATION

Because key tree location is a multinomial variable with three distinct categories, directional correlations indicate both a broad association with farm trees as opposed to off-farm trees and with trees in the home garden in particular[32]. Positive correlations were found with citing fruit and construction wood, as well as with knowledge profiles vis-à-vis tree products. Clear inverse correlations were found with all four environmental variables.

The linkages between key location and recognition of diverse tree products and services are subtle, but show some clear trends. On one hand, they suggest that households emphasising farm-based trees tend to recognise higher-value tree products yet may fail to cite lower-value products, perhaps due to their relative deprioritisation. On the other hand, the inverse correlations with the environmental service variables suggest that these services tend to be seen as being provided by off-farm trees. Also, citing soil fertilisation showed a modest correlation with citing the fields as the key tree location.

[32] To ensure that significant associations were not omitted by this imposition of three ranked categories, two alternative versions of the tree location variable were also correlated with the species-specific knowledge data, namely home garden vs. other locations and farm-based vs. off-farm. These findings were not discussed separately, since they closely mirrored the findings for the multinomial case.

The net picture is that emphasising the farm as the location of useful trees tends to be associated with viewing trees as the source of high-value products. By contrast, tree services do not tend to be associated with growing trees on the farm, suggesting that they do not tend to be seen as sufficiently significant to be provided by private tree stocks.

HARMSOIL

Of the various tree knowledge variables, the strongest and most consistent correlations with *tree harms crops via soil effects* are inverse correlations with the two soil fertilisation variables. These findings suggest that households tend to have either a more sympathetic or more hostile attitude towards trees that colours their perceptions of a particular tree's characteristics and significance to the farm system. That is, these correlations suggest that households tend to mention either a positive soil effect or a negative one, but not both. Those emphasising negative soil impacts thus either fail to recognise the accompanying positive impacts or choose to de-emphasise them[33]. As hypothesised, the danger is that negative farmer attitudes towards trees may obscure recognition and harnessing of advantageous management options.

By contrast, the positive correlation with citing construction wood suggests that households emphasising the negative impact of trees on crops tend nonetheless to recognise that these trees produce useful products. That is, while households emphasising harmful crop impacts may fail to recognise that trees can provide agricultural support services, they nonetheless see trees as useful in a sense.

The resulting picture is not of households either viewing trees in a negative or a positive light, but rather of seeing them as providing either a narrow range of tangible benefits or diverse benefits including services with positive feedback loops into the farm system. Thus, while all households may tend to weigh tree costs and benefits against each other when making tree management decisions, some appear to consider a broader, more inclusive set of factors than others.

HARMSHADE

The findings for the variable *cited shading as harmful to crops* largely mirror the findings for *tree harms crops via soil effects*. On the one hand, they show an inverse correlation between citing shading as harmful to crops

[33] This finding is particularly striking because households with significant numbers of trees in their fields would be expected to cite both effects, since both necessarily apply in the majority of cases. The fact that this correlation is strong despite many households citing only home garden-based or bush-based trees underlines the significance of these underlying attitudes to informing households' perceptions of trees.

and recognition of various tree services, including both the soil fertilisation effect and other environmental services. On the other hand, they show positive correlations between *cited shading as harmful to crops* and citing diverse tree products, implying that households tend to view trees as providing at least some benefits to the farm. As in the case of *tree harms crops via soil effects*, the net picture is not of households either viewing trees in a negative or a positive light, but rather of seeing them as providing either a narrow range of tangibie benefits or diverse benefits including agricultural support services.

DENSITY DEPENDENCE

Density dependence was found to be positively correlated with citing livestock fodder as well as with the environmental variables 'trees make rain' and trees improve the microclimate. It was also found to be modestly inversely correlated with the two soil fertilisation variables. The net picture is of a critically minded yet still fundamentally sceptical view of the impact of farm-based trees on annual crops. While some environmental services provided by trees are recognised, this recognition does not extend to the critical tree service of soil fertilisation. These households do however tend to recognise livestock fodder, which can play a key role in ensuring the survival and vitality of livestock at times when grass fodder grows scarce.

TREES' ROLE VIS-À-VIS CROPS

Viewing trees as having favourable interactions with annual crops tends to be associated with recognising diverse tree products and certain tree services, such as improving the local microclimate. The implication is that households have either a more positive or a more negative view of trees, and that these views colour their recognition of tree products and services. The one exception to this finding is that positive views of trees' role vis-à-vis crops do not seem to correspond with recognising the windbreak function of trees. Instead, this service tends to be cited by those with more negative views of trees' impact on crops, perhaps because windbreak effects tend to be associated with off-farm trees.

DIAGNOSIS OF KEY PRODUCTION DIFFICULTIES

Correlation findings of species-specific knowledge variables with *diagnosis of key production difficulties* were relatively few, implying either subtle or insignificant linkages. The one clear finding was the positive correlation with recognising trees' soil fertilisation function. Besides this, the tenuousness of the associations findings suggest that knowledge of tree species and households' assessments of farm production difficulties are

not by and large meaningfully linked. The implication is that trees are generally not viewed as directly related to addressing production difficulties, except in the case of trees' soil fertilisation function.

ALTERNATIVE DIAGNOSES OF PRODUCTION CONSTRAINTS

'Tired' soil as a key constraint: The findings for this diagnosis variable closely resembled those for the diagnosis variable examined above, and hence were not discussed separately.

Inadequate rainfall as a key constraint: This diagnosis of the households' key production constraints was found to be positively correlated with citing fencing as a tree product as well as with the four environmental services variables. It was also found to be inversely correlated with citing fodder provision by trees. The net picture is of a fundamentally passive view of trees that recognises some of their positive aspects but fails to appreciate their potential role in helping meet household livelihood objectives. Notably, the lack of correlation with the soil fertilisation function of trees suggests that households subscribing to this view may take a passive view of tree services, seeing them as being provided by off-farm trees and not having any direct relationship with crop production.

Inadequate rainfall as the sole key constraint: This diagnosis of the households' key production constraints was found to be inversely correlated with recognition of both tree fodder and construction wood, as well as with the diverse environmental service variables. Households subscribing to this diagnosis are characterised by a failure to recognise diverse aspects of local trees, including a general failure to appreciate the provision of environmental services by off-farm trees[34]. The fact that such households were unlikely to cite tree fodder is also significant, given the importance of livestock in the District and the potential significance of this source of supplementary fodder. These households may be seen as having both a negative overall view of trees highlighted by their failure to cite obvious tree products and as subscribing to a narrow assessment of production problems that does not envisage activist responses to perceived production challenges.

[34] The fact these diverse environmental services were positively associated with citing rainfall as *among* the farm's key production constraints but inversely correlated with citing it as the *sole* production constraint suggests that the latter are a highly distinct group.

6.4.10 Summarising the associations findings

Figure 6.1 summarises these exploratory pairwise correlations. Specifically, it summarises observed associations between species-specific tree knowledge and both farm management and perspective variables. It also notes particularly clear associations with resource and outside influence variables.

The resulting analysis presents a suggestive anatomy of distinct knowledge categories based on these statistical findings. The categories as defined are strictly empirical, following from the associations found. Various associations were left out of this summary analysis due to their not showing clear linkages with other associations. Yet many associations of species-specific tree knowledge with 'intangible' associative variables fell neatly into one category or another[35]. This analysis defines three broad categories of farmer thinking vis-à-vis trees and farm management.

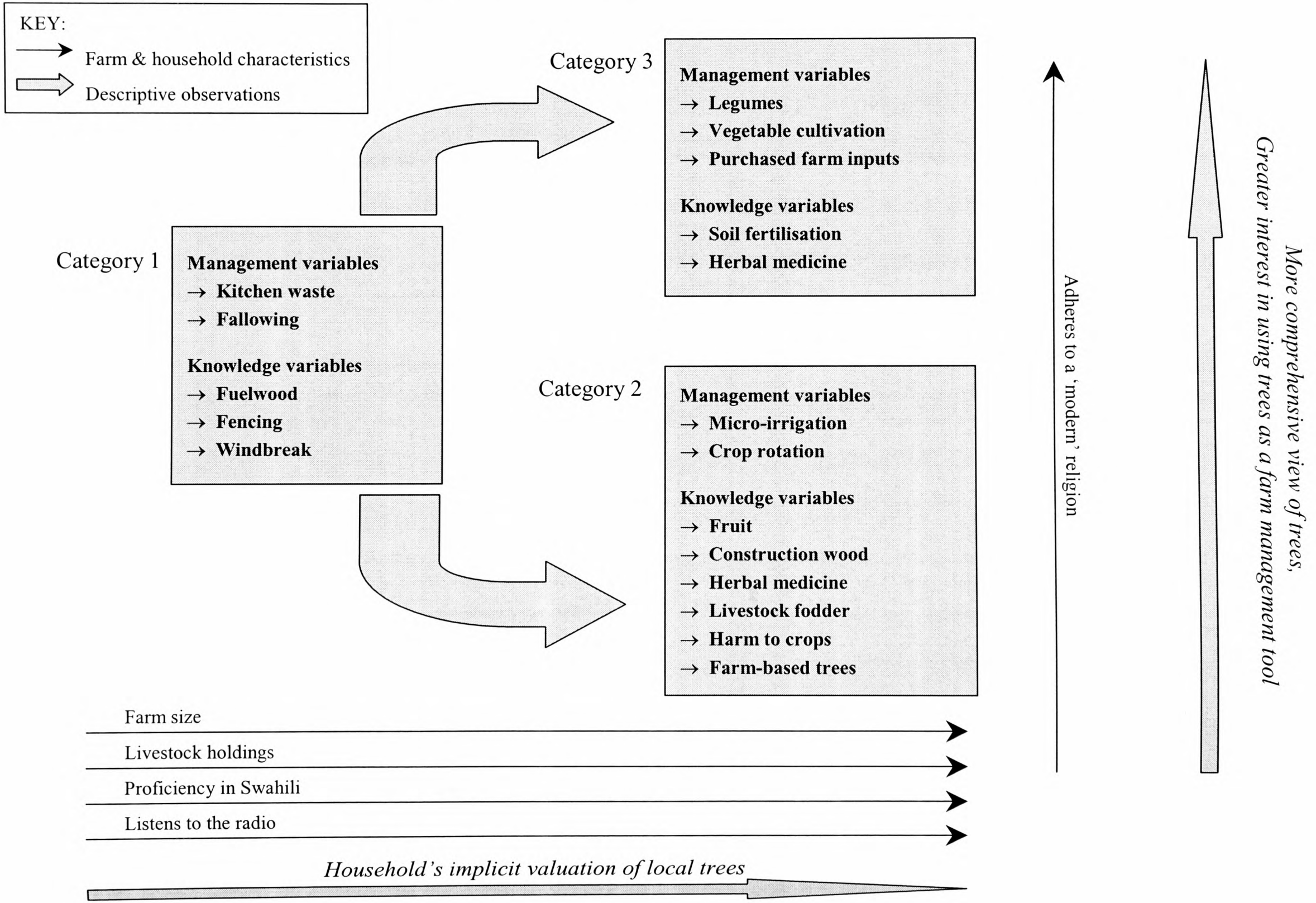
Category one may be characterised as disinterest in trees and a narrow view of their role in the farm system. Households in this category emphasise low-value tree products and neglect potential feedback loops with other farm components. They take a passive view of replenishing soil fertility and securing tree products, and only make minimal comments about the environmental benefits of off-farm trees.

Category two may be characterised as viewing trees as the source of high-value tree products. Households in this category emphasise the capacity of trees to provide such products while de-emphasising their capacity to provide agricultural support services, notably soil fertilisation. These households also emphasise harmful impacts of trees on crops, whether via soil effects or shading. Their emphasis on crop rotation and micro-irrigation suggests that such households show a degree of agency vis-à-vis responding to pressure on resources, although this agency does not extend to integrating trees into the farming system. Finally, their recognition of environmental services suggests some appreciation that trees may have uses beyond providing products.

Category three may be characterised as a comprehensive view of trees, including harnessing positive feedback loops. Households in this category are particularly likely to cite agricultural support services such as soil fertilisation, yet may also emphasise diverse tree products. Their tendency to cultivate leguminous crops suggests an appreciation of the need to respond to pressure on resources, while their tendency to cultivate

[35] The resulting findings *do not* imply that all households citing a given factor fell into a particular category, just that there was a clear tendency for such households to do so. Thus, while households citing kitchen waste may show a clear tendency to fall into category one, such households may also fall into other knowledge categories.

Figure 6.1 Diagram of the associations analysis



vegetables suggests dynamism. Their greater tendency to use purchased inputs in their farming system suggests that these households may be comparatively well-off. Finally, the fact that these households show a strong tendency to subscribe to a 'modern' religion suggests that not being beholden to traditional ideas may be a key determinant of this way of thinking.

Figure 6.1 also shows how these categories relate to several key resource and outside influence variables. These show directional associations between household and farm characteristics with specific knowledge patterns. Resource variables found to be clearly associated with this categorisation included farm size and livestock holdings. Both larger farmers and ownership of livestock were positively associated with categories two and three but not category one. Swahili language skills and listening to the radio showed a similar association.

This figure also includes ex-post interpretative comments of how the different categories defined compare with one another. Such comparisons are meaningful in view of the fact that individual households may move between categories in response to changing circumstances and associated incentives. Categories two and three represent higher implicit valuations of trees relative to category one. Meanwhile, category three represents both a more comprehensive view of trees than category two as well as indicating greater interest in using trees as a farm management tool.

Chapter 7

Conclusions

The present study identifies gaps in the knowledge of some peasant households vis-à-vis trees, with clear implications for tree management. The policy implication is that development interventions could help local people to capture untapped opportunities existing *within* low-potential agricultural systems. Specifically, such interventions would involve highlighting advantageous management options that are neglected by some households despite being readily accessible.

Such knowledge gaps and their corresponding opportunities are not acknowledged by the contemporary literature, as any such opportunities are assumed to be both recognised and acted upon by local people. Indeed, the 'poor but efficient peasant' thesis and the theory of induced innovation whereby economic actors spontaneously respond to emerging opportunities are both pillars of contemporary agricultural development theory. While these concepts may apply under normal circumstances, the study suggests that under certain conditions common in contemporary Africa they may *not* apply.

Despite the plausibility of this conceptual premise, the practical difficulties involved in testing the 'knowledge failure' hypothesis and exploring the nature of knowledge gaps are great. Specifically, knowledge data are both inherently complex and plagued by inherent measurement difficulties. While the study is therefore necessarily exploratory and inconclusive, its findings are nonetheless important, given the potentially critical nature of the issues involved. Moreover, the trends identified are strong and clear, providing grounds for optimism that the underlying theory is valid.

Thus, the data were found to strongly support the study hypothesis. Specifically, variables characterising households' knowledge about trees were found to greatly increase the explanatory power of tree management regression models. The implication is that households' technical knowledge has significant explanatory power that operates independently of tangible resource constraints. This being established, the study then sought to elucidate different strands of local knowledge by identifying diverse correlates with them.

The implications of these findings are various and profound, suggesting a strategic pathway distinct from those normally advocated as strategies for addressing rural poverty. This concluding chapter will first reiterate the

theoretical case demonstrated by the present study, then highlight the various practical and policy implications of this work.

7.1 Theoretical implications

7.1.1 Identifying limiting assets

The rural poor are primarily farmers, and the most intractable agricultural challenges are those facing low-potential agricultural areas. Typically, such areas are remote, are experiencing resource degradation due to pressures associated with growing human and livestock populations, and lack access to Green Revolution technologies such as hybrid seeds and chemical fertilisers. Instead, farm inputs available to households in such areas are generally limited to land, labour, livestock, and renewable natural resources[1] such as soil and vegetation. Given these distinctive characteristics, it has been suggested that a different model of agricultural development is needed for such areas.

A critical characteristic of many such areas is 'environmental' or resource degradation. In Shinyanga District and other parts of rural Africa, such degradation is reported to be widespread, placing acute pressures on land and remaining natural resources and constraining rural production. Examples of resource degradation drawn from the household survey include frequent comments about soils being 'tired', difficulties securing dry season fodder, and spending as much as several hours per day in securing supplies of fuelwood and water.

Given this backdrop, a key question is what management options are available to local people to cope with falling stocks of natural resources coupled with rising demands on existing resources. Theoretical options which may or may not be accessible include (1) substituting purchased farm inputs for traditional natural inputs, e.g., chemical fertilisers instead of fallowing or gas stoves instead of fuelwood; (2) allocating additional labour to carrying out traditional tasks, e.g., spending more time herding livestock or gathering fuel; (3) 'belt-tightening', or making do with less, (4) allocating labour to non-traditional tasks, notably 'investing' labour to increase local stocks of natural capital; (5) migrating to an area where land remains abundant or leaving agriculture altogether.

The strategy chosen by different households depends critically on the opportunities and constraints of their situation, notably household assets. Assets are seen by economic theory as an uncontroversial good, enhancing

[1] Henceforth these will simply be referred to as 'natural resources', in the interest of simplicity.

the well-being of economic actors both rich and poor. Yet the elaboration by economic theory of several distinct asset types in recent years raises potentially complex questions regarding which assets are relevant in a given situation. Identifying the limiting asset(s) is particularly important, since these determine the critical interventions to improve livelihoods and/or growth in a given situation.

The sustainable livelihood framework defines five critical asset categories, namely physical, financial, natural, human and social. The study hypothesises that in cases where the local natural resource base has become degraded, natural capital may be limiting, significantly reducing the marginal productivity of both land and labour inputs into production. This is particularly likely where purchased agricultural inputs are generally inaccessible to local people, since in such cases sustained production depends on the ongoing vitality of local natural resource stocks. It further hypothesises that local people may fail to fully appreciate the gravity of this need or available means to address it via intensive natural resource management. In short, the study hypothesises that insufficient local stocks of natural capital may be the proximate cause of production problems while problematic LK may be the root cause of these problems.

7.1.2 Natural capital and the local economy

Natural capital is unusual due to its capacity to reproduce itself naturally, i.e., spontaneously and without need of human intervention. In practice, however, this only occurs under favourable conditions. Specifically, where pressure on renewable natural resources is great, the regenerative capacity of these resources may not manage to keep pace with the demands on them without active investment in natural capital by users, and natural capital may become depleted. Thus, the phenomenon of resource degradation is both evidence of stressed natural systems and imposes further stresses on the remaining resources. The result may be a vicious circle or 'poverty – environment nexus', where pressure on natural resources leads to degradation which in turn leads to further pressures in the form of agricultural stagnation and poverty.

In cases where natural capital is depleted, local agents may wish to increase it. Unlike other household assets such as land, labour or capital, securing additional stocks of natural capital via 'investment' in stocks of natural resources tends to be both feasible and straightforward. Critically, the needed physical inputs tend to be readily available. Although it may require additional labour inputs, it may also reduce such inputs while improving welfare if natural capital is strongly limiting and existing knowledge gaps are large.

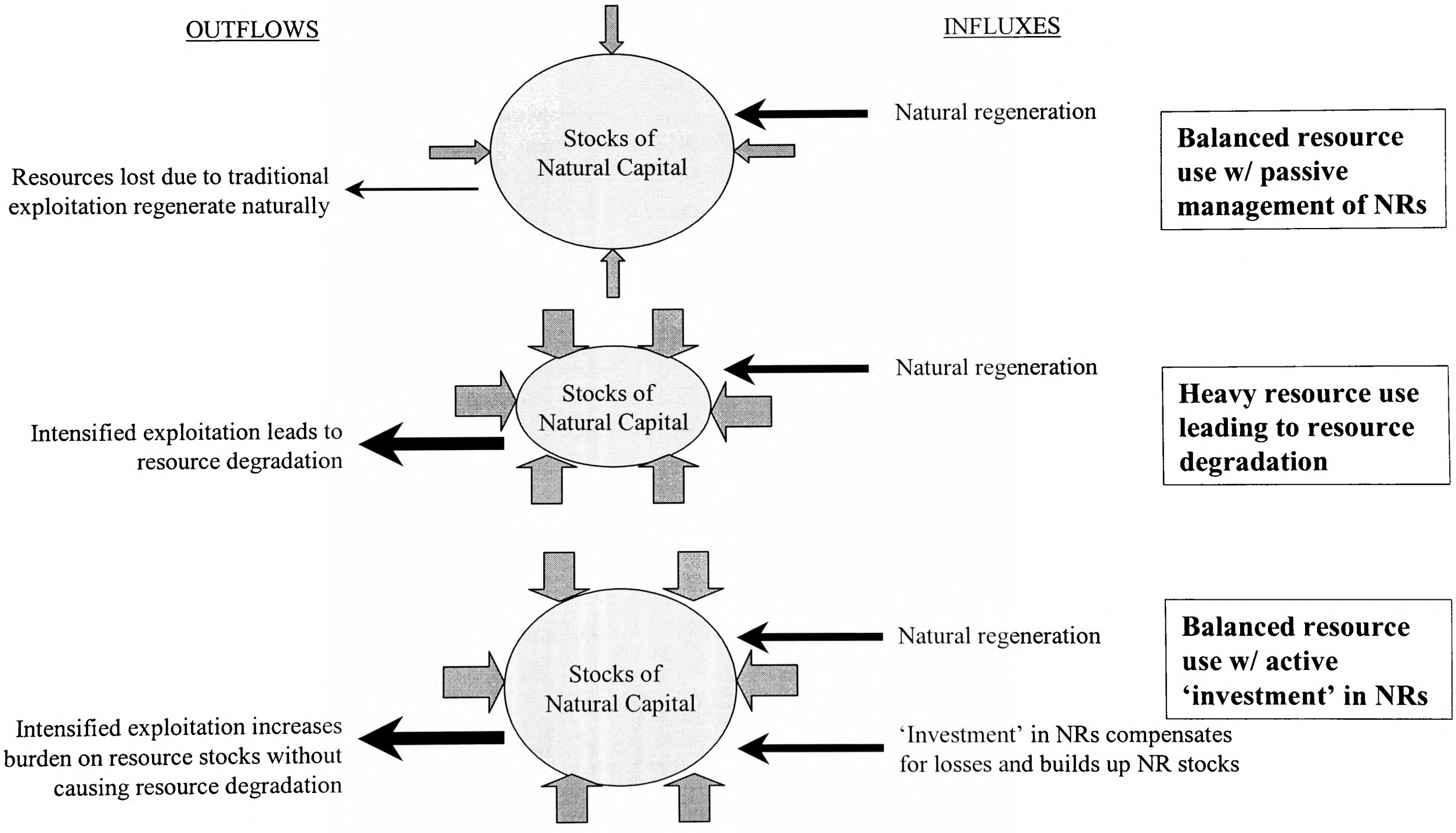
Figure 7.1 summarises the alternative possibilities vis-à-vis natural resource dynamics, showing that the volume of local natural capital stocks varies depending on the relevant influxes and outflows. The three diagrams shown depict the cases of (i) ample natural capital with low use rates, (ii) depleted natural capital with high use rates, and (iii) ample natural capital despite high use rates due to active regeneration of natural resources. See Appendix A.i for further discussion of natural resource dynamics.

Natural capital plays two distinct roles in the local economy. On the one hand it provides useful and perhaps marketable products while on the other it provides environmental services, including support services to agricultural production. Both of these aspects of natural capital are compromised by resource degradation.

Whether farm households conserve and/or invest in natural capital is significant economically because it contributes to both of these functions. It is particularly significant in areas experiencing resource degradation, since in these areas natural assets are more likely to be limiting. For instance, means of improving soil fertility via increasing natural capital are particularly significant in areas where soil fertility is a problem. Generalising from its diverse functions, it may be said that conserving and/or investing in natural capital serves to bolster or reinforce the foundations of production systems, whether they be semi-subsistence or market-oriented. Specifically, vital stocks of natural capital ensure the continued provision to the farming system of basic products and environmental services.

Historically, local stocks of key natural resources have tended to be abundant in the study zone and similar communities, as a result of which their associated products and services could be safely taken for granted. Given this general abundance, the economics literature has traditionally recognised such goods and services to be essentially 'free' to users. Arguably, local users of these resources across the world have likewise tended historically to view these resources as essentially 'free', since in cases where resources were abundant this assessment represented a safe generalisation. Examples relevant to the context of Shinyanga District, Tanzania include treating fertile land as 'free' by practising shifting cultivation and treating fuelwood and livestock fodder as 'free' by relying on supplies from the surrounding bush. In areas where key natural resources become scarce due to overexploitation or conversion of land to novel uses, the question arises as to how local economic agents adapt to this change. This question has widespread relevance, given the contemporary reality of widespread resource degradation.

Figure 7.1 Natural resource (NR) dynamics



The discipline that has emerged to address these issues is environmental economics. It envisages two types of responses to environmental scarcity, one by resource users and one by the state. In both cases, the measures envisaged involve minimising resource degradation and wasteful use, and may result in net increases in resource stocks. These measures address concerns about scarce natural capital by shifting incentives regarding resource use.

Responses by users involve privatising resources that were formerly either common property or open access resources. In farming communities, this typically means substituting farm-based resource stocks for resources from commons or open-access areas. Examples include building up soil fertility via soil amendments instead of relying on shifting cultivation and growing farm trees instead of relying on off-farm trees to provide tree products and services. This transition serves to shift the incentives from favouring simple exploitation to favouring conservation and/or active investment of labour, land and other resources in creating private resource stocks to ensure continued access to key resources over time. The net effect in agrarian communities is to increase farm-based resource stocks while reducing pressure on off-farm stocks, possibly allowing them the chance to regenerate[2].

Responses by the state involve imposing costs on the use of open-access resources via mechanisms such as regulations and taxes. These measures seek to create a situation in which users face the full 'social costs' associated with use of the resource, i.e., all the ways in which society loses when an economic agent uses an additional unit of the resource. The result is that users are more careful about using the resource, only doing so when it is worthwhile despite the associated costs. Moreover, entrepreneurs may step in to create additional supplies of the resource as a money-making venture.

The present work diverges from this body of literature by focusing not on incentives but on recognition of these incentives and full knowledge of the associated resources[3]. While favourable incentives may be necessary to secure conservation and long-term use of natural resources, they may not be sufficient to achieve this end. The danger is that under certain conditions, resource users may fail to recognise existing incentives to conserve and/or invest in private stocks of local natural resources. Specifically, users may have difficulty keeping pace with shifting incentives vis-à-vis natural resource management during periods of rapid change in local resource stocks.

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[2] While this may simply involve increased tree retention and cultivation on existing farms, it may also involve the progressive incorporation of commons land into farms using tree cultivation as a means of establishing tenure rights.
[3] While of great interest, examining such incentives lies beyond the scope of the present study.

Two sets of factors may contribute to farmers having trouble recognising existing incentives vis-à-vis managing natural resources. One set of factors comprises major demands on the capacity of local peoples' knowledge and perceptions to adapt to change. The second set of factors involves reasons for concern about the adaptability of local knowledge in remote, low-potential agrarian communities. The former are demand-side factors; the latter are supply-side factors[4].

7.1.3 Major demands on the adaptive capacity of local knowledge

Changes in the opportunities and constraints facing rural actors may be due to diverse factors, including shifts in resource abundance and the pervading policy climate. When rapid, any such changes place great demands on the knowledge base and adaptive capacity of households, arguably making problems with local knowledge more likely. Factors likely to be relevant to poor agrarian communities in the contemporary African context include (i) population growth, (ii) increasing livestock numbers, (iii) large-scale migrations of people and livestock, (iv) resource degradation, including loss of vegetative cover, problems with soil erosion and soil fertility, and disruption of hydrological cycles, (v) growing market opportunities associated with liberalisation, (vi) large fluctuations over recent decades in the prices of agricultural inputs and outputs, (vii) instability associated with forced relocations due to the government's *Vijiji wa Maendeleo* initiative of the 1970s and 1980s, (viii) sometimes conflicting advice from project and government initiatives.

Of these factors, resource degradation is of particular significance, given the nature of natural assets and the dependence of many production systems on these assets. The danger is that due to their capacity to reproduce themselves, natural resources may be taken for granted. That is, economic actors may assume that these resources will reproduce themselves naturally regardless of whether this is realistic in the situation in question. In cases where natural resources become degraded, it may be advantageous for households to conserve resources such as trees or to actively cultivate them. Some households and some communities will doubtless do so but many may not, with the latter suggestion supported by reports of widespread resource degradation. Whether or not local people perceive this transition from these resources being abundant and essentially free to being relatively scarce and hence valuable is a question of knowledge and perceptions.

Such transitions are likely to be especially difficult – and knowledge problems are likely to be especially common – vis-à-vis complex resources such as trees. Although this depends on the species in question, trees

[4] Although Shinyanga District is a semi-subsistence economy, questions of supply and demand nonetheless apply. Even purely subsistence households are involved in allocating factors of production and meeting consumption needs.

typically provide both diverse products and services while also imposing costs on the farm system[5]. In theory, households weigh these various factors against one another to determine the net value of a given tree to the farm, and hence which management strategy best serves household welfare. Tree management decisions are thus complex by definition. Yet this complexity is vastly increased during periods of rapid change in local tree cover, since in such situations the relative significance of these various costs and benefits tends to shift. Simply put, the value of trees to households is density-dependent. In areas where trees are abundant, the benefits they provide are likewise abundant and hence of low value (e.g., providing livestock fodder or fertilising soils), while the costs they impose may be great (e.g., providing favourable habitat for pests and competing with annual crops for water, soil nutrients or sunlight). By contrast, where trees are scarce the benefits they provide may be precious while the costs they impose may be minimal. Thus, valuing trees accurately is particularly difficult in cases where an area switches in a relatively short space of time from tree abundance to tree scarcity.

Besides their capacity to reproduce themselves and their complexity, a third quality of natural resources that may complicate their management is that these resources are not generally priced. Economic theory suggests that resource management decisions are made principally on the basis of their economic or livelihood value to households. Typically, such valuations are made via the price mechanism and the play of markets. Yet because natural resources in poor rural areas are not generally marketed, they do not generally bear established prices. The value or 'shadow price' of these resources must instead be estimated by local people in a process which may be termed 'implicit valuation'[6]. This process places great demands on local knowledge, since estimates of environmental value are made entirely in peoples' heads, without the benefit of clipboards or calculators. In cases where the transition must be made from natural resources being abundant and essentially free to being relatively scarce and hence valuable, responsibility for 'conferring value' on these resources thus lies wholly with local knowledge.

7.1.4 Reasons for concern about the adaptability of local knowledge

Local views and practices may be culturally embedded, with many households having fixed views about how things are done in the local context that are not typically held up to critical scrutiny or re-evaluation. Such an attitude is apparent in some of the qualitative comments from survey households. To the degree that it occurs, cultural embedding is likely to impede the adaptation of local actors to a changing rural context. The specific

[5] Tree costs may include competition for sunlight, water or soil nutrients and harbouring dangerous animals and crop pests. Tree benefits include both products – such as fruit, construction wood, fuelwood, livestock fodder, fencing and herbal medicine – and services – such as establishing a clement microclimate, acting as a windbreak and fertilising soils.
[6] This applies equally to the cases of market-oriented and subsistence-oriented production activities.

danger is that negative historical associations of trees with pests such as tsetse fly and the quelea quelea (i.e., weaver) bird could sometimes crystallise into cultural biases against trees. Such biases could constrain the capacity of local people to recognise and harness opportunities presented by tree management.

A related issue involves status considerations. Despite the fact that many farmers in Tanzania and elsewhere in Africa can no longer access formerly subsidised agricultural inputs due to market liberalisation driven by structural adjustment, some may view the traditional methods employed prior to the introduction of these 'modern' inputs as backwards and of low status. As such, they may be hesitant to use them, even in cases where the modern substitutes are no longer available. Where farmers fail to revert to traditional low-tech practices, an alternative explanation is that the relevant skills may have been lost during the intervening period of reliance on modern inputs. One anecdotal sign of status orientation is found in the explanations of some households for why they do not grow sorghum or millet despite their greater capacity (relative to maize) to cope with irregular rainfall and drought conditions. Farmers repeatedly suggested that they 'did not like' these crops or that these crops 'hurt my tummy'. While such comments may be accurate in some sense, they also seem to be indications of people seeking to assert their status.

A third factor involves the possibility that the decisions of local people may be partly influenced by adverse reactions against former colonial policies or more recent policies viewed as hostile to local people. Notably, the emphasis of the former colonial administration on conservation initiatives such as tied ridging has led to anti-conservationist views among some ordinary Tanzanians, given the historical association of such views with nationalist sentiment.

A fourth factor that can make problems with local knowledge more likely is provision of inappropriate knowledge by outside institutions and actors. Even where local people originally subscribe to a different view than that advocated by the outside institutions, they may adopt the advocated view against their better judgement on the basis of the authority ascribed to these outsiders and the assumption that as experts they must possess useful knowledge. Even if they do not adopt these outside views, however, seeing powerful outsiders forcefully asserting a differing view could serve to confuse locals and shake their confidence in their own judgement.

In sum, given a rapidly changing rural context, historical experience may not be a suitable guide to informing current resource management decisions. Nonetheless, some households may follow historical experience or

outside advice even in cases where these are ill-suited to the contemporary context and work to their detriment. Moreover, some may continue doing so for longer than others.

7.1.5 'Knowledge failure' and its differing manifestations

In cases where rural peoples' knowledge fails to keep pace with the changing meaning and value of locally available natural resources and hence where people fail to manage these resources efficiently, outcomes may be said to be constrained by 'knowledge failure'. As in the cases of 'market failure' and 'government failure', 'knowledge failure' identifies situations where the dynamics associated with certain variables fail to produce an optimal outcome. With 'knowledge failure', the variable in question is the local knowledge informing the day-to-day decisions of agents, specifically decisions involving adaptation to changing circumstances. Simply put, the knowledge in question *misinforms* the agent, causing him to make a sub-optimal decision regarding natural resource management. A critical qualification is that this phenomenon applies to some households but not others, and to varying degrees with different households. In extreme cases, it is conceivable that either all or no households in a given community could be plagued by knowledge failure. Yet this eventuality is likely to be rare, given inherent differences between the personal traits, experiences and beliefs of different households.

Instances of 'knowledge failure' vis-à-vis natural resource management have different manifestations and meaning in different types of farming system. A fundamental distinction occurs between market-orientated production and subsistence or semi-subsistence production.

In market-orientated systems, falls in local stocks of natural resources may reduce farm production, since reduced environmental services may only partly fulfill their historical agricultural support functions. Yet often any falls in agricultural support services will simply be offset by increased use of purchased farm inputs. For instance, falling soil fertility associated with continuous or near-continuous exploitation may simply be offset by increased use of chemical fertilisers. In such cases, information provision to secure better recognition of natural resource values is likely to result in reduced expenditures on farm inputs and higher farm profits. A second set of benefits includes more resilient farming systems and more sustainable production over time. In sum, securing a vital natural resource base may be said to create the preconditions for successful market-orientated growth.

In subsistence or semi-subsistence farming systems, instances of 'knowledge failure' have a very different meaning. Here, households generally lack access to purchased farm inputs, and hence may have difficulty substituting for lost goods and services associated with falls in local stocks of natural resources. In such cases, therefore, falls in available natural resources may simply result in lower, more volatile production. Given the fact that such households are already poor, any such production falls could have a critical welfare impact. At the same time, 'sustainable agriculture' practices such as agroforestry technologies may represent the only accessible means of addressing any reductions in local resource stocks and their production impacts. In such cases, then, 'knowledge failure' vis-à-vis natural resource management may have critical welfare impacts, making the difference between hardship and secure, adequate livelihoods.

Given the difficulty of assessing farmer knowledge, the study seeks to simplify this task via its choice of natural resources considered. It emphasises farm-based resources, as a result of which the environmental values being assessed by rural people are private values. This emphasis is useful for the task of assessing knowledge gaps, since the incentives facing private landholders tend to be simple. Because they tend to have secure access to the long-run benefit stream associated with any privately held resource, they face an incentive to fully recognise any valuable natural resources, including their various costs and benefits. Cases where households neglect such values can thus readily be interpreted as knowledge gaps. A second major benefit of emphasising privately-held resources is the promise of any interventions revealing knowledge gaps vis-à-vis these resources. Because they are privately advantageous, any such opportunities should be relatively easy to capture, requiring only that informational obstacles to actors heeding existing private incentives are removed.

7.1.6 Theoretical models as impediments to sustainable livelihoods

Theoretical models inform the way that economic actors and others conceptualise a given situation. Although models are normally thought of as formal structures described in textbooks and used in scientific research, they may also be informal structures existing only in peoples' minds. Either way, their function is to identify the key elements and linkages characterising a given situation and to inform decision making based on these simplifications. The present discussion raises the question of whether the models informing farm and resource management might sometimes become outmoded or be otherwise inappropriate, and hence provide poor guidance to understanding the situation in question. When might such an eventuality occur?

Given the widespread historical abundance of natural resources in agricultural areas, one way in which diverse models of farm production may be maladapted is by paying insufficient attention to the role of natural resources in farming systems. Specifically, these diverse models may fail to recognise the economic significance of these resources, simply treating them as either insignificant or harmful. In a context where these resources were abundant and hence of low value, this generalisation made sense and did not pose an obstacle to optimal production. Yet in cases where this background context has shifted and these resources have become scarce, it could represent a critical oversight, impeding both sound management and efficient production.

This oversight applies equally to formal models based on western science and informal models based on farmers' experience and perceptions. Formal models of smallholder agricultural production fall into two broad categories, namely Green Revolution agriculture and 'peasant' agriculture. The former tend to view natural resources such as trees as obstacles to production, and envisage using agricultural inputs such as fertilisers, pesticides and irrigation as substitutes for services traditionally provided by natural resources[7]. The latter have no particular view on the role of natural resources in farm systems, but assume that farm households tend to manage available resources efficiently. Thus, formal models of peasant production defer to the judgement of farmers vis-à-vis the significance and management of available resources, based on a priori ideas about their knowledge being adapted to the local context. Despite its elegance, this formulation is problematic in practice because it implicitly accepts farmers' assessments even in cases where they are prone to critical oversights. The tendency for formal models of peasant production to neglect the economic significance of natural resources is thus linked to the fact that the informal 'models' directing the thinking of farm households likewise tend to neglect these resources.

The fact that these various models dovetail around a tendency to neglect the economic significance of natural resources makes this particular oversight especially tenacious and difficult to detect. The common denominator is a failure of these models to adapt to a situation of environmental scarcity, having been developed during a period of relative resource abundance.

[7] In practice, it is often true that these various purchased inputs are readily available, particularly in high-potential areas. As such, natural resources such as trees may in truth be largely redundant.

7.1.7 Existing models and assumptions about knowledge

Various economic models and models of resource management have at their core assumptions about information and knowledge. This includes models of farm production and explanations about observed patterns of tree management and technology adoption. These assumptions can be summarised as viewing the knowledge of rural people as unproblematic and existing livelihood strategies, management responses and technology adoption as roughly optimal, given the constraints affecting these actors. Notably, the poor but efficient peasant thesis suggests that households do as well as possible given their relative lack of opportunities, which echoes the assumption of 'perfect information' underlying neo-classical economics. The theory of imperfect information suggests that where agents do not possess perfect information, this is because the associated procurement costs are too high, making the net effect of securing and utilising this information disadvantageous. Finally, the theory of induced innovation suggests that households tend to adopt advantageous technological innovations, with its corollary that if households do not adopt a given technology it may be seen as problematic, for instance due to hidden costs or the availability of preferable alternatives.

The general assumption underlying these various models is that knowledge tends to be unproblematic. The contemporary literature on both scientific knowledge and local knowledge makes this assumption explicit. Modern scientific knowledge (MSK) tends to be seen as a critical resource that is often 'missing' in poor countries. "Poor countries – and poor people – differ from rich ones not only because they have less capital, but because they have less knowledge" (WDR 1999). Meanwhile, the dominant view of local knowledge (LK) is that this knowledge is both sound and well-adapted to local conditions. "LK is the basis for local-level decision making... and the main asset [of the poor] to invest in the struggle for survival. It is developed and adapted continuously to gradually changing environments" (World Bank IK Website). "LK provides a basis for sustainable and environmentally-sound approaches to agriculture and NRM" ('IK- Network' Website)[8].

Given the logic of these theories, knowledge is only seen as a matter of concern and policy interest when dealing with novel farm components and unfamiliar outside opportunities. In terms of farming strategies, these assumptions suggest that low-input, semi-subsistence systems are well adapted to existing opportunities and constraints but are simply poor. It follows that securing development objectives such as poverty reduction and growth depends on replacing this farming strategy with a more powerful strategy such as Green Revolution agriculture. In other words, given these assumptions there is no point in looking for slippages and unharnessed

[8] In both of these quotations, the acronym LK was substituted for IK, in keeping with the terminology of the present study.

opportunities *within* existing systems. Conversely, questioning the assumption that knowledge is unproblematic leads to a reassessment of these various models of farm and natural resource management.

The resulting reluctance to take a critical view of LK is reinforced by political considerations, notably fearing accusations of being disrespectful of local perspectives or neo-colonial. Such fears on the part of authors and sensitivities on the part of audiences are understandable, given the prevalence of disregard for local views during the colonial era and within 'transfer of technology' approaches. While understandable, however, such fears may impede the search for solutions to pressing contemporary problems.

Dasgupta (1997) rightly suggests it is bizarre that the literature on smallholder African agriculture neglects questions of natural resource management, since many such areas are essentially 'biomass-based subsistence economies'. Yet noting the assumptions of contemporary theory vis-à-vis local knowledge and farmer efficiency explains this paradox.

7.1.8 The proposed alternative view of knowledge

The alternative view of knowledge proposed diverges from established views vis-à-vis MSK and LK, yet also holds promise of harmonising them. It is suggested that neither type of knowledge is good *a priori*. Each contains numerous, often conflicting strands (i.e., farmers, scientists and institutions disagreeing), and each of these competing voices may or may not be appropriate to a given context. Whether or not a given view is appropriate to a particular context depends on whether or not it has been adapted to it[9]. One type of adaptation involves adaptations over space, or whether a technology developed in one location has been adapted to suit another, for instance its climate and ease of access to complementary farm inputs. A second type of adaptation involves adaptations over time, or whether a technology developed locally sometime in the past has adapted to changes in the opportunities and constraints characterising the contemporary context. Problems with the applicability of MSK to the farm context involve the former, while problems with the applicability of LK involve the latter.

Given its concern with smallholder agriculture, the study focuses on LK, since it is this knowledge that informs the resource management decisions of survey households. Despite the study's focus on LK, the proposed view of knowledge applies equally to MSK and LK.

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[9] While it may also be due to farmer objectives, these may not be a critical determinant of management strategy among poor farmers, as argued in section 5.7.4.

Ultimately, this alternative view envisions identifying the characteristic problems plaguing each body of knowledge in the context of poor, agrarian communities experiencing resource degradation. Such insights would help negotiate conflicts both between MSK and LK vis-à-vis natural resource management and between competing voices within each of these broad categories. More significantly, these insights could guide efforts to address characteristic weaknesses. In the case of MSK, this would involve considering how theory could be better adapted to such communities, while in the case of LK it would involve targeted information provision to remove impediments to optimal management.

7.1.9 The proposed alternative model of peasant production

The alternative model of peasant production elaborated by the present study highlights opportunities masked by existing models. Its defining characteristic is questioning the assumptions about knowledge made within the literature and proposing an alternative perspective on knowledge as it relates to poor agrarian communities experiencing environmental stresses. Once this knowledge is seen as potentially flawed, a whole new set of opportunities comes into view. In other words, these assumptions of unproblematic knowledge obscure potential problems with the management decisions of local people. Knowledge is particularly likely to be flawed vis-à-vis natural resources, and the key untapped opportunities may therefore involve alternative management of these resources. In sum, natural capital may be the limiting asset on poor farms, while knowledge problems may be the underlying root cause of its being limited.

The new set of opportunities revealed by the proposed model recalls a known type of farming system and suggests a renewed emphasis on it. This system is neither a traditional semi-subsistence system relying on abundant land nor a 'modern' system relying on Green Revolution technologies and inputs. Instead, this farming system relies on the conservation and active cultivation of key natural capital stocks, and emphasises the use of 'sustainable agriculture' technologies such as agroforestry systems and soil and water conserving practices. These three cases correspond to the three broad alternative farming systems emphasised in the contemporary literature on smallholder agriculture. To help illustrate the differences between these competing farming systems, the way each meets key household needs is highlighted in Table 7.1.

While intensive sustainable agriculture has long been recognised as a *potentially* promising means of addressing the challenges facing poor farmers, the *actual* relevance of specific 'sustainable agriculture'

Table 7.1 Alternative means of meeting key household needs

Household needs	**Traditional extensive agriculture**	**Green Revolution agriculture**	**Intensive sustainable agriculture**
Fuel	Gather wood from bush, livestock manure	Gas stove, charcoal	Wood from cultivated trees
Livestock fodder	Graze in bush	Purchase fodder, graze in bush	Cultivated trees, enclosed grasses, improved grasses
Medicine	Gather herbal medicines in bush	Pharmacy, clinic, hospital	Cultivated herbs and trees give valued medicines
Soil fertilisation	Fallowing, burn weeds & residues	Chemical fertiliser	Increase soil organic matter via composing, digging in crop residues, cultivating soil-enhancing trees
Water for crops	Typically rely on rainfall	Irrigation works	Micro-irrigation, soil organic matter retains soil moisture
Pesticide	Remove vegetation to reduce pest habitat	Chemical pesticides	Intercropping, natural pesticides
Clement microclimate	Selectively retain certain trees on farm	None	Cultivated trees reduce wind and mulch lowers soil heat

technologies has been assessed based on the adoption response of target beneficiaries. Because adoption of these technologies has generally been hesitant and limited, professional and institutional interest in the possibilities associated with this system has waned, despite the promise shown in farm trials and case studies. The proposed model calls into question this means of assessing technologies in the contemporary context and suggests how these assessments may be problematic.

Thus, although the 'sustainable agriculture' farming system is already known, the present study highlights newfound opportunities in the sense that it rekindles interest in the potential significance of this system under certain conditions. This novel perspective may be most easily illustrated by positing a fourth broad farming system characterising farms plagued by knowledge failure. This system results where households continue relying on means of meeting needs associated with the first two farming systems in cases where these strategies are no longer viable.

7.1.10 Sustainable livelihood framework diagrams

The four diagrams appearing in Figures 7.2 – 7.5 use the sustainable livelihoods framework to illustrate the key linkages and dynamics characterising different farming systems. Three diagrams highlight the three farming systems highlighted above, while the fourth illustrates the case of a household plagued by knowledge failure. The intensive sustainable agriculture diagram may be said to represent cases where neither extensive agriculture nor Green Revolution agriculture is viable, yet where knowledge failure is not a problem, either due to effective adaptation to change or because any knowledge gaps have been addressed.

Relative to the present study, the key aspects of each diagram are as follows:

Figure 7.2

This farming system relies on regular access to purchased agricultural inputs and market opportunities. Natural capital is seen as either insignificant or undesirable, depending on the natural resource in question, and hence is either ignored (i.e., soil organic matter) or actively removed (i.e., farm trees). While LK may be sound, it is not seen as powerful, and MSK is seen as a more powerful substitute, holding promise of market-based growth. Yet this farming system also depends upon access to relevant infrastructure, finance and market opportunities.

Figure 7.3

This farming system relies on the ongoing viability and natural abundance of natural resources. Natural capital tends to be seen as abundant and essentially 'free', so conservation or investment in natural capital are not priorities. At most, these generally entail 'passive' management of useful natural resources, such as retaining useful species of naturally sprouting farm trees and practicing fallowing. LK is assumed to be sound and to adapt spontaneously to changing circumstances, accurately informing the management of natural resources.

Figure 7.4

This farming system relies on natural resources, but these have become scarce, undermining productivity. Despite this, household views and management of natural resources resemble are as in model 2. Thus, LK has failed to adapt spontaneously to changing circumstances, and households neglect incentives favouring conservation of and investment in farm-based natural capital.

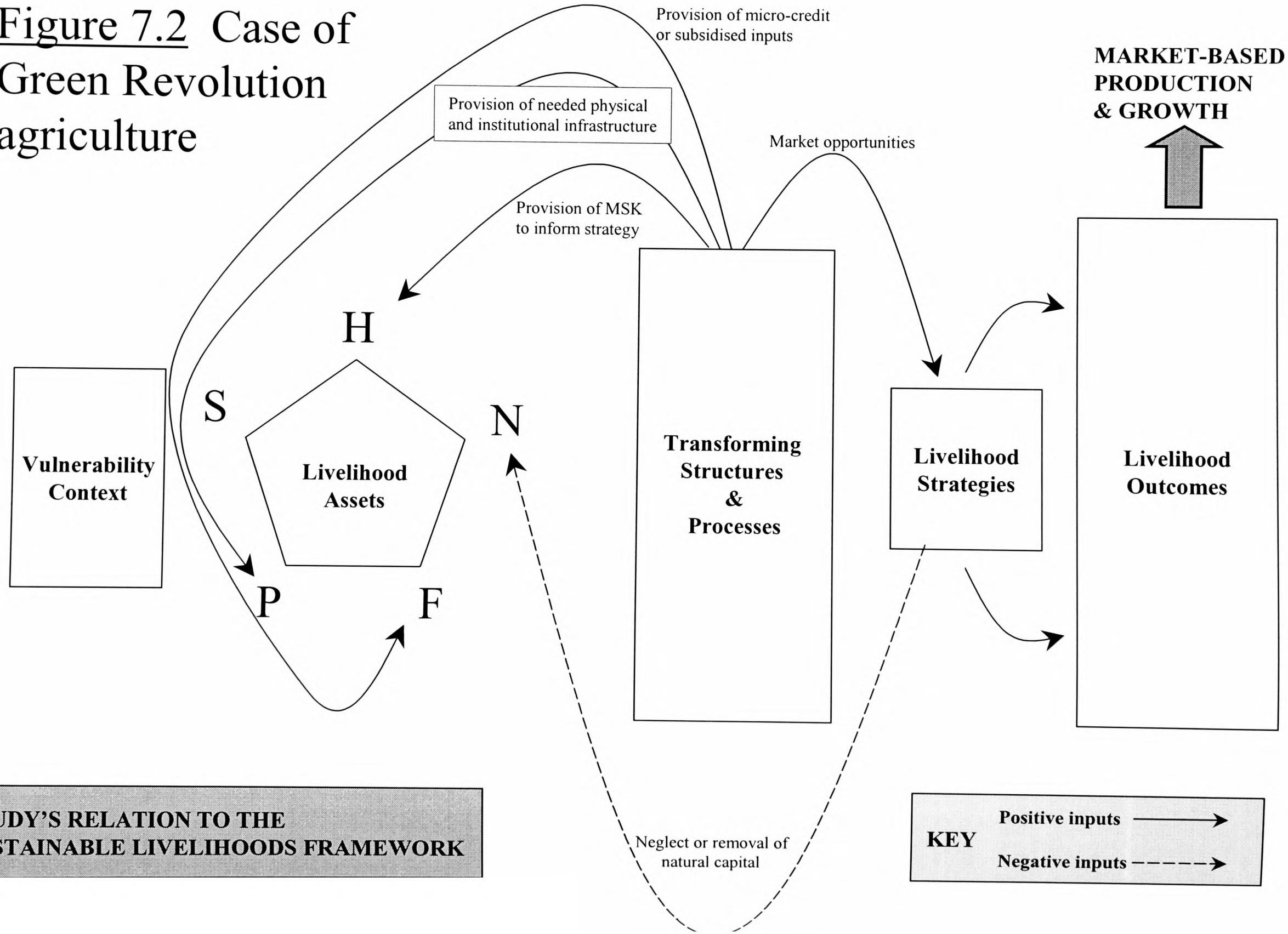
Figure 7.5

This farming system relies on natural resources, and the household conserves and/or invests in farm-based natural capital to sustain the basis of the system. Thus, LK vis-à-vis natural resources has shifted, and households recognise the need to actively increase natural capital stocks given growing environmental scarcity coupled with difficulty accessing purchased agricultural inputs.

The management question raised by the present study is what happens if the inputs on which the first two farming systems depend are no longer available. If households continue relying on the farm for their livelihood, their two options are 'belt-tightening' to cope with stagnant production (Figure 7.4) and shifting their resource management strategy to actively compensate for growing environmental scarcity (Figure 7.5). Alternatively, those with access to such opportunities may rely increasingly on off-farm labour or remittances, or may seek new agricultural opportunities via out-migration from the area.

The net picture is one of complexity, with diverse linkages and feedback loops between factors that may or may not function effectively in any given case. These issues represent an appropriate unit of analysis for complex systems theory, which examines non-linear linkages between factors that are overlooked due to simplistic or maladapted theoretical models. The challenge in such cases is to employ a cross-disciplinary perspective to develop new models to fill existing theoretical gaps and help understand observed phenomena.

Figure 7.2 Case of Green Revolution agriculture



STUDY'S RELATION TO THE SUSTAINABLE LIVELIHOODS FRAMEWORK

Figure 7.3 Standard view of 'peasant' agriculture

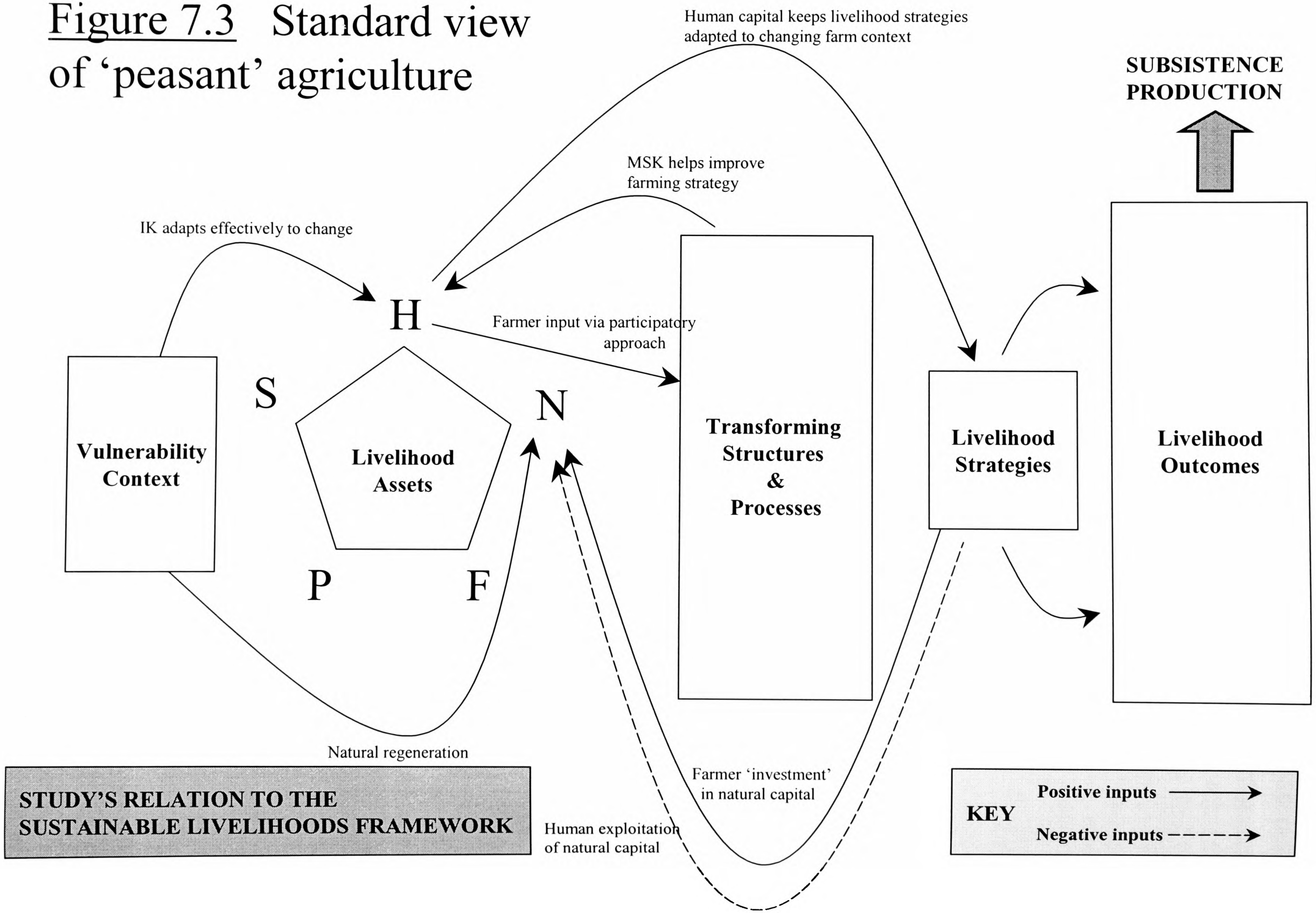


Figure 7.4 Case of knowledge failure

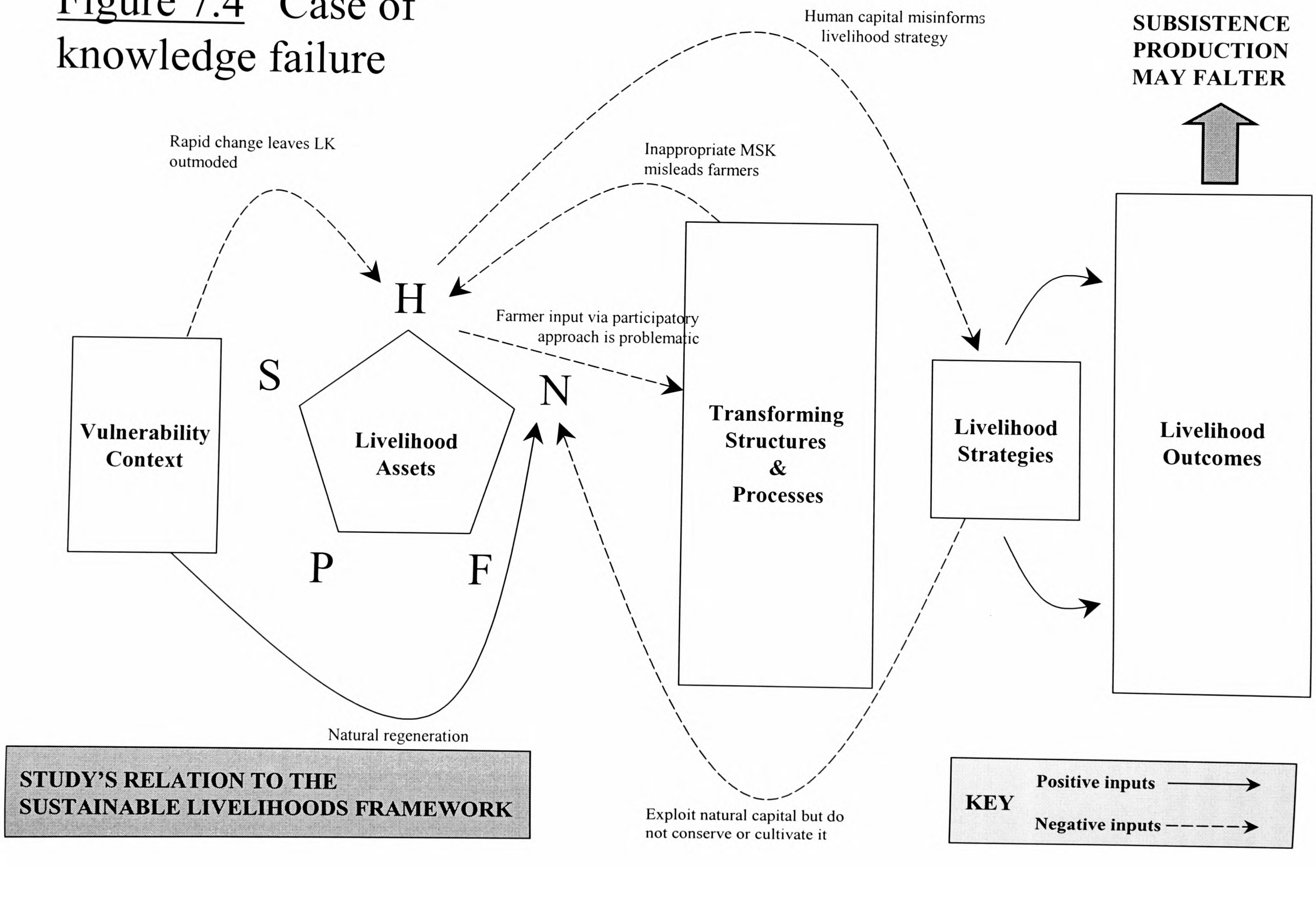
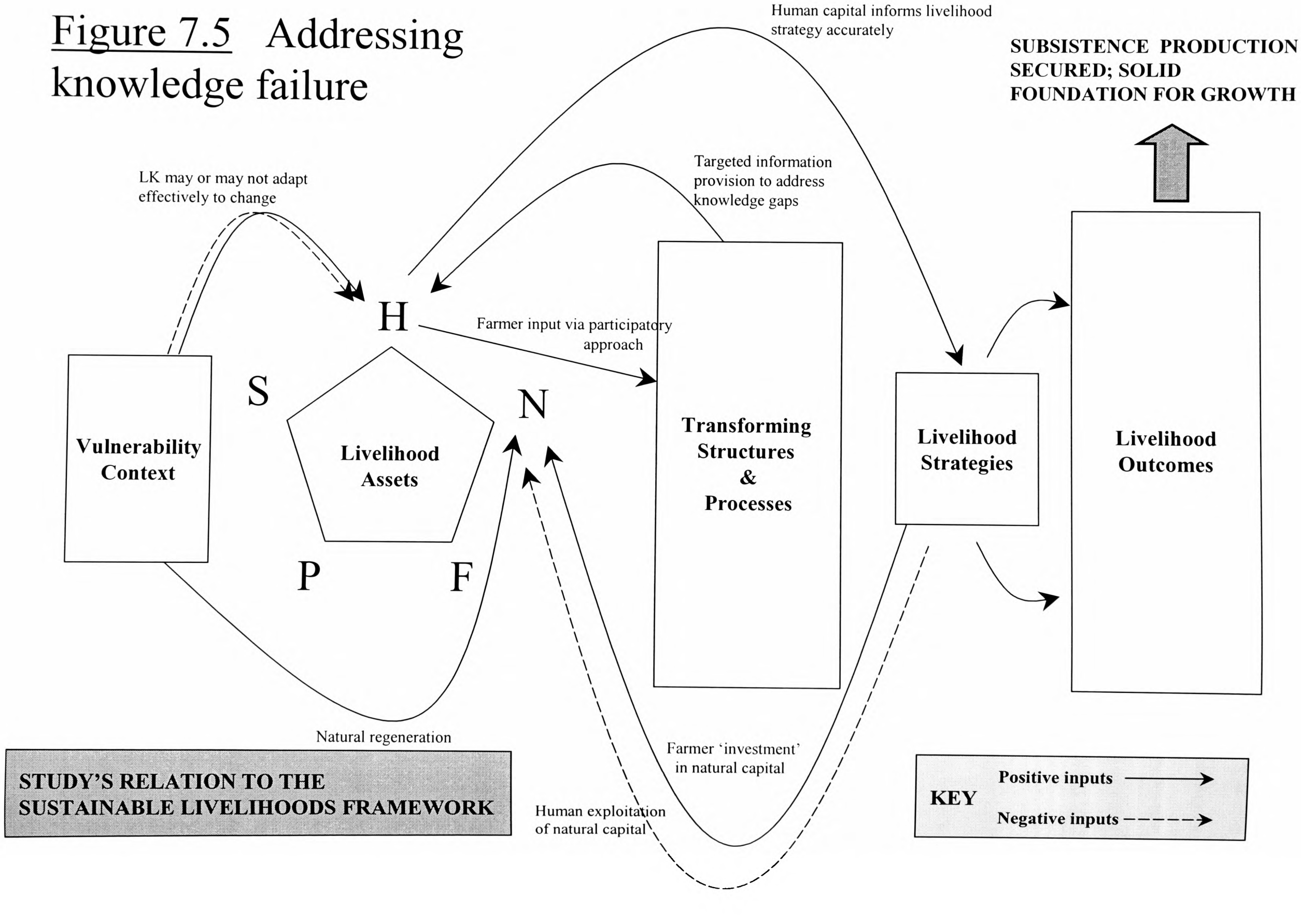


Figure 7.5 Addressing knowledge failure



7.1.11 The set of alternative possibilities revealed

Where the knowledge informing household decisions is problematic, as in Shinyanga District, a whole new set of opportunities is opened up by the prospect that advantageous, accessible opportunities are being neglected. Specifically, measures can be taken to see that these opportunities are harnessed. Moreover, because such measures simply involve information instead of tangible opportunities or constraints, they hold promise of being inexpensive to disseminate. Notably, if a successful approach to information provision could be found to address any such gaps, it could be readily 'scaled up', broadening institutional coverage beyond what is possible with resource-intensive approaches, whether transfer of technology or participatory. Table 7.2 illustrates this alternative set of possibilities relative to historical subsistence systems and modern Green Revolution systems. Each of its principal aspects is discussed in turn.

Although emphasising semi-subsistence production may seem like a retrograde step, this is arguably inaccurate in the contemporary context. The relevant question regards the viability of the available alternatives. While full market participation may be preferable, the willingness of farmers to engage with markets depends largely on their capacity to bear risks, and hence on their capacity to meet their basic needs via subsistence production. Thus, many households may fail to engage with markets because they are not in a position to seize them, given their poverty and perceptions of market participation as risky. Given this situation, emphasising market solutions and farming strategies that essentially seek to make farmers behave more like farmers in the industrialised North represents a singular lack of imagination. Meanwhile, the viability of subsistence production in contemporary Africa is often threatened by land scarcity and resource degradation, imposing hardship and suffering on local people. In this context, a stable, moderately productive semi-subsistence farming system that is resilient in the face of climatic variations is a relevant and sensible goal. Moreover, such stability forms a solid foundation on which to build for farmers working towards an objective of full market participation.

The key production constraints recognised by each of these alternative models are highlighted in the rows 'characteristic problems' and 'limiting asset'. These factors are the focus of efforts by both development interventions and farmers themselves to improve rural livelihoods. Arguably, the constraints associated with the first two models are comparatively obvious, since they represent tangible, often physical adjustments to the incentives facing households. The danger is that both locals and outsiders may become preoccupied with these opportunities and fail to recognise the possibilities associated with the third model. Specifically, they may fail

Table 7.2 The 'set of alternative possibilities' hidden by theoretical models and their assumptions

Farming system type	**Traditional / historical**	**Modern, 'Green' or 'Doubly Green' Revolution**	**Alternative possibility: Intensive sustainable agriculture**
Orientation	Subsistence or semi-subsistence production	Production for market sale	Semi-subsistence production
Objective	Sufficing / leisure	Market participation, growth, 'little version of us in North'	Bolstering production, food security, resilience, increased market participation and growth
Characteristic problems	Pests, disease, insufficient labour, natural disasters	Lack of inputs or finance, pricing, market access	Failure to recognise sustainable agriculture technologies as a viable, advantageous response to resource degradation OR technologies simply are not good enough (i.e., time to migrate or leave farming)
Limiting asset	Labour to exploit available resources	Working capital (hybrid seeds, chemical inputs)	Relevant types of natural capital / natural resources
Strategy to increase it	Larger household	Microcredit, earnings	Appropriate knowledge, differential labour allocation, notably towards investing in natural capital
Policy tools	None, what getting away from	Infrastructure, credit, market liberalisation, land titling, formal education, agricultural extension	Sustainable agriculture technologies, targeted information provision
Characteristic prejudice	Old ways best, 'this is how it is done here'	New ways are superior, higher status	None; strategy's essence is not to fall into prejudices but rather to soberly assess alternative options

to recognise when sustainable agriculture technologies represent advantageous, accessible opportunities to address key production constraints. Because these opportunities have been neglected, they represent a novel means of improving rural livelihoods in these areas. By contrast, interventions to address the problems cited in columns one and two have either been tried or hampered by cost constraints. In cases where neither of the first two strategies is viable *and* no knowledge gaps are found, it may be concluded that available technologies are simply not advantageous. In such cases, the case for out-migration from the area or leaving agriculture in search of alternative livelihood options would be strong.

Policy tools associated with these three alternative strategies are distinct. The first category is the simplest case, since traditional subsistence agriculture is not seen as a policy objective, but rather as the state from which policy makers are seeking to free rural people. Thus, no policy tools are associated with this farming system type. Existing policy tools fall largely within the second category. Because it is assumed that local people take advantage of any accessible, advantageous opportunities, the goals of poverty reduction and securing development advances are seen to depend upon creating new opportunities for local people[10]. While such tools may be powerful, their effectiveness in low-potential agricultural areas is far from clear, given the intractability of poverty in such areas. Finally, the key policy tool suggested by the present study is addressing knowledge gaps via carefully targeted information provision based on applied research.

Characteristic prejudices apply only to the first two strategies, since the essence of the third strategy is that it moves beyond prejudices and soberly assesses the opportunities and constraints facing households. The prejudices associated with the first two strategies suggest particular biases into which local people or development actors may tend to fall. These prejudices are unproblematic as long as the associated inputs are accessible. It follows that the third strategy is relevant only where these first two strategies are compromised by a lack of needed inputs. In such cases, biases favouring either of these strategies are detrimental to household livelihoods. By contrast, the absence of bias involves recognising that intensive sustainable agriculture represents the optimal strategy under the circumstances. In sum, households in this third category see the first two strategies as attractive but inaccessible. Specifically, traditional semi-subsistence agriculture is seen as meeting basic needs while offering leisure in cases where households have access to ample virgin land, while Green Revolution strategies are seen as offering myriad opportunities in cases where the relevant inputs can be accessed. Where neither is a viable option, the third strategy may be optimal.

[10] While other initiatives seek to enhance peoples' capacity to seize opportunities, they tend to do so in a way that may be characterised as 'making them more like us'. Examples include education that emphasises literacy and numeracy and extension services that emphasise 'modern' practices.

7.1.12 Adjustments to human capital and management decisions

These theoretical advances suggest that optimal management of local natural resources may depend on ensuring that local users heed changing incentives. The principal application of these findings is to guide information provision to rural people. Notably, they may be used to guide extension service reform, thus helping these services fulfill their remit of improving rural welfare via provision of technical advice. In contrast to conventional extension strategies, however, the information provision envisaged would not simply impose outside ideas or technologies, as is often still done by extensionists. At the same time, it would not simply defer to local ideas or technologies, as advocates of participatory approaches sometimes suggest.

Instead, the information provision efforts envisaged are based on critical examination of LK vis-à-vis natural resource management. Via this process, the strengths and weaknesses characterising a particular body of LK are identified by dividing households into different LK categories. The determinants of these categories are also explored. Using these insights, information provision efforts are designed to target the knowledge gaps highlighted. In sum, the proposed approach would directly address demonstrated slippages *within* LK vis-à-vis natural resource management, where advantageous technologies (whether indigenous or exotic) are neglected by a subset of farm households.

By ensuring that information provision efforts are carefully targeted, surgical adjustments to LK could be secured. The purpose of these efforts would be to ensure that users heed incentives vis-à-vis management of natural resources. These adjustments are potentially critical in the agrarian context because they can shift how natural resources are valued, and hence how resource management decisions are made. Moreover, given the fact that farm households are the day-to-day managers of wide swaths of rural Africa (Upton 1996:18), the abundance and vitality of natural resources depend to a great degree on the independent decisions of innumerable local land users, each of which functions as an independent decision making unit (Timmer 1989), albeit one bound by certain social and institutional controls.

One possible didactic tool for addressing knowledge gaps builds on Table 7.1, 'the alternative means of meeting key household needs'. Simply put, information provision efforts could emphasise the idea that several alternative means exist of meeting any basic household need. Specifically, they could stress how each need can be met by any of three broad alternative strategies, namely a 'traditional' strategy relying on abundant resources, a 'modern' strategy emphasising purchased inputs, and a 'sustainable' strategy emphasising

intensified natural resource management. Households could be trained to weigh these competing theoretical possibilities against each other before deciding on the strategy most relevant to the case at hand. For instance, the need for fuel could be met either by gathering wood in the bush, purchasing charcoal or a gas canister, or cultivating farm trees. Yet which strategy is most relevant to a given household may depend on their present circumstances and how these are evolving. Such a didactic tool could help move the less critically-minded farmers away from simply thinking in terms of 'the way it is done here', as often suggested by farm households in explanation for their practices, and towards weighing up alternatives in their mind on a case-by-case basis.

7.2 Practical and policy implications

Summarising, the present study posits and substantiates the 'knowledge failure' concept. By critically assessing LK, the study shows where it is robust and dynamic and where it is rigid, dated or otherwise problematic. More generally, it improves understanding of knowledge for development as it relates to African agrarian communities.

The implications of the present study include both the implications of its actual findings and the implications of its eventual outcomes, if it were used to guide information provision efforts. In each of these two broad categories, both theoretical and practical implications may be distinguished.

7.2.1 Direct implications of the study findings

a. Questions the generality of claims that farmers adapt spontaneously and effectively to change

By highlighting potential problems with LK under conditions of rapid change, the study calls into question the generality of recent findings (e.g., Dewees 1997; Fairhead & Leach 1994; Giblin & Maddox 1996; Reij & Byers-Wates 2002) that smallholder farmers tend to adapt spontaneously and effectively to changing opportunities and constraints. Notably, the case of Kenya's Machakos District is widely cited as providing powerful evidence that rural people respond dynamically to emerging opportunities and cultivate natural resources to compensate for economic losses associated with resource degradation. Yet others seeking to replicate this work elsewhere have had mixed results, raising questions about whether these findings can be generalised.

In its effort to understand these contradictory findings, the study re-examines the theories that underpin these assessments of farmer efficiency. Notably, it revisits the theories of induced innovation and small-farm

efficiency, the latter of which has been characterised as the paradigm that has most dominated agricultural development thinking throughout the last half-century (Ellis & Biggs 2001). The study demonstrates that these theories may not apply under certain conditions common in contemporary Africa, then expands this body of theory to accommodate these competing findings.

b. Provides a framework for understanding instances of seemingly poor resource management by farmers

Fills a gap in contemporary development theory by providing a conceptual framework for understanding instances where farmers appear to make unwise land management decisions by failing to conserve key resources or to adopt proven technologies. The literature is littered with references to 'poor' management practices, yet these often appear alongside references to the ingenuity of local people and the need to defer to their judgement. Such contradictions are difficult to understand without reference to theoretical traps set by current conceptual models. On one hand, such authors may observe farmers pursuing seemingly unsustainable practices and neglecting seemingly advantageous technologies, while production stagnates and resource degradation worsens. On the other, they may see some households being palpably insightful and resourceful and may adhere to contemporary conceptions of indigenous knowledge and participatory approaches. Such competing precepts and observations explain these contradictory utterances but fail to suggest how best to manage them. The present study addresses this theoretical gap.

c. Addresses the theoretical gulf between 'optimists' and 'pessimists'

By examining the phenomenon of knowledge failure, the research explores a possible explanation of how rational, profit-maximising farmers intimately familiar with their local environment could become the agents of sub-optimal practice. In so doing, it could help bridge the theoretical gulf in contemporary African development literature between 'optimists' who maintain that farmers tend to adapt effectively to change or even thrive on it and 'pessimists' who fear that farmers are undermining future productivity by dissipating key resources.

d. Calls into question means of assessing novel technologies

The study calls into question the tendancy of agronomists and agroforestry scientists to assess the effectiveness and profitability of proposed innovative technologies by inferring from farmers' uptake decisions. The alternative possibility is that uptake decisions might fail to reflect the profitability of technologies, and that profitable technologies might be neglected due to knowledge gaps. The implication is that technologies,

including agroforestry technologies, that have not generally been adopted may nonetheless be advantageous to local people. In such cases, the policy challenge is to convey these opportunities effectively to locals, rather than to develop alternative technologies or simply assume that local people have preferable alternatives.

e. Develops methods to resolve contradictory knowledge

By developing methods to test for knowledge failure, the study addresses the methodological conundrum of how to contend with conflicting assessments by MSK and LK as well as competing versions of LK. These methods include (i) compare actual performance among statistically selected households in an area where technical information has been disseminated, (ii) identify distinct household types based on household assets and management practice, notably management of trees (iii) identify distinct categories of household knowledge, (iv) assess linkages between what different households actually do and what they say about it, (v) identify distinguishing characteristics of differing knowledge categories, notably policy-relevant characteristics.

f. Addresses the problems plaguing low-potential farming systems

Speaks to the 'crisis' in agricultural development vis-à-vis Africa by exploring a neglected set of factors that may be constraining the efforts of poor farmers to secure their livelihood objectives via improving farm production. This work is especially relevant to 'low-potential' areas, given the intractability of poverty in these areas and their frequent reliance on locally available natural inputs to sustain farm production.

g. Identifies potential policy levers for addressing knowledge gaps

Identifies specific types of knowledge, attitudes and perceptions associated with farmers being willing to invest labour resources in the conservation and/or cultivation of farm-based trees. These insights form the basis of policy levers to encourage farmers to recognise the opportunities associated with such investments.

7.2.2 Implications of applying these findings

The key practical implications of the present study depend upon applying its findings to reforming information provision vis-à-vis agriculture and natural resource management. Where this is done, information provision efforts promise to address knowledge gaps that constrain households' capacity to effectively pursue their livelihood objectives. Specifically, such information provision efforts promise to increase farm-based stocks of natural capital. In areas where natural capital is the limiting asset, the resulting benefits may include raising the

marginal productivity of both land and labour while also increasing the resilience and sustainability of production. Conversely, knowledge failure left unaddressed could impair both endogenous adaptation to changing circumstances and farmer input into development initiatives via the participatory approach.

In sum, applying the findings of the present study could enhance local people's capacity for self-help, promising potentially large welfare gains to poor farmers, and possibly allow them to escape from the 'vicious circle' wherein resource degradation and stagnation of the rural economy tend to mutually reinforce one another. Specific implications of applying these findings include:

a. Increasing the effectiveness of information provision vis-à-vis farm and resource management

By shedding light on how to adjudicate scientific knowledge with the skills, perspective and needs of poor farmers, the research could help tailor information products to addressing identified knowledge gaps. If so applied, the research promises to improve the effectiveness of information flows between local people and outside agents, notably between extensionists and farmers, teachers and rural pupils, and the various parties to participatory initiatives. The net effect would be to secure increased and lasting uptake of improved strategies by farmers. More generally, this emphasis on addressing knowledge gaps could help guide reforms to sectoral policy in agriculture and forestry.

b. Harnessing rural peoples' entrepreneurial spirit

Provision of rural credit, particularly microfinance, is often characterised as a means to harness poor peoples' entrepreneurial spirit. Where knowledge failure is significant, addressing the knowledge gaps in question can similarly serve to harness this entrepreneurial spirit. This follows because failing to recognise available opportunities is analogous to these opportunities not existing, in terms of its effect on rural livelihoods.

c. Increasing the effectiveness of the participatory approach

The participatory approach is now widely used to increase the suitability of interventions and technologies to local conditions and to empower target communities to help themselves. It is often seen as the remedy to conventional 'transfer of technology' approaches to development, which have tended to be ineffective in low-income areas (Farrington 1998; Wallace & Nilsson 1997). This solution, however, depends crucially on the accuracy of the information provided.

By critically examining LK with regard to available management options, the research highlights situations where the participatory approach could produce poor guidance for interventions, as well as suggesting how to improve this situation. Specific benefits include ensuring interventions are not just *apparently* appropriate to the local context and freeing up farmers' experimental and analytical capacity. The study thus helps adapt participatory approaches to a reality where different households facing similar resource constraints often disagree with each other about 'best practice' resource management, creating a need to negotiate competing versions of LK.

d. Increasing the abundance and vitality of local natural resources

It is widely recognised that environmental considerations are integral to delivering sustainable project outputs. Yet this is especially true in low-input agrarian communities, since livelihoods in such areas typically rely upon the ongoing vitality of local natural resources. While natural resources are thus important to rural livelihoods, the livelihood strategies of local people likewise impact natural resources. Indeed, given the role of smallholder farmers as the day-to-day managers of much of rural Africa (Upton 1996:18), the management decisions of farmers may critically determine the state of local natural resources.

The research could have a major positive impact on the local environment in agricultural areas and surrounding lands. Specifically, addressing knowledge gaps vis-à-vis natural resources could avoid unnecessary resource degradation and secure advantageous 'investment' in natural capital by ensuring that farmers perceive the shifting significance and value of natural resources. Such information provision could lead to increased stocks of farm-based natural capital. A likely side effect is increased stocks of natural resources both on commons land and in the bush, due to the decreased pressure on these resources associated with increased reliance of local people on farm-based resources[11]. Taken together, these increases in local natural capital stocks could fundamentally shift the resource constraints under which households operate. While more esoteric aspects of the environment may suffer (e.g., biodiversity), those aspects directly relevant to farmer needs will tend to be maintained (e.g., soil fertility). In sum, the net effect of addressing knowledge gaps would be to slow or reverse local resource degradation.

[11] Notably, encouraging increased cultivation of farm trees is increasingly viewed as a promising way to protect remaining natural forests (Current et al 1995).

e. Reducing the labour burden of women

Insofar as reformed information provision strategies lead to increased stocks of farm trees and decreased pressure on off-farm trees, they promise to reduce the labour burden on women. This follows because trees facilitate various tasks that tend to be the responsibility of women in African societies. Notably, trees provide fuelwood and diverse tree foods, and may also make it easier to secure household water supplies via their impact on local hydrological cycles. They also provide amenity value to those working in the family compound via shading and the windbreak effect. More generally, any positive impacts on poor rural communities may particularly benefit women, given the predominance of women in such communities.

f. Securing diverse social benefits

If the findings were applied to information provision efforts and farmers' management of natural resources were improved, diverse social benefits might ensue. These include both environmental and socio-economic benefits. Environmental benefits might include stabilising watersheds, enhancing biodiversity and creating carbon sinks. Socio-economic benefits might include greater food security, providing additional employment and income within rural communities, spurring local demand for goods and services provided by rural non-farm enterprises, minimising potential strife over competition for resources and slowing rural exodus.

7.3 Limits of the study

Geographical area: The study's sample frame fell entirely within Shinyanga Rural District, Tanzania. It covered the majority of this District (area 8,906 square kilometers), but omitted several outlying divisions and wards due to their excessive distance from the offices of the study's host institutions.

Cultural zone: The study area falls within Sukumaland and is overwhelmingly populated by Sukuma people, as reflected in the fact that survey households were ninety-eight percent Sukuma. This ethnicity is known for its strong attachment to cattle and scepticism about trees and natural vegetation, given their association with tsetse fly. As such, conducting a study about households' knowledge of trees in such an area is bound to reveal considerable scepticism, despite their potential utility to addressing key livelihood challenges. Conversely, evidence of intensified tree management and positive views about trees are all the more significant in such an area.

Agricultural system: The study area occurs in a semi-arid agro-ecological zone characterised by a semi-subsistence agro-pastoral economy. As such, most survey households may be characterised as peasant farmers, given their typically small farms and limited participation in markets.

Private resources: The study focuses on households' management of farm-based resources, specifically on the degree to which they substitute farm trees for scarce products and services historically provided by off-farm trees. As such, the study is not directly concerned with common property resources and their management. While this distinction is clear in theory, in practice it is less clear.

Types of knowledge and resources considered: The study focused specifically on knowledge about and management of trees, although it also briefly considered soil-and-water-conserving practices.

Intra-household differences: Despite the gendered nature of work in Sukuma society, the study did not emphasise gender differences vis-à-vis how trees are viewed and their appropriate role in the farm system.

Specification of tree management strategies: The specification of alternative tree management strategies was left fairly general. This followed due both to the limited sample size and the fact that households pursued a broad range of different strategies that had to be aggregated to allow analysis.

Households selected: The household survey was not limited to those households that have had contact with tree planting initiatives, but includes both those that have had contact with development initiatives and those that have not. This is unusual for a study of tree management practice.

Social and institutional factors: The study paid only limited attention to the local social and institutional context, yet such factors could be significant determinants of tree management practice.

Performance: The study does not assess the performance of households pursuing different natural resource management strategies, including different tree management practices. Such questions have been explored elsewhere, and time and resource constraints on the present study obliged it to focus on its principal interest, namely the linkages between differential knowledge and differential resource management.

Moreover, rigorously assessing performance differences associated with differential tree management strategies would have been difficult given the study design. Namely, because the households surveyed represented a random selection of households within the sample frame, the sample survey included diverse tree management strategies. In contrast to past studies that have examined particular tree management strategies advocated by projects or extensionists, the present study examines the myriad ways trees are integrated into farm systems by average farmers. Notably, these practices include both different patterns of tree cultivation and diverse patterns of naturally-occurring trees retained on the farm. Even given precise technologies replicated across numerous farms, assessing the performance impacts of tree technologies would be difficult, given the complexity of these peasant farms and of tree 'technologies' themselves[12]. But without precise, widely replicated technologies, assessing the impact of tree management patterns on household welfare would require a very large dataset to ensure that each distinct management pattern was represented by a significant number of data points. Such a study would also require emphasis on direct observation of precise differences between farm tree incidence.

Examining impacts of differing information provision strategies: Although it assessed the overall impact of several outside influence variables, the study did not examine the specific impact of differing information provision strategies. Doing so would have required either a very large sample or purposive selection to compare those exposed to different types of information, and hence was beyond the study's scope.

Addressing knowledge gaps: The study did not consider how to address knowledge gaps, namely the specific types of information provision strategy needed to do so. Instead, it simply sought to demonstrate the significance of knowledge gaps to explaining observed management patterns. The fact that this assessment turned out to be positive suggests that identifying and addressing such gaps represents a significant means of improving rural welfare. While the study suggests potentially fruitful directions for future enquiry, these suggestions are merely indicative and must be carefully examined.

7.4 Future research priorities

Future research priorities fall into two broad categories. One set of priorities involves ways that local knowledge vis-à-vis tree management could be better examined in future. A second set of priorities involves ways the scope of the present study could be usefully expanded. The former follow naturally from the shortcomings of the present study, while the latter follow from its limited scope.

[12] Notably, the diverse products, services and costs associated with these technologies, the gradual onset of benefit streams as trees mature, and their particular significance during drought years and to securing favourable production trends over time.

7.4.1 Priorities for examining local knowledge vis-à-vis tree management

a. Probe the nature and impact of ambiguous key variables: Given the importance of L.IN and L.OUT to explaining tree management but questions as to what precisely they signify, the nature of the linkages in question could be usefully explored.

b. Examine potentially key variables more closely: Despite not being found to be significant, the following variables could be usefully re-examined, given their potential importance to explaining tree management decisions.

- SOILTYPE: The variable considered was crude, yet soil type is expected to be a critical determinant of farm management practices. Because the degree of soil fertility / degradation is also critical, multicriteria soil indicators are needed.
- LABOUR: Despite the unequivocal finding that labour was not significant to determining tree management practice, this factor merits closer examination given its centrality to the literature. One possibility would be to examine its significance to determining specific tree management practices thought to involve significant management inputs.
- DEGRADATION: Since tree cultivation is a potentially key means of responding to resource degradation and improving land quality, how precisely different management practices relate to different types and degrees of resource degradation could be usefully explored. The present study only considered subjective assessments of degradation, which showed little variation. Thus, virtually all households described soil as 'tired' and cited problems with meeting needs for fuel and fodder.

c. Probe the deprioritisation of livestock fodder: Given the centrality of cattle to livelihoods in the District and the potential significance of tree fodder to addressing the scarcity of dry season fodder, there is a need to better understand why this tree product is not prioritised and why fodder provision is not seen as a prime basis for tree cultivation.

d. Explore intra-household differences: Given the gendered nature of work in Sukuma society, it would be useful to explore the different views of women and men regarding the significance of trees and how best to manage them in support of rural livelihoods.

e. Explore agency vis-à-vis tree cultivation: Given the differing prioritisation of tree management each implies, it would be useful to differentiate between households that planted trees just once in response to a tree planting initiative versus those that have done so independently and/or repeatedly.

f. Prioritise qualitative comments: Given the invaluable insights they afford into households' thinking, obtaining a complete set of qualitative comments regarding tree management practices would be a high priority.

g. Further specify tree management categories: More detailed data on alternative tree management strategies could help better specify the resource and knowledge determinants of households in different situations. Distinctions of particular interest include whether or not trees were protected and how, where precisely trees were planted, and how frequently trees were watered.

h. Assess the impact of differing information provision strategies: Given the demonstrated problems with local knowledge, addressing how well existing information provision strategies address these problems is a key question.

i. Develop effective information products for use in information provision: Develop tailored information products based on critical analysis of local knowledge vis-à-vis natural resource management and piloting of prospective products. Information products should address documented knowledge gaps while also being based on simplifying generalisations regarding the problems affecting a particular type of farming community.

j. Identify effective dissemination strategy: Examine alternative vehicles to convey the information products developed to farmers, including employing village-based para-extensionists with brief but targeted training.

k. Integrate socio-institutional factors and local knowledge into a common analysis: Given the impact of customary rules and local injunctions on resource management decisions, such factors should ideally be examined in conjunction with local knowledge to assess the range of 'intangible' determinants of tree management practice.

7.4.2 Priorities for expanding the scope of the present study

a. Expand the analysis to include commons resources: Given the importance of CPRs in peasant societies, the analysis of knowledge vis-à-vis natural resource management could usefully be expanded to include these resources. Notably, it would be useful to examine how the management of CPRs adapts to intensified use and how different farmers explain any degradation of these resources. In Sukumaland, traditional commons pastures (*ngitili*) provide an ideal case study for such effects.

b. Examine knowledge vis-à-vis SWC practices: Although local knowledge of soil and water conserving (SWC) practices was briefly considered, these practices could usefully be examined in greater depth, given their potential significance to coping with resource degradation and intensified population pressure in low-potential agricultural areas.

c. Examine other potential knowledge gaps: Given the findings of the present study, it would be useful to examine whether local knowledge might be plagued by significant gaps in other domains besides whether households adapt their management of natural resources to newfound resource scarcity. For instance, misplaced adherence to established views or practices could conceivably constrain rural welfare vis-à-vis issues like nutrition and health care. Any such studies would first have to establish a theoretical framework clarifying how rational, profit-maximising agents could inadvertently find themselves in the position of possessing problematic local knowledge.

d. Assess production impacts: Given the range of indigenous and adopted tree management practices observed, it would be useful to critically assess the diverse production impacts of these different practices.

e. Identify 'best practice' tree management: Although this would have to include a range of options for different farm types, it might be useful to determine a set of 'best practice' tree management strategies for households in the study zone under current conditions. This assessment would be based on their net livelihood impacts.

f. Conduct a similar study in another cultural and geographical area: Given the cultural and geographical particularities of the study zone, it would be useful to conduct a similar study elsewhere to assess the broader applicability of its findings.

7.5 A personal take on the issues examined

Studying problems facing poor communities and existing policy responses breeds strong personal views about key constraints and the best way forward. The present author is no exception.

My main concern is the impact on the rural poor of current theoretical work concerning local knowledge (LK) vis-à-vis natural resources. Due largely to the failure of this work to problematise LK, local people and development professionals alike may fail to recognise advantageous alternatives to current management practices[13], despite the centrality of such choices to the current and future welfare of rural people, particularly the very poor. That is, the assumption by outsiders that rural people already know about the various opportunities available locally may leave these people in a bad situation. Some current literature not only fails to question LK and the management decisions it informs, but suggests it is better a priori than alternative ways of knowing. Building on such ideas, current development practice emphasises participatory approaches to development. While it is laudable to fully respect and carefully listen to local views, the critical question is how this exchange is conducted. Arguably, the challenges of development cannot be met simply by deferring to LK and the judgment of target communities. Although intellectually and politically appealing, such an approach fails to face the thorny issues surrounding poverty and how best to address them.

Assertions that LK is well-adapted to the local context – including its challenges and opportunities – and that local management decisions are optimal have played a useful role. For instance, Chambers (1983) makes a strong case for why such ideas had to be forcefully asserted at a certain point in order to push development debates in a more fruitful direction. Yet given the current widespread acceptance of this view, the utility of continuing down the path of uncritical celebration of LK seems questionable. At best, such assertions are stale and unedifying. At worst, they encourage poor households to continue pursuing established management strategies beyond the point where these are no longer helpful, confident that they are condoned by wealthy, prestigious outsiders. Arguably, such assertions may even betray an underlying lack of faith in the utility and good sense of LK and decisions.

Instead, the present author suggests that the importance, logic and validity of LK should be taken as givens. Building on this base, the focus of research on LK could shift to examining ways in which such knowledge may be either better or worse adapted to particular situations, and how outsiders might facilitate the rapid

[13] Notably, agroforestry and other 'sustainable agriculture' technologies are seen as weak and/or failing to respond to pressing concerns, investments of scarce development resources in low-potential lands are seen as unpromising, and bolstering subsistence production is not considered a key development objective.

dissemination of 'best practice' knowledge and management strategies. Again, this is not to suggest that farmers do not have good reasons for saying and doing as they do, but rather that despite such reasons, some beliefs and practices may be disadvantageous or counterproductive. Given this backdrop, focussing on cases where rural people may need help adapting to change and rising to difficult challenges is a more useful exercise than trusting things turn out for the best while leaving the onus for meeting difficult challenges on the knowledge and judgement of poor and often disempowered rural people.

Coupled with this failure to consider specific ways in which some local people may need help in diagnosing and addressing the immense challenges many face, the development establishment persists in lazy, unquestioning perspectives on information provision to rural people. Most notably, basic education is emphasised as essential to poverty reduction and progress, based on clear associations between educational participation and household welfare. While it is possible that schooling is a key cause of better welfare, the reverse explanation is equally plausible, given the status associations with schooling, the fact that schooling provides hope of a household member securing a treasured position in the formal labour market, and the simple fact that in poor communities only better-off families may be able to afford the various direct and indirect costs of schooling. Moreover, while schooling itself is emphasised, the precise content of teaching and its relevance to the local context goes largely unquestioned. The basics of literacy and numeracy are stressed, although these may be unattainable goals of questionable relevance to children that remain in school for only one or two years, as is typical in the study zone.

As with the case of schooling, information provision to rural people via extension agents tends to follow rigid formulas and is of debatable relevance. In the study zone, such information provision tends to stress Green Revolution technologies and market participation as well as certain SWC practices. Its defining refrain is asserting the superiority of 'modern' agriculture, even though many aspects of the strategies it promotes are inaccessible to all but the most well-to-do households.

Given the pressing needs facing rural households in low-potential agrarian communities, uncritical thinking by researchers and development practitioners is as unacceptable as it is unnecessary. Describing examples of ingenious farmers and successful endogenous adaptation to change may still have its place, as may conventional strategies of information provision. Yet the critical question at this juncture is how such success stories could be replicated more widely via identifying and addressing obstacles to their realisation.

In both schooling and extension services, the question of what informational content would be most useful to poor rural people is a difficult one. Yet given the centrality of knowledge to rural welfare, this question must be addressed squarely, with open minds and a critical perspective. The insights regarding knowledge gaps highlighted in the present study provide a foundation on which to build.

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Appendix A Increased Demand and the Dynamics of Natural Resource Systems

Rural resource economics shows that biological resources display a common relationship between resource stocks per unit area and growth rate that may be depicted by a logistic curve (see Figure A.1). Specifically, biomass increases slowly at first when biomass per unit area is low, then more rapidly as it increases, then more slowly once again as biomass levels approach the carrying capacity of the land or water body in question. Resources that follow this pattern include woodlands, pastures, populations of plant or animal species, and levels of soil fertility.

The example of individuals of a fish species in a pool provides a simple illustration. When the biomass of the species is low, individuals have difficulty finding a mate and living conditions are relatively unfavourable, perhaps due to the fact that the few individuals of that species face many predators. As the fish population increases, it becomes easier to find a mate, and the danger to each individual from predation decreases. As the fish population approaches its carrying capacity, individuals begin to face 'environmental resistance', for instance due to difficulty finding food or shelter given increased competition. For the case of natural woodlands, the difficulties encountered at low biomass levels include inclement microclimate and excessive predation by herbivores, while at higher biomass levels individual trees begin competing for sunlight, water and soil nutrients. For the case of soil, natural regeneration of fertility after a period of exploitation proceeds slowly at first when natural vegetation cover is low and erosion is high, then slows again once vegetation and wildlife levels approach their carrying capacities.

Figure A.2, which is derived directly from the biological growth curve, shows the relationship between the resource's biomass and its natural growth rate. As biomass levels increase from zero, the resource's growth rate increases slowly at first, then more quickly, then slows again as biomass approaches K, the carrying capacity. The farmer's task is to operate at the optimal point of the biomass growth curve from the viewpoint of farm production, which typically means that he should choose the optimal harvest rate. For the case of farm-based resource stocks, however, he also must decide whether to invest labour or capital in replenishing these stocks if they become depleted.

The relevance of these dynamics to farm management is that the farmer must understand at which point of the logistic growth curve he is operating in order to optimise the role of a given resource in farm production. In order to determine whether it is optimal to deplete, maintain, or actively increase stocks of a given resource, the

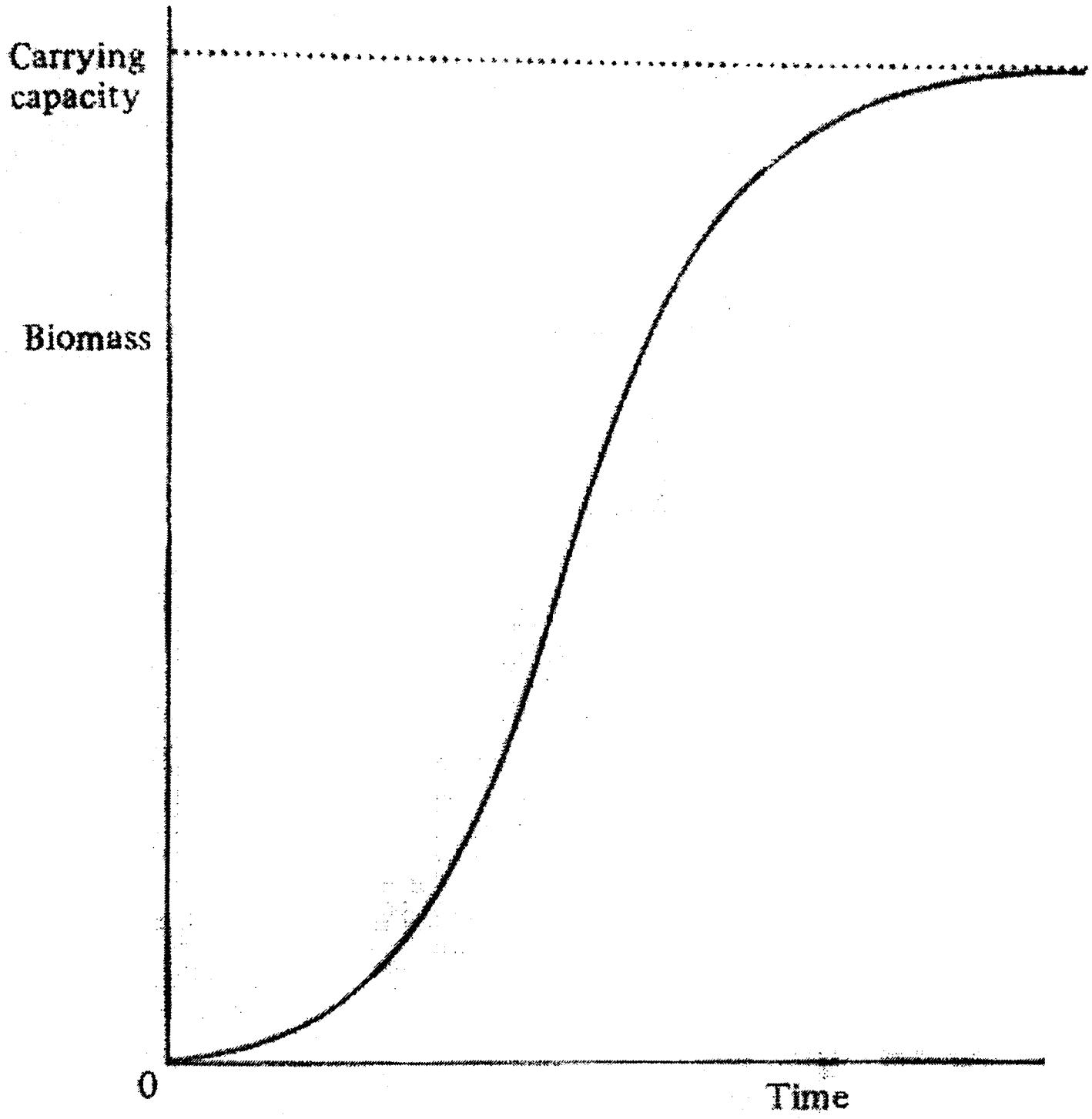
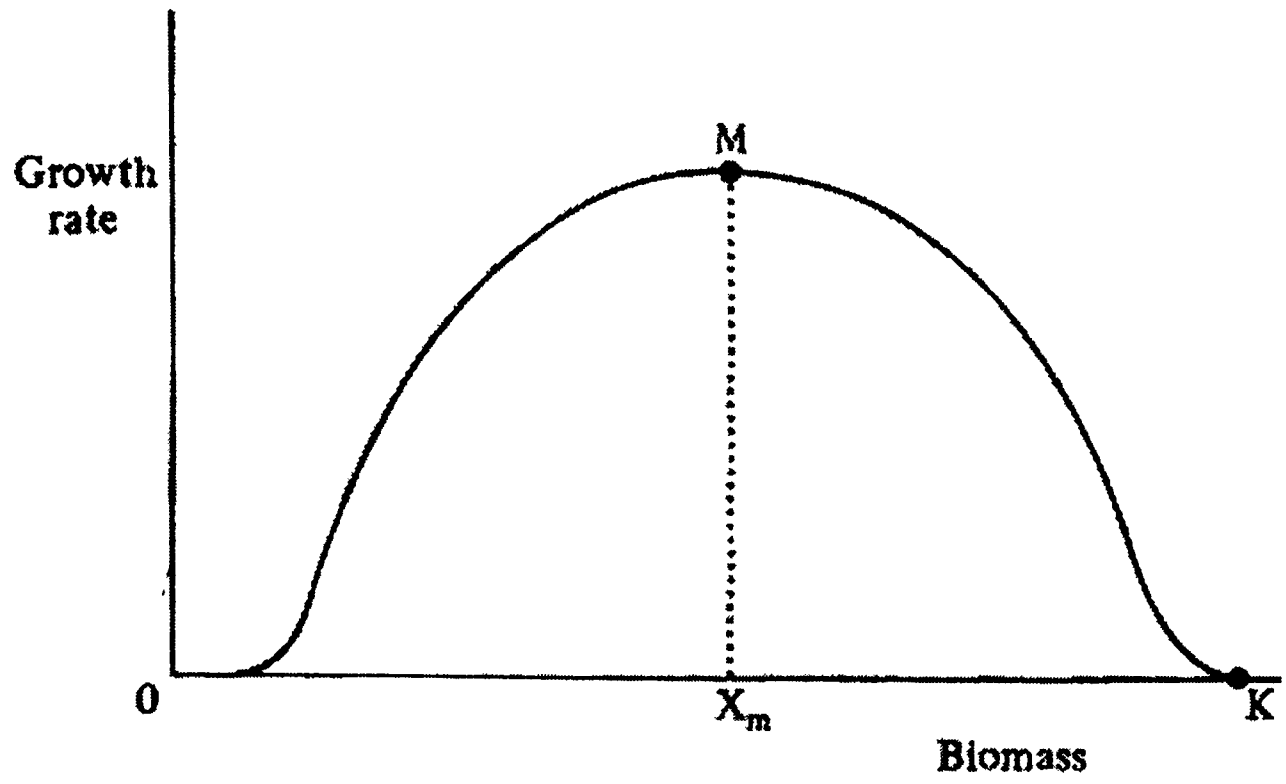


Figure A.1 Biological growth curve characterising renewable natural resources



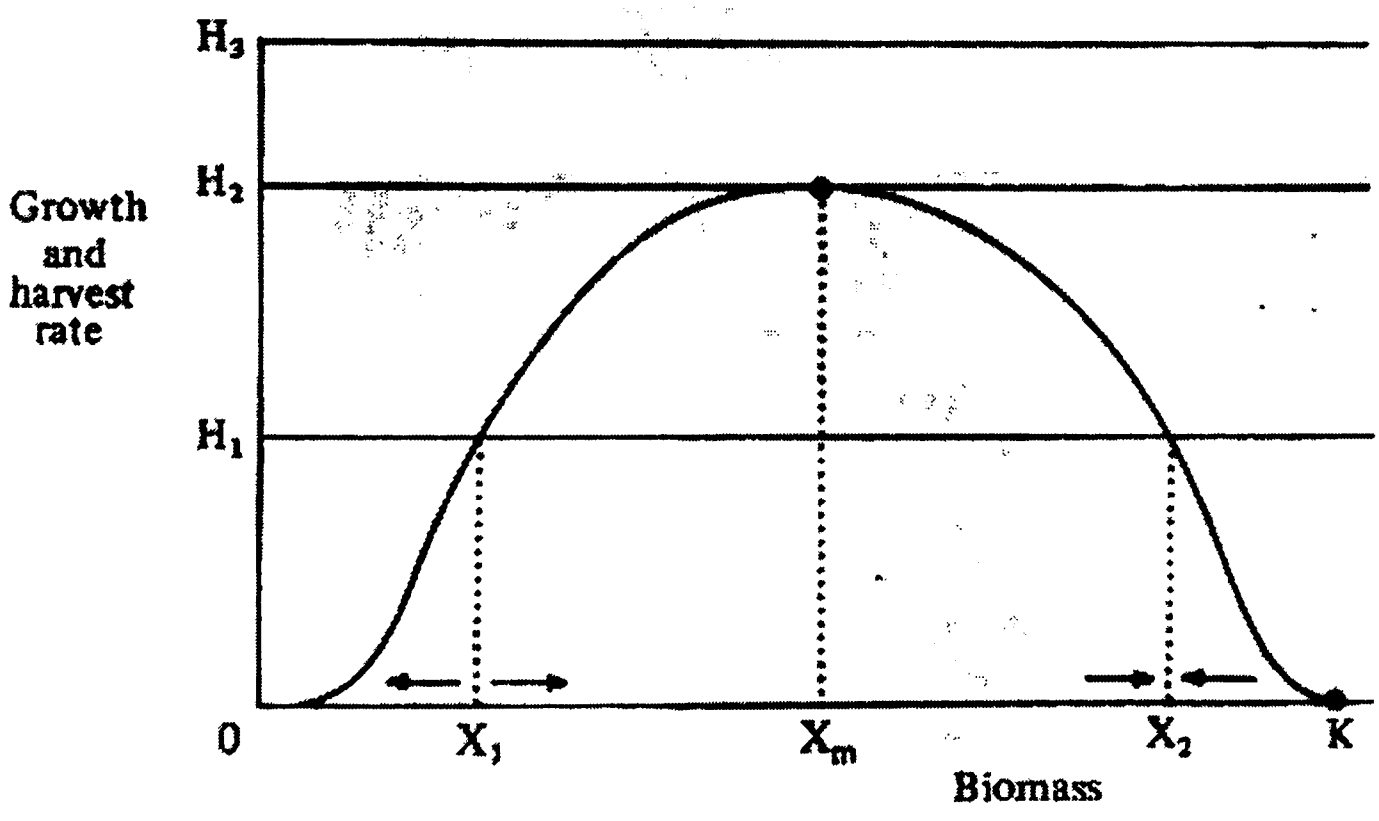


Figure A.2 Harvest rates versus growth rates

farmer must understand how its biomass relates to its current growth rate and harvest rate. Moreover, he must understand how such management decisions are impacted by and can respond to broader trends such as those associated with changes in population, off-farm natural resources, markets and policy.

To understand the relationship between harvest rate and biomass level, consider several alternative combinations representing equilibria where resource stocks are expected to remain in a steady state. Graphically, these equilibrium points are represented by points located along the bell-shaped curve. At harvest level H_1 and biomass stock X_2, the harvest rate is below the 'maximum sustainable yield' level H_2 and the biomass is relatively abundant. At this point, moving along the curve towards the left to a higher harvest rate and lower biomass increases the resource's productivity per unit area. At harvest level H_2 and biomass X_m, both the harvest rate and natural growth rate are at their maximum. At harvest level H_1 and biomass stock X_1, the resource is producing less than it did at higher biomass levels, and further decreases in biomass levels only further reduces the resource's growth rate and productivity per unit area. Clearly, resource productivity is at its technical optimum, or 'maximum sustainable yield', when the farmer is operating close to harvest level H_2 and biomass X_m

A second issue to consider is the relative stability of these alternative equilibrium points, or steady-state combinations of biomass level and harvest rate. For all points along the bell-shaped curve between biomass K and X_m, the equilibrium between these competing processes is stable. This is because minor variations in the biomass level or harvest rate tend to be corrected by opposing processes, thus re-establishing equilibrium at the former level. For all points along the curve between biomass 0 and X_m, on the other hand, the equilibrium between these competing processes is unstable. For these equilibria, minor variations in the biomass level or harvest rate do not tend to be offset by opposing processes, but rather exacerbated. The danger is that if the resource user strays to the left side of the curve due to excessive exploitation and resource degradation, he may 'slip' down the curve to the left until the resource is depleted. Once underway, this depletion process can only be halted if it is addressed either by reducing the harvest rate to below the current natural growth rate, or by actively assisting the natural regeneration process by investment in biomass stocks of the resource[1].

A third issue is what happens if harvest rates exceed the maximum sustainable yield, as reflected in the case of operating at harvest rate H_3 in Figure A.2. In this case, no equilibrium is possible, since the harvest rates exceed the productive capacity of the resource. While such a harvest rate may be sustained temporarily, this is

[1] Alternatively, the farmer could simply shift to an entirely different production system, if such alternative opportunities are available.

possible only at the expense of depleting the resource stock. Such a strategy is therefore short-termist, reflecting either a relative lack of concern for the ongoing viability of the resource or circumstances making conservation impracticable (Upton 1996).

This discussion helps illustrate why the informational demands of managing farm-based natural resources may be high under conditions of rapid population growth. One reason is that where formerly abundant resources become degraded due to intensified use, resource managers may suddenly find themselves on the 'slippery' left-hand side of the bell-shaped curve relating biomass stocks and natural growth rate. Resource managers finding themselves in this position must either reduce harvest rates or actively replenish biomass stocks if they wish to avoid depletion of the resource. In practice, however, farmers facing serious resource degradation may not be in a position to reduce their exploitation of the resource, since their livelihood may depend on it. If they are to avoid its depletion, then, their only option may be to invest in replenishing resource stocks. Yet if they have only recently shifted from the right-hand side to the left-hand side of the biomass-growth rate curve for the resource in question, their prior experience will have ill-prepared them for this task.

Appendix B.i Sample Frame

Division	Ward	Village	Population	Aggregate population
Itwangi	Didia	Buyubi	820	820
		Bukumbi	1,478	2,298
		Chembeli	1,407	3,705
		Didia	1,230	4,935
		Mwamalulu	1,379	6,314
		Mwanono	1,465	7,779
		Nyashimbi	2,173	9,952
		Puni	806	10,758
	Ilola	Ihalo	3,314	14,072
		Kasingili	2,512	16,584
		Mendo	1,272	17,856
	Imesela	Maskati	1,067	18,923
		Mwamanyuda	3,184	22,107
		Nyika	2,070	24,177
		Imesela	957	25,134
	Itwangi	Butini	2,064	27,198
		Igembya	572	27,770
		Itwangi	2,720	30,490
		Nduguti	1,463	31,953
		Nyida	3,045	34,998
		Zobogo	1,673	36,671
		Kidanda	1,430	38,101
	Usule	Bukene	1,585	39,686
		Ishololo	1,215	40,901
		Igalamya	1,615	42,516
		Kazuni	1,245	43,761
		Maseekelo	1,386	45,147
		Masunula	1,912	47,059
		Tindengulu	772	47,831
		Sumbigu	2,298	50,129
	Tinde	Buchama	1,834	51,963
		Jomu	3,787	55,750
		Kituli	3,082	58,832
		Mwamkanga	1,858	60,690
		Nhumbili	2,158	62,848
		Nsalala	2,601	65,449
		Nshishinulu	1,884	67,333
Kishapu	Kishapu	Isoso	1,561	68,894
		Kishapu	1,754	70,648
		Lubaga	1,802	72,450
		Migunga	1,865	74,315
		Mhunze	3,681	77,996
		Mwamagembe	1,342	79,338
		Mwanulu	775	80,113
		Mwataga	1,688	83,489
	Masanga	Bulekela	2,766	86,255
		Buzinza	2,653	88,908
		Masanga	2,514	91,422
		Mwajidalala	1,777	93,199
		Mwangalanga	1,632	94,831
	Mwakipoya	Iboja	1,308	96,139
		Mwakipoya	2,738	98,877
		Mwangongo	1,980	100,857
		Ngeme	1,670	102,527

Division	Ward	Village	Population	Aggregate population
	Mwamalasa	Kinampanda	2,959	105,486
		Magalata	2,787	108,273
		Mwamalasa	2,253	110,526
		Mwamashimba	1,914	112,440
	Shagihilu	Mangu	1,305	113,745
		Gimagi	1,668	115,413
		Mwamalata	811	116,224
		Ndoleleji	2,467	118,691
		Sanjo	2,114	120,805
		Shagihilu	1,763	122,568
	Somagedi	Kisesa	1,936	124,504
		Malwilo	2,038	126,542
		Wimate	1,282	127,824
	Uchunga	Dugushilu	1,038	128,862
		Bunyanyembe	2,019	130,881
		Bupigi	2,453	133,334
		Igaga A	1,039	134,373
		Kakola	838	135,211
		Ngundangali	1,641	136,852
		Wela	1,770	138,622
		Igaga B	2,126	140,748
Mondo	Bubuki	Bubiki	3,429	144,177
		Busangwa	4,153	148,330
		Mwajinungu	1,623	149,953
		Mwamishoni	2,220	152,173
		Mwanima	1,982	154,155
		Nyasamba	2,408	156,563
	Bunambiyu	Bunambiyu	3,413	159,976
		Butuyu	2,792	162,768
		Itongoitale	1,645	164,413
		Mwanghili	1,525	165,938
		Mwasubi	1,887	167,825
	Mondo	Buganika	4,220	172,045
		Kabila	1,957	174,002
		Mwigumbi	2,564	176,566
		Wishiteleja	2,404	178,970
	Mwadui/Lohumbo	Bulima	3,011	181,981
		Idukilo	4,272	186,253
		Lohumbo	3,289	189,542
		Niense	2,602	192,144
		Mwadui Mines	11,257	203,401
	Seke/Bugoro	Bugoro	1,904	205,305
		Dulisi	2,333	207,638
		Mipa	3,085	210,723
		Mwashinongela	2,912	213,635
		Seke	2,124	215,759
	Songwa	Ikonongo	1,769	217,528
		Maganzo	4,329	221,857
		Masagala	2,072	223,929
		Mpumbula	1,560	225,489
		Seseko	1,583	227,072
		Songwa	1,716	228,788
Ngezi	Itilima	Ikoma	1,614	230,402
		Ikonokelo	1,003	231,405

Division	Ward	Village	Population	Aggregate population
		Itilima	1,419	232,824
		Ipeja	1,227	234,051
		Ilebelebe	810	234,861
		Mwamala A	1,297	236,158
		Mwajiginya B	741	236,899
		Lilindilo	1,447	238,346
	Kiloleli	Kiloleli	2,213	240,559
		Miyuguyu	1,282	241,841
		Muguda	1,404	243,245
	Lagana	Beledi	1,070	244,315
		Lagana	2,311	246,626
		Mihama	2,495	249,121
		Mwamadulu	1,886	251,007
	Mwamashele	Bubinza	2,374	253,381
		Busongo	1,493	254,874
		Isagala	1,215	256,089
		Mwamashele	1,600	257,689
	Ngofila	Inolelo	969	258,658
		Kalitu	1,178	259,836
		Mwamanota	1,567	261,403
		Ngofila	2,117	263,520
		Idushi	1,111	264,631
	Talaga	Kijongo	2,337	266,968
		Lunguya	940	267,908
		Ngunga	2,956	270,864
		Nhobola	2,662	273,526
	Ukenyenge	Bulimba	1,587	275,113
		Ikonda A	2,221	277,334
		Mayanji	1,243	278,577
		Mwajiginya	1,325	279,902
		Mwaweja	1,246	281,148
		Negezi	1,878	283,026
		Ukenyenge	2,968	285,994
Nindo	Iselamagazi	Ibubu	1,309	287,303
		Ichongo	1,043	288,346
		Iselemagazi	3,713	292,059
		Layabusalo	3,371	295,430
		Mwabundala	1,158	296,588
		Mwajiji	4,445	301,033
		Mwamakalanga	2,369	303,402
		Mwambasha	3,403	306,805
		Mwashiningu	1,215	308,020
		Masingu	2,704	310,724
		Nghomango	2,739	313,463
	Layabukande	Bukiliguru	3,102	316,565
		Ihugi	2,682	319,247
		Kadoto	1,588	320,835
		Kimandaguli	3,861	324,696
		Kizungu	4,841	329,537
		Layabukande	8,257	337,794
		Layamidati	4,213	342,007
	Mwakitolyo	Mahembe	1,392	343,399
		Mwawemilu	1,433	344,832
		Mwakitolyo	3,634	348,466

Division	Ward	Village	Population	Aggregate population
		Mwasenge	1,813	350,279
		Nyangombe	1,289	351,568
	Mwantini	Kilimawe	1,430	352,998
		Mishepo	3,866	356,864
		Mwangosha	2,758	359,622
		Nyamalogo	1,937	361,559
		Shatimba	2,702	364,261
		Jimondoli	1,141	365,402
		Zumve	3,108	368,510
	Pandagichiza	Bulambila	2,780	371,290
		Mwalukwa	3,387	374,677
		Mwamadilana	2,975	377,652
		Pandagichiza	2,717	380,369
		Sayu	3,009	383,378
		Shilabela	2,929	386,307
	Salawe	Amani	1,802	388,109
		Azimio	2,568	390,677
		Ipango	1,139	391,816
		Mwenge	5,108	396,924
		Mwangozo	2,107	399,031
		Nzonzo	1,565	400,596
		Songambele	3,907	404,503
		Zunzuli	2,958	407,461
	Solwa	Manhigana	4,073	411,534
		Mwandutu	1,547	413,081
		Mwasekagi	2,727	415,808
		Mwuiseme	2,246	418,054
		Solwa	2,237	420,291
Samuye	Mwamala	Bugogo	1,652	421,943
		Bunonga	2,993	424,936
		Ibanza	1,309	426,245
		Mwamala B	2,142	428,387
Samuye		Bubale	2,917	431,304
		Ibingo	2,353	433,657
		Idodoma	1,310	434,967
		Ikonda B	1,946	436,913
		Ilobashi	2,003	438,916
		Isela	1,406	440,322
		Ishinabulandi	2,141	442,463
		Masengwa	2,454	444,917
		Mwahalangwa	2,333	447,250
Usanda		Manyada	2,822	450,072
		Ngaganulwa	2,401	452,473
		Shabuluba	1,120	453,593
		Nzagaluba	845	454,438
		Singita	4,097	458,535

Appendix B.ii Questionnaire

DODOSO LA KAYA

Household Head: _____ Check box if HHH is a women ☐

Informants: HHH Wife Sibling Elder Son Elder Daughter — *try to have both men and women present*

Swahili of principal informant: ☐ minimal ☐ understands, but speaks with difficulty ☐ speaks well

Interviewer: JK FM AN AT

Introduction

Madhumone Kutafitti maoni shughuli na matatizo ya wakulima yaliyopo

Wahusika Taasisi husika ni chuo kikuu cha Uingereza na chuo cha utafitti cha Kenya. Tuna wataalam tano.

Shughuli zitakazo fanyika

- Mahojiano ya kawaida katika kaya 20 kwa kila kijiji. Hii itakuwa NISIRI. Shughuli hii itafanyika katika vijiji 20 katika wilaya Shinyanga.
- Baada ya mwaka moja ya utafitti, tutarudi kufanya mjadala na wanakijiji kutokana na utafitti uliofanyika.

Manufaa ya kijiji na wanakijiji

- Itakuwa rahisi kwa wanakijiji kusikilizwa na vilevile hali yao halisi kueleweka.
- Kuwezesha wanakijiji kutambua hali zao na kuona njia za kujikwamua kimaisha.
- Kuwezesha serikali na taasisi zingine za maendeleo kuona njia nzuri za kuwasiadia.

Takwimu za kijamii

1. Wana kaya ni kabila gani? [Sukuma; mengineyo_____]
2. Dini ya jadi? [Wakristo; waislamu; pagani; nyingine_____]
3. Je wana kaya au wazazi wake wanahamia hapa? [ndiyo / hapana] — *say 'yes' even if just moved from another kitongogi*

   · Kama ndiyo, eleza lini na **SABABU** _____

   _____

Vyanzo vya habari za nje katika kaya

4. Je wanakaya wanasikiliza radio? [ndiyo / hapana]

   · Kama ndiyo

   - Ni mara ngapi? [marachache; kila wiki; kila siku]
   - Stesheni ipi?_____

5. Je wanakaya hii wanasoma magazeti? [ndiyo / hapana]

   · Kama ndiyo, ni mara ngapi? [marachache; kila wiki; kila siku]

6. Je mna sikiliza wengine wakisoma magazeti kwa sauti? [ndiyo / hapana]

Appendix B.ii Questionnaire

· Kama ndiyo, ni mara ngapi? [marachache; kila wiki; kila siku]

7. Je mna angalia televishen au video? [ndiyo / hapana]

· Kama ndiyo, ni mara ngapi? [marachache; kila wiki; kila siku]

· Kama video, aina gani?_____

8. Je wataalamu uliokutana nao, kama bwana shamba, bwana mifugo au bwana miti? [ndiyo / hapana]

· Kama ndiyo

- Nani? Bwana shamba [mwaka huu; mwaka uliopita; zamani]
  Bwana mifugo [mwaka huu; mwaka uliopita; zamani]
  Bwana miti [mwaka huu; mwaka uliopita; zamani]
  Bwana afya [mwaka huu; mwaka uliopita; zamani]
- Mna pata faida gani? _____

_____

9. Kuna mahusiano na taasisi za maendeleo au makampuni yanayotoa pembejeo, e.g., Oxfam, Caritas, World Vision, ICRAF, UNICEF, HASHI, Shirecu? [ndiyo / hapana]

· Kama ndiyo

- Taja mashirika au makampuni hayo _____
- Je ulipata ushauri gani au mafunzo gani?_____

_____

- Je kuna faida ya ushauri au mafunzo hii? _____

Mikopo

10. Je wanakaya walisha wahi kupata mkopo wa fedha, mbegu, mbolea, dawa au vifaa katika mwaka uliopita? [ndiyo / hapana]

· Kama ndiyo

- Aina? [fedha; mbegu; mbolea; dawa ya wadudu; dawa ya mifugo; vifaa; maksai]
- Wakopeshaji gani? _____

· Kama hapana

- Kwa nini hujachukuwa mkopo?_____

11. Je wanakaya walisha wahi kupata mkopo (wa fedha, mbega, mbolea…) zamani? [ndiyo / hapana]

Appendix B.ii Questionnaire

- Kama ndiyo
  - Aina? [fedha; mbegu; mbolea; dawa ya wadudu; dawa ya mifugo; vifaa; maksai]
  - Wakopeshaji gani? _____

Mashamba

12. Je una jua eneo kamili mashamba lako? [ndiyo / hapana]
    - Kama ndiyo, taja ecres ya kila shamba **I**_____ **II**_____ **III**_____ **IV**_____ **V**_____
    - Kama hapana, una mashamba makubwa mangapi, mashamba makati mangapi, na mashamba madogo mangapi?

      Shamba kubwa _____; shamba la kati_____; shamba dogo _____

13. Je mashamba yana rutuba kiasi gani? **I**_____ **II**_____ **III**_____ **IV**_____ **V**_____

    Indicate code for each field [NS = nzuri sana; N = nzuri; I = inatosha; H = haitoshi]

    - Kama rutuba ya mashamba yako siyo nzuri, eleza kwa nini_____

14. Je unabadilisha mazao yako? [ndiyo / hapana]
    - Kama ndiyo, mazao gani?_____

15. Je huwa unapumzisha shamba? [ndiyo / hapana]
    - Kama ndiyo
      - Kwa miaka mingapi? **I**_____ **II**_____ **III**_____ **IV**_____ **V**_____
      - Halafu pumzisha, una tumia miaka ngapi? **I**_____ **II**_____ **III**_____ **IV**_____ **V**_____
      - Maoni ya upumzisha _____

16. Je unaya miliki vipi mashamba yako? **I**_____ **II**_____ **III**_____ **IV**_____ **V**_____

    Indicate code for each field [NM = ninamiliki; AZ = kuazima; KO = kukodisha]

17. Ni wadudu wapi ni waharibifwa mazao? Mnafanyaje kuka biriana na tatizo hilo?_____

    _____

18. Ni magonjwa yapi yanayo athiri mifugo? Mnafanyaje kuka biriana na magonjwa hayo?_____

    _____

19. Una tosheka na mavuno unayo ya pata? Kama siyo, kwa nini mavuno ni kidogo?_____

    _____

Appendix B.ii Questionnaire

'Uboreshaji ardhi

20. Je kuna pembejeo ulizotumia ambazo ulizonunua dukani, kama mbegu, mbolea au dawa?

    · Aina gani? [mbegu; mbolea; dawa ya wadudu; dawa za tiba; dawa ya josho; HAKUNA]

    · Maoni juu pembejeo hizo _____

    _____

21. Matumizi ya mbolea ya asili, kama samadi, mabua au takataka za nyumbani?

    · Aina gani? [samadi; mabua; takataka; HAKUNA]

    · Maoni juu ya mbolea hizo_____

    _____

22. Je shamba lako lina kinga maji? Je unaliwekea mfreji ya kupunguza maji shambani? [ndiyo / hapana]

    · Kama ndiyo, aina gani? _____

Mifugo

23. Ni manufaa yapi muhimu yanayotokana na mifugo? (*) [ngozi; maziwa; samadi; kunfanya kazi; mayai; nyama; mifugo]

    · Yalikuwepo mauzo yeyote? (*) [ngozi; maziwa; samadi; kunfanya kazi; mayai; nyama; mifugo; HAKUNA]

    · Maoni ya manufaa ya mifugo_____

24. Kuna **ONGEZEKO** zaidi au **PUNGUFU** zaidi ya mifugo kuliko miaka uliopita? Kama ndiyo, eleza. _____

    _____

    _____

25. Ni malisho aina gani ambayoni muhimu? [shambani ya kaya; ngitiri ya kaya; ngitiri ya kijiji; porini]

    · Eleza sababu_____

    _____

26. Umuhimu wa miti ya malisho katika sehemu kame_____

27. Aina ya mifugo [Ngombe; Maksai; Kondoo; Mbuzi; Punda; Kuku; Nyngine_____]

28. Una ridhishwa na uzalishaji wa mifugo yako? Kama ni mdogo, kwa nini?_____

Appendix B.ii Questionnaire

'Miti

29. Ni aina gani moja ya miti muhimu zaidi kwenye kaya? -- A_____

A1 Sehemu ya miti hii, kama...? (*)

[bustani ya nyumbani; mipakani; miti iliyohifadhiwa shambani; bustani za miti; porini; eneo lililo hifadhiwa]

A2 Je mnatunza miti hii, kama.....? — *Skip to A3 if they only use trees from porini.*

[tunzaji wa machipukizi; wateshaji wa mbegu; upandiji wa miche; kuzuia watu wasikate; kuzuia wa mifugo; umwagiliaji]

A3 Je kuna ongezeko au pungufu ya miti hii kuliko miaka iliopita? Kama ndiyo, kwa nini? _____

_____

A4 Mazao yapi yanapatikana kutokana na miti hii? (*)

[mpini; nguzo; mbao; kuni; matunda; chakula cha mifigo; uzio; dawa; HAKUNA]

A5 Mazao ya miti hii yaliyouzwa (*) [mpini; nguzo; mbao; kuni; matunda; chakula cha mifigo; uzio; dawa; HAKUNA]

A6 Kuna **FAIDA** gani au **HASARA** gani ya miti hii **KWA MIFUGO?** _____

_____

A7 Kuna **FAIDA** gani au **HASARA** gani ya miti hii **KWA MAZAO**? _____

_____

A8 Matumizi mengine ya miti hii _____

⇒ *If they are obviously unhappy or bored talking about trees, skip to #29. If not, go to #28.*

30. Ni aina yengine ya miti muhimu zaidi ya kaya? -- B_____; C_____

B1 Sehemu ya miti hii, kama...? (*)

[bustani ya nyumbani; mipakani; miti iliyohifadhiwa shambani; bustani za miti; porini; eneo lililo hifadhiwa]

B2 Je mnatunza miti hii, kama.....? — *Skip to B3 if they only use trees from porini.*

[tunzaji wa machipukizi; wateshaji wa mbegu; upandiji wa miche; kuzuia watu wasikate; kuzuia wa mifugo; umwagiliaji]

B3 Je kuna ongezeko au pungufu ya miti hii kuliko miaka iliopita? Kama ndiyo, kwa nini? _____

_____

B4 Mazao yapi yanapatikana kutokana na miti hii? (*)

[mpini; nguzo; mbao; kuni; matunda; chakula cha mifigo; uzio; dawa; HAKUNA]

Appendix B.ii Questionnaire

B5 Mazao ya miti hii yaliyouzwa (*) [mpini; nguzo; mbao; kuni; matunda; chakula cha mifigo; uzio; dawa; HAKUNA]

B6 Kuna **FAIDA** gani au **HASARA** gani ya miti hii **KWA MIFUGO?** _____

_____

B7 Kuna **FAIDA** gani au **HASARA** gani ya miti hii **KWA MAZAO**? _____

_____

B8 Matumizi mengine ya miti hii _____

Aina C: _____

C1 Sehemu ya miti hii, kama.....? (*)

[bustani ya nyumbani; mipakani; miti iliyohifadhiwa shambani; bustani za miti; porini; eneo lililo hifadhiwa]

C2 Je mnatunza miti hii, kama.....? — *Skip to C3 if they only use trees from porini.*

[tunzaji wa machipukizi; wateshaji wa mbegu; upandiji wa miche; kuzuia watu wasikate; kuzuia wa mifugo; umwagiliaji]

C3 Je kuna ongezeko au pungufu ya miti hii kuliko miaka iliopita? Kama ndiyo, kwa nini? _____

_____

C4 Mazao yapi yanapatikana kutokana na miti hii? (*)

[mpini; nguzo; mbao; kuni; matunda; chakula cha mifigo; uzio; dawa; HAKUNA]

C5 Mazao ya miti hii yaliyouzwa (*) [mpini; nguzo; mbao; kuni; matunda; chakula cha mifigo; uzio; dawa; HAKUNA]

C6 Kuna **FAIDA** gani au **HASARA** gani ya miti hii **KWA MIFUGO?** _____

_____

C7 Kuna **FAIDA** gani au **HASARA** gani ya miti hii **KWA MAZAO**? _____

_____

C8 Matumizi mengine ya miti hii _____

⇒ *Ask #29 only if skipped #28.*

31. Taja aina yengine ya miti katika shambani au porini. Sema kama kila aina ni nzuri au mbaya kwa kaya na kwa nini.

- B _____

_____

- C _____

Appendix B.ii Questionnaire

32. Je utunzaji wa machipukizi au upandiji wa miti ni mzuri au mbaya? Eleza.

Uzalishaji wa mazao shambani

33. Mazao yanayolimwa mashambani? [pamba; mahindi; uwele; karanga; viazi; mpunga; mtama; mihogo; katani]

34. Je mlishawahi kulima mazao ya aina nyingine miaka iliyopita?

35. Je una changanya mazao shambani? — *list combinations*

36. Makadiriyo ya mavuno ya msimu uliopita — *see below*

37. Je kuna ongezeko zaidi au pungufu zaidi ya mavuno kuliko miaka iliopita? — *see below*

mazao	mavuno (# bags)	mabadiliko (<<; <; = ; >; >>)	Sababu na mabadiliko
a.			
b.			
c.			
d.			
e.			
f.			

38. Je uliweka vibarua shambani katika msimu uliopita? [ndiyo / hapana]

39. Je mnauza mazao ya kaya wakati mwingine? [ndiyo / hapana]

- Kama ndiyo
  - Mazao yapi wakati mwingine una yauza? [pamba; mahindi; uwele; karanga; viazi; mpunga; mtama; mihogo]
  - Je masoko yanafikika kwa urahisi? [ndiyo / hapana]

40. Je masoko yalikuwa mazuri zaidi kuliko zamani? [ndiyo / hapana]

Appendix B.ii Questionnaire

41. Maoni juu masoko_____

_____

42. Kaya inapata chakula cha kutosha kwa mwaka mzima? Eleza. _____

_____

43. Kuna ugumu gani wa kupata chakula wakati wa njaa? Eleza. _____

_____

Vyanzo vingine vya mapato — *Point is whether money is coming into the household*

44. Je una zalisha mboga? [ndiyo / hapana]

- Kama ndiyo
  - Mboga gani? _____
  - Ni umihimu ya kaya? Kwa nini? _____

_____

45. Je kuna yeyote anayejihusisha na uchimbaji wa madini? [ndiyo / hapana]

- Kama ndiyo, ni umuhimu ya kaya?_____

46. Je kuna shughuli zingine za kiuchumi? [ndiyo / hapana]

- Kama ndiyo
  - Aina gani? _____
  - Ni umihimu ya kaya? _____

47. Je kuna mtu katika kaya hii anayefanya kazi nje ya shamba la kaya? [ndiyo / hapana]

- Kama ndiyo
  - Wapi? _____
  - Kwa miezi ngapi katika mwaka uliopita?_____

48. Je wana kaya wanapata misaada kutoka kwa jamaa? [ndiyo / hapana]

Appendix B.ii Questionnaire

Matumizi ya kaya

49. Je umekuwa ukinunuwa mazao ya fuatayo kwa mwaka uliopita? -- *Read items one-by-one to see if have purchased*

[mtama; mahindi; viazi; mpunga; mafuta ya kupikia; maharagwe; nyama; mboga; sukari; majani ya chai; tambak]

50. Ikiwa watoto katika kaya wamekwenda shule, unategemea kupata nini au faida gani? — *Ask WHY what they mention is usful.*

_____

_____

E. TAARIFA YA KILA MTU KATIKA KAYA — *See Matrix E.i and E.ii*

F. QUESTIONS FOR WOMEN — *Ask HHH if can interview woman alone. Check one: HHH ☐ present ☐ not present*

51. Nishati kubwa inayotumika kupikia? (*) [kuni; mkaa; samadi; gesi; nyingine_____]

· Kama kuni

- Una pata kuni wapi? (*) [shambani ya kaya; ngitiri ya kijiji; porini; tunanunua]
- Watu wa kaya wanatumia masaa ngapi kila siku kutafuta kuni? [- ½; 1; 2; 3; 4; 5; 6; 7; 8+]
- Ni masaa mangapi unaona yanafaa kwa kutafuta kuni? Ni masaa mangapi unaona ni usumbufu[1]? Eleza._____

_____

52. Kama unatumia muda mrefu kwa kutafuta kuni, kwa nini inakuwa hivyo? _____

_____

53. Kama kwenye kaya kuna miti iliyopandwa, je wakinamama wanaweza kuvuna kuni kutokana na miti hiyo? _____

_____

54. Je unatumia muda gani kwenda kuchota maji kila siku? [- ½; 1; 2; 3; 4; 5; 6; 7; 8+]

55. Je kuna tatizo la ulevi linalo athiri kaya hii?_____

_____

56. Je kuna maamuzi katika umilikaji wa rasilimali mlizonazo? Taja na eleza. _____

_____

57. Kaya inapata chakula cha kutosha kwa mwaka mzima? Eleza. _____

_____

Appendix B.ii Questionnaire

3. DIRECT OBSERVATIONS

- *Do answers fit with observations?* _____
- Jinsi ilivyoezekwa? [upande nyasi; upande bati; upande tembe]
- Jinsi ilivyosakafiwa? [upande udongo; upande simenti]
- Chora ramani ya mashamba lako ukionyesha mwinuko, mipaka, aina ya udongo, na miti.
  - Soils: MB = mbuga; IBU = ibusihi; IBA = ibambasi; JI = jikungu; LO = loseni; LU = lusanga
  - Trees: = small trees only; = < 5 trees in area; = 6-20 trees in area; = > 21 trees in area
  - Slopes: ⟶ ⟶ ⟶
  - Crops: Write in names if they associate particular crops with partcular fields.

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he point is, do they like the chance to get away from the household? If so, how long is best?

Appendix C Background for Regression Analysis

Appendix C.i Interpreting logit models

Logistic regression predicts the presence or absence of a characteristic or outcome based on the values of a set of predictor variables. With logistic regression, the model's predictor variables may be either categorical or continuous, but its dependent variable must be categorical. Three alternative cases are possible, all of which are used in the present analysis.

When the dependent variable has only two alternative outcomes, a binary logit model is appropriate. Such a model is written as follows:

$$\log\left[\frac{P(\text{event})}{1 - P(\text{event})}\right] = B_0 + B_1X_1 + B_2X_2 + \ldots + B_pX_p$$

Here, B_0 is the intercept while B_1 to B_p are the logistic regression coefficients and X_1 to X_p are the independent variables. The quantity to the left of the equals sign is the logit, or natural log of the odds that the event will occur. When the dependent variable is binary, only one non-redundant logit exists, and the logit model consists of a single logit equation.

When the dependent variable has more than two possible values, a multinomial logit model is needed. In this case, the dependent variable may or may not be ranked. Multinomial logit models with a ranked dependent variable are assessed using ordinal regression, while those where the dependent variable is not ranked are assessed using nominal regression.

In either case, the multinomial logit model includes more than one separate logit equation, since more than one non-redundant logit exists. Given a dependent variable with J possible values, the number of non-redundant logits that can be formed is $J - 1$[1]. This follows because given categorical data, a statement can only be made about a particular category in comparison to some other category. Typically, such comparisons are done by selecting the lowest-ranking value of the dependent variable as the baseline value or reference category, then relating all other categories to it. A separate set of coefficients is determined for each value of the dependent variable except the baseline value[2], for which all coefficients are defined to be zero. The intercept term thus indicates the probability that a household will fall into the baseline category. The logit for each non-baseline value of the dependent variable is written as follows:

---

[1] E.g., if the dependent variable has three categories, then two non-redundant logits can be formed.

[2] Because nominal regression generates separate coefficients for each constituent logit of the multinomial model, factors included in the model may or may not be significant to a particular logit, despite being significant to the overall model. The overall significance of factors reflects their role as determinants of

$$\log\left[\frac{P(\text{category}_I)}{P(\text{category}_J)}\right] = B_{i0} + B_{i1}X_1 + B_{i2}X_2 + \ldots + B_{ip}X_p$$

Taken together, these logits comprise the multinomial logit model, with each constituent logit identified by a subscript.

Appendix C.ii Diagnostic tests

Common problems plaguing regression models include multicollinearity, heteroscedasticity and autocorrelation. The relation of each to the present regression analysis is briefly discussed.

A. Multicollinearity

* Multicollinearity occurs where one explanatory variable can be explained as a linear function of one or more other such variables. It affects the significance of findings, but not the findings themselves. Thus, while the coefficients obtained are accurate, they may be found to be insignificant when in fact they are significant.

* One test for multicollinearity conducted as part of the present analysis involved assessing bivariate correlations among independent variables using Spearman's rho. None of the correlations examined was found to be near the value of 0.8 typically used as the gauge for dangerously high levels of multicollinearity. In fact, all the correlations were below 0.4, with most far below this value (see below).

* A second test for multicollinearity involved running a set of auxiliary regressions, or regressing each X variable on the remaining X variables. The basic idea is that if an X is not a linear combination of the remaining X's, then the resulting R-square value should not be significantly different from zero. Despite combining all the resource variables examined, in no case was the proportion of variability explained higher than 30%, and in most cases it was closer to 10%.

B. Autocorrelation

* Autocorrelation is not relevant to the present study, since only cross-sectional data were collected. Although some of the data gathered extend backwards in time, e.g., the data on past resources, practices and outcomes, such data are recall data collected at one moment in time, and hence are not plagued by autocorrelation.

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the full range of alternative outcomes of the dependent variable taken together, while their significance in any given logit reflects their capacity to help explain differences between the two alternative outcomes being compared.

C. Heteroscedasticity

* Heteroscedasticity occurs when cross-sectional data are characterised by non-constant error variance. While it does not affect the coefficients, their significance is affected as in the case of multicollinearity.

* Heteroscedasticity was not assessed, since it only applies to continuous variables, while both the dependent variables and most of the independent variables analysed were categorical. Nonetheless, to minimise the chances of heteroscedasticity plaguing the analysis, the two continuous variables most central to the analysis – farm size and household labour – were transformed to minimise non-constant error variance.

* Observing frequency data for these variables both in the form of decile groups and histograms showed that variation increased with increasing farm or household size. Taking the natural log of these two variables transformed them to make variation roughly constant across both farm and household sizes.

* Although they did not affect multicorrelation findings, these transformations were found to affect the results of regression models. Namely, the statistical significance of independent variables tended to be marginally higher.

* A second reason for transforming these variables is that if any two independent variables are related in a non-linear fashion, this relationship may be overlooked by correlation statistics while nonetheless affecting findings. Transforming these continuous variables into a roughly linear form helps detect any relationships between them and other variables via correlation statistics.

Logit 1: Ordinal Regression, RVs Only

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	421.428			
Final	387.093	34.335	4	.000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	234.836	252	.774
Deviance	257.333	252	.395

Link function: Logit.

Pseudo R-Square

Cox and Snell	.100
Nagelkerke	.113
McFadden	.048

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[LOGIT1 = 2]	.856	.371	5.330	1	.021	.129	1.583
	[LOGIT1 = 3]	2.378	.392	36.868	1	.000	1.611	3.146
Location	FARMSIZE	.503	.133	14.284	1	.000	.242	.764
	[TENURE=1]	.693	.277	6.254	1	.012	.150	1.236
	[TENURE=2]	0[a]	.	.	0	.	.	.
	[LAB.OUT=1]	-.561	.271	4.289	1	.038	-1.092	-.030
	[LAB.OUT=2]	0[a]	.	.	0	.	.	.
	[MAJINCOM=1]	.666	.278	5.718	1	.017	.120	1.211
	[MAJINCOM=2]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Asymptotic Correlation Matrix

		Threshold		Location					
		[LOGIT 1 = 2]	[LOGIT 1 = 3]	FARM SIZE	[TEN URE= 1]		[LAB.O UT=1]	[MAJIN COM=1]	
Threshold	[LOGIT1 = 2]	1.000	.943	.711	.495	.	.114	.137	.
	[LOGIT1 = 3]	.943	1.000	.721	.501	.	.082	.159	.
Location	FARMSIZE	.711	.721	1.000	-.128	.	-.024	.013	.
	[TENURE=1]	.495	.501	-.128	1.000	.	-.012	.036	.
	[TENURE=2]	.	.	.	.	.	.	.	.
	[LAB.OUT=1]	.114	.082	-.024	-.012	.	1.000	-.052	.
	[LAB.OUT=2]	.	.	.	.	.	.	.	.
	[MAJINCOM= 1]	.137	.159	.013	.036	.	-.052	1.000	.
	[MAJINCOM= 2]	.	.	.	.	.	.	.	.

Link function: Logit.

Logit 1: Ordinal Regression, RVs and OIVs

Case Processing Summary

		N	Marginal Percentage
Farm tree numbers	<5	94	30.5%
	6-20	104	33.8%
	>20	110	35.7%
Religion of HH	Christian or Muslim	149	48.4%
	indigenous religion	159	51.6%
HASHI village?	HASHI village	203	65.9%
	no	105	34.1%
Swahili of principal informant	Speaks well	230	74.7%
	Understands, but speaks with difficulty	29	9.4%
	Minimal	49	15.9%
Tenure status of farm	privately owned	251	81.5%
	partly rented or borrowed	57	18.5%
Do HH members sell their labour to work	yes	54	17.5%
	no	254	82.5%
Valid		308	100.0%
Missing		41	
Total		349	

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	562.405			
Final	519.004	43.401	7	.000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	417.885	403	.294
Deviance	433.116	403	.145

Link function: Logit.

Pseudo R-Square

Cox and Snell	.131
Nagelkerke	.148
McFadden	.064

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.
Threshold	[LOGIT1 = 2]	1.036	.477	4.717	1	.030
	[LOGIT1 = 3]	2.611	.497	27.607	1	.000
Location	FARMSIZE	.610	.145	17.616	1	.000
	[RELIGION=1]	.652	.226	8.311	1	.004
	[RELIGION=2]	0[a]	.	.	0	.
	[HASHI=1]	.442	.230	3.690	1	.055
	[HASHI=2]	0[a]	.	.	0	.
	[SWAHILI=3]	-.564	.311	3.297	1	.069
	[SWAHILI=4]	-.490	.451	1.180	1	.277
	[SWAHILI=5]	0[a]	.	.	0	.
	[TENURE=1]	.647	.286	5.130	1	.024
	[TENURE=2]	0[a]	.	.	0	.
	[LAB.OUT=1]	-.600	.288	4.344	1	.037
	[LAB.OUT=2]	0[a]	.	.	0	.

Link function: Logit.

Parameter Estimates

		95% Confidence Interval	
		Lower Bound	Upper Bound
Threshold	[LOGIT1 = 2]	.101	1.971
	[LOGIT1 = 3]	1.637	3.585
Location	FARMSIZE	.325	.895
	[RELIGION=1]	.209	1.095
	[RELIGION=2]	.	.
	[HASHI=1]	-9.002E-03	.893
	[HASHI=2]	.	.
	[SWAHILI=3]	-1.173	4.480E-02
	[SWAHILI=4]	-1.375	.394
	[SWAHILI=5]	.	.
	[TENURE=1]	8.713E-02	1.207
	[TENURE=2]	.	.
	[LAB.OUT=1]	-1.164	-3.577E-02
	[LAB.OUT=2]	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Logit 1: Ordinal Regression, RVs, OIVs and KVs

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	479.786			
Final	419.691	60.094	10	.000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	410.992	412	.505
Deviance	402.061	412	.628

Link function: Logit.

Pseudo R-Square

Cox and Snell	.233
Nagelkerke	.262
McFadden	.121

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[LOGIT1 = 2]	.828	.649	1.629	1	.202	-.444	2.100
	[LOGIT1 = 3]	2.617	.670	15.270	1	.000	1.304	3.930
Location	FARMSIZE	.666	.176	14.392	1	.000	.322	1.010
	[LAB.OUT=1]	-.651	.344	3.586	1	.058	-1.324	2.E-02
	[LAB.OUT=2]	0[a]	.	.	0	.	.	.
	[TENURE=1]	.746	.345	4.693	1	.030	7.1E-02	1.422
	[TENURE=2]	0[a]	.	.	0	.	.	.
	[RELIGION=1]	.854	.275	9.636	1	.002	.315	1.394
	[RELIGION=2]	0[a]	.	.	0	.	.	.
	[SWAHILI=3]	-1.492	.451	10.970	1	.001	-2.375	-.609
	[SWAHILI=4]	-1.134	.603	3.538	1	.060	-2.316	5.E-02
	[SWAHILI=5]	0[a]	.	.	0	.	.	.
	[HARMSHA=1]	.852	.278	9.408	1	.002	.308	1.397
	[HARMSHA=2]	0[a]	.	.	0	.	.	.
	[HARMSOI=1]	.566	.271	4.358	1	.037	3.5E-02	1.097
	[HARMSOI=2]	0[a]	.	.	0	.	.	.
	[KEYOTHER=1]	.660	.277	5.672	1	.017	.117	1.202
	[KEYOTHER=2]	0[a]	.	.	0	.	.	.
	[MAKERAIN=1]	-.520	.290	3.218	1	.073	-1.089	5.E-02
	[MAKERAIN=2]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Logit 2: Binary Regression, RVs Only

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	326	93.4
	Missing Cases	23	6.6
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	23.293	6	.001
	Block	23.293	6	.001
	Model	23.293	6	.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	252.660	.069	.121

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	FARM.BIG(1)	-.617	.346	3.179	1	.075	.539
	LAB.IN(1)	.915	.373	6.021	1	.014	2.497
	LAB.OUT(1)	.859	.400	4.610	1	.032	2.360
	LIVESTCK			.666	2	.717	
	LIVESTCK(1)	6.738	14.705	.210	1	.647	844.107
	LIVESTCK(2)	6.452	14.708	.192	1	.661	633.861
	INCIDENC(1)	-.983	.335	8.610	1	.003	.374
	Constant	-7.915	14.705	.290	1	.590	.000

Variables in the Equation

		95.0% C.I.for EXP(B)	
		Lower	Upper
Step 1[a]	FARM.BIG(1)	.274	1.063
	LAB.IN(1)	1.202	5.187
	LAB.OUT(1)	1.078	5.170
	LIVESTCK		
	LIVESTCK(1)	.000	2.77E+15
	LIVESTCK(2)	.000	2.09E+15
	INCIDENC(1)	.194	.722
	Constant		

a. Variable(s) entered on step 1: FARM.BIG, LAB.IN, LAB.OUT, LIVESTCK, INCIDENC.

Correlation Matrix

		Constant	FARM.BIG(1)	LAB.IN(1)	LAB.OUT(1)	LIVESTCK(1)
Step 1	Constant	1.000	-.001	-.005	-.009	-1.000
	FARM.BIG(1)	-.001	1.000	-.170	-.107	-.008
	LAB.IN(1)	-.005	-.170	1.000	.128	.001
	LAB.OUT(1)	-.009	-.107	.128	1.000	.006
	LIVESTCK(1)	-1.000	-.008	.001	.006	1.000
	LIVESTCK(2)	-1.000	-.001	.002	.004	1.000
	INCIDENC(1)	-.009	.031	-.184	-.210	.000

Correlation Matrix

		LIVESTCK(2)	INCIDENC(1)
Step 1	Constant	-1.000	-.009
	FARM.BIG(1)	-.001	.031
	LAB.IN(1)	.002	-.184
	LAB.OUT(1)	.004	-.210
	LIVESTCK(1)	1.000	.000
	LIVESTCK(2)	1.000	-.002
	INCIDENC(1)	-.002	1.000

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	FARM.BIG	-127.988	3.315	1	.069
	LAB.IN	-129.245	5.831	1	.016
	LAB.OUT	-128.528	4.396	1	.036
	LIVESTCK	-129.729	6.799	2	.033
	INCIDENC	-130.778	8.895	1	.003

a. Based on conditional parameter estimates

Logit 2: Binary Regression, RVs, OIVs and KVs

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	268	76.8
	Missing Cases	81	23.2
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	33.447	6	.000
	Block	33.447	6	.000
	Model	33.447	6	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	178.022	.117	.215

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	RADIO			9.591	2	.008	
	RADIO(1)	1.298	.457	8.071	1	.004	3.661
	RADIO(2)	.168	.519	.104	1	.747	1.183
	MAKERAIN(1)	-.858	.477	3.230	1	.072	.424
	OTHENVTL(1)	1.372	.453	9.181	1	.002	3.942
	HARMSOI(1)	-.778	.422	3.402	1	.065	.459
	HARMSHA(1)	1.406	.429	10.749	1	.001	4.080
	Constant	-3.338	.583	32.807	1	.000	.036

Variables in the Equation

		95.0% C.I.for EXP(B)	
		Lower	Upper
Step 1[a]	RADIO		
	RADIO(1)	1.495	8.962
	RADIO(2)	.427	3.274
	MAKERAIN(1)	.166	1.081
	OTHENVTL(1)	1.623	9.574
	HARMSOI(1)	.201	1.050
	HARMSHA(1)	1.760	9.457
	Constant		

a. Variable(s) entered on step 1: RADIO, MAKERAIN, OTHENVTL, HARMSOI, HARMSHA.

Correlation Matrix

		Constant	RADIO(1)	RADIO(2)	MAKERAIN(1)	OTHENVTL(1)
Step 1	Constant	1.000	-.552	-.360	-.110	-.561
	RADIO(1)	-.552	1.000	.492	.019	.086
	RADIO(2)	-.360	.492	1.000	.004	-.029
	MAKERAIN(1)	-.110	.019	.004	1.000	-.302
	OTHENVTL(1)	-.561	.086	-.029	-.302	1.000
	HARMSOI(1)	-.241	.035	-.036	.073	-.078
	HARMSHA(1)	-.653	.120	-.017	.053	.340

Correlation Matrix

		HARMSOI(1)	HARMSHA(1)
Step 1	Constant	-.241	-.653
	RADIO(1)	.035	.120
	RADIO(2)	-.036	-.017
	MAKERAIN(1)	.073	.053
	OTHENVTL(1)	-.078	.340
	HARMSOI(1)	1.000	.070
	HARMSHA(1)	.070	1.000

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	RADIO	-93.958	9.895	2	.007
	MAKERAIN	-90.772	3.522	1	.061
	OTHENVTL	-94.165	10.308	1	.001
	HARMSOI	-90.842	3.661	1	.056
	HARMSHA	-95.022	12.022	1	.001

a. Based on conditional parameter estimates

Logit 3: Binary Regression, RVs Only

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	336	96.3
	Missing Cases	13	3.7
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	19.872	4	.001
	Block	19.872	4	.001
	Model	19.872	4	.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	213.153	.057	.115

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	LAB.OUT(1)	-1.160	.632	3.371	1	.066	.313
	LAB.IN(1)	-1.660	.746	4.949	1	.026	.190
	LIVESTCK			8.862	2	.012	
	LIVESTCK(1)	-.979	.694	1.988	1	.159	.376
	LIVESTCK(2)	.121	.714	.029	1	.866	1.129
	Constant	-1.147	.659	3.031	1	.082	.318

Variables in the Equation

		95.0% C.I.for EXP(B)	
		Lower	Upper
Step 1[a]	LAB.OUT(1)	.091	1.081
	LAB.IN(1)	.044	.821
	LIVESTCK		
	LIVESTCK(1)	.096	1.465
	LIVESTCK(2)	.278	4.575
	Constant		

a. Variable(s) entered on step 1: LAB.OUT, LAB.IN, LIVESTCK.

Correlation Matrix

		Constant	LAB.OUT(1)	LAB.IN(1)	LIVESTCK(1)	LIVESTCK(2)
Step 1	Constant	1.000	-.138	-.109	-.933	-.903
	LAB.OUT(1)	-.138	1.000	.049	.066	.024
	LAB.IN(1)	-.109	.049	1.000	.032	.039
	LIVESTCK(1)	-.933	.066	.032	1.000	.852
	LIVESTCK(2)	-.903	.024	.039	.852	1.000

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	LAB.OUT	-108.808	4.463	1	.035
	LAB.IN	-110.588	8.023	1	.005
	LIVESTCK	-111.027	8.901	2	.012

a. Based on conditional parameter estimates

Logit 3: Binary Regression, RVs and OIVs

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	334	95.7
	Missing Cases	15	4.3
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	26.736	5	.000
	Block	26.736	5	.000
	Model	26.736	5	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	201.625	.077	.155

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	LAB.OUT(1)	-1.329	.644	4.257	1	.039	.265
	LAB.IN(1)	-1.643	.751	4.788	1	.029	.193
	LIVESTCK			7.228	2	.027	
	LIVESTCK(1)	-.765	.823	.863	1	.353	.465
	LIVESTCK(2)	.273	.841	.105	1	.746	1.314
	RELIGION(1)	-1.123	.416	7.302	1	.007	.325
	Constant	-.915	.814	1.264	1	.261	.400

Variables in the Equation

		95.0% C.I.for EXP(B)	
		Lower	Upper
Step 1[a]	LAB.OUT(1)	.075	.936
	LAB.IN(1)	.044	.843
	LIVESTCK		
	LIVESTCK(1)	.093	2.337
	LIVESTCK(2)	.253	6.833
	RELIGION(1)	.144	.734
	Constant		

a. Variable(s) entered on step 1: LAB.OUT, LAB.IN, LIVESTCK, RELIGION.

Correlation Matrix

		Constant	LAB.OUT(1)	LAB.IN(1)	LIVESTCK(1)
Step 1	Constant	1.000	-.145	-.113	-.941
	LAB.OUT(1)	-.145	1.000	.052	.076
	LAB.IN(1)	-.113	.052	1.000	.045
	LIVESTCK(1)	-.941	.076	.045	1.000
	LIVESTCK(2)	-.917	.022	.052	.890
	RELIGION(1)	-.240	.112	.025	.090

Correlation Matrix

		LIVESTCK(2)	RELIGION(1)
Step 1	Constant	-.917	-.240
	LAB.OUT(1)	.022	.112
	LAB.IN(1)	.052	.025
	LIVESTCK(1)	.890	.090
	LIVESTCK(2)	1.000	.093
	RELIGION(1)	.093	1.000

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	LAB.OUT	-103.692	5.758	1	.016
	LAB.IN	-104.618	7.611	1	.006
	LIVESTCK	-104.414	7.203	2	.027
	RELIGION	-105.059	8.492	1	.004

a. Based on conditional parameter estimates

Logit 4: Binary Regression, RVs Only

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	289	82.8
	Missing Cases	60	17.2
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	17.431	5	.004
	Block	17.431	5	.004
	Model	17.431	5	.004

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	311.388	.059	.086

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	FARMCATS			11.090	3	.011			
	FARMCATS(1)	1.225	.489	6.264	1	.012	3.403	1.304	8.879
	FARMCATS(2)	.773	.442	3.059	1	.080	2.166	.911	5.149
	FARMCATS(3)	.076	.445	.029	1	.865	1.079	.450	2.582
	LAB.IN(1)	-.684	.368	3.449	1	.063	.505	.245	1.039
	INCIDENC(1)	-.535	.285	3.523	1	.061	.586	.335	1.024
	Constant	-1.09	.410	7.011	1	.008	.337		

a. Variable(s) entered on step 1: FARMCATS, LAB.IN, INCIDENC.

Correlation Matrix

		Constant	FARMCATS (1)	FARMCATS (2)	FARMCATS (3)	LAB.IN (1)	INCIDEN C(1)
Step 1	Constant	1.000	-.679	-.739	-.772	-.092	-.413
	FARMCATS(1)	-.679	1.000	.643	.631	-.143	.023
	FARMCATS(2)	-.739	.643	1.000	.697	-.050	-.033
	FARMCATS(3)	-.772	.631	.697	1.000	.005	.045
	LAB.IN(1)	-.092	-.143	-.050	.005	1.000	-.048
	INCIDENC(1)	-.413	.023	-.033	.045	-.048	1.000

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	FARMCATS	-161.418	11.449	3	.010
	LAB.IN	-157.573	3.758	1	.053
	INCIDENC	-157.448	3.508	1	.061

a. Based on conditional parameter estimates

Logit 4: Binary Regression, RVs and OIVs

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	288	82.5
	Missing Cases	61	17.5
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	32.099	6	.000
	Block	32.099	6	.000
	Model	32.099	6	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	296.127	.105	.155

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	FARMCATS			11.057	3	.011	
	FARMCATS(1)	1.124	.499	5.071	1	.024	3.076
	FARMCATS(2)	.615	.455	1.823	1	.177	1.849
	FARMCATS(3)	-.129	.458	.079	1	.779	.879
	LAB.IN(1)	-.826	.379	4.749	1	.029	.438
	RELIGION(1)	-.525	.289	3.308	1	.069	.592
	HASHI(1)	-1.107	.293	14.271	1	.000	.330
	Constant	-.312	.457	.465	1	.495	.732

a. Variable(s) entered on step 1: FARMCATS, LAB.IN, RELIGION, HASHI.

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	FARMCATS	-153.752	11.378	3	.010
	LAB.IN	-150.699	5.270	1	.022
	RELIGION	-149.747	3.366	1	.067
	HASHI	-155.378	14.628	1	.000

a. Based on conditional parameter estimates

Logit 4: Binary Regression, RVs, OIVs and KVs

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	255	73.1
	Missing Cases	94	26.9
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	51.478	9	.000
	Block	51.478	9	.000
	Model	51.478	9	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	242.236	.183	.267

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	FARMCATS			10.965	3	.012	
	FARMCATS(1)	1.246	.560	4.955	1	.026	3.477
	FARMCATS(2)	.717	.503	2.030	1	.154	2.048
	FARMCATS(3)	-.159	.506	.099	1	.753	.853
	LAB.IN(1)	-1.212	.466	6.769	1	.009	.297
	RELIGION(1)	-.677	.325	4.351	1	.037	.508
	HASHI(1)	-.865	.338	6.531	1	.011	.421
	KEYFODD(1)	1.256	.559	5.041	1	.025	3.511
	KEYMEDS(1)	-1.890	.793	5.677	1	.017	.151
	KEYCWOOD(1)	-.899	.413	4.739	1	.029	.407
	Constant	-.124	.513	.058	1	.809	.883

a. Variable(s) entered on step 1: FARMCATS, LAB.IN, RELIGION, HASHI, KEYFODD, KEYMEDS, KEYCWOOD.

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	FARMCATS	-126.911	11.587	3	.009
	LAB.IN	-125.118	8.001	1	.005
	RELIGION	-123.363	4.491	1	.034
	HASHI	-124.406	6.577	1	.010
	KEYFODD	-123.724	5.212	1	.022
	KEYMEDS	-125.405	8.574	1	.003
	KEYCWOOD	-123.739	5.242	1	.022

a. Based on conditional parameter estimates

Logit 5: Binary Regression, RVs Only

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	346	99.1
	Missing Cases	3	.9
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	18.991	2	.000
	Block	18.991	2	.000
	Model	18.991	2	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	355.200	.053	.081

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	FARM.BIG(1)	-1.124	.289	15.099	1	.000	.325	.184	.573
	LSTOCK.2(1)	.810	.324	6.237	1	.013	2.248	1.190	4.245
	Constant	-1.385	.279	24.573	1	.000	.250		

a. Variable(s) entered on step 1: FARM.BIG, LSTOCK.2.

Correlation Matrix

		Constant	FARM.BIG(1)	LSTOCK.2(1)
Step 1	Constant	1.000	-.116	-.821
	FARM.BIG(1)	-.116	1.000	-.241
	LSTOCK.2(1)	-.821	-.241	1.000

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	FARM.BIG	-185.960	16.720	1	.000
	LSTOCK.2	-181.012	6.824	1	.009

a. Based on conditional parameter estimates

Logit 5: Binary Regression, RVs, OIVs and KVs

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	302	86.5
	Missing Cases	47	13.5
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	68.152	9	.000
	Block	68.152	9	.000
	Model	68.152	9	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	261.248	.202	.304

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	RELIGION(1)	.565	.321	3.091	1	.079	1.759
	RADIO			10.405	2	.006	
	RADIO(1)	1.250	.392	10.147	1	.001	3.491
	RADIO(2)	.410	.391	1.098	1	.295	1.507
	FARM.BIG(1)	-.982	.335	8.624	1	.003	.374
	FERTILAG(1)	-.898	.373	5.798	1	.016	.407
	HARMSOI(1)	-1.232	.339	13.230	1	.000	.292
	HARMSHA(1)	.871	.316	7.608	1	.006	2.389
	KEYFODD(1)	-2.429	1.075	5.104	1	.024	.088
	TENURE(1)	.902	.453	3.971	1	.046	2.465
	Constant	-1.909	.502	14.464	1	.000	.148

a. Variable(s) entered on step 1: RELIGION, RADIO, FARM.BIG, FERTILAG, HARMSOI, HARMSHA, KEYFODD, TENURE.

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	RELIGION	-132.190	3.133	1	.077
	RADIO	-136.023	10.797	2	.005
	FARM.BIG	-135.253	9.257	1	.002
	FERTILAG	-133.777	6.305	1	.012
	HARMSOI	-138.004	14.760	1	.000
	HARMSHA	-134.519	7.789	1	.005
	KEYFODD	-135.322	9.396	1	.002
	TENURE	-132.837	4.426	1	.035

a. Based on conditional parameter estimates

Logit 6: Binary Regression, RVs Only

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	340	97.4
	Missing Cases	9	2.6
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	3.057	1	.080
	Block	3.057	1	.080
	Model	3.057	1	.080

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	222.361	.009	.018

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	SOILTYPE(1)	.807	.500	2.609	1	.106	2.242	.842	5.969
	Constant	2.001	.195	105.87	1	.000	7.400		

a. Variable(s) entered on step 1: SOILTYPE.

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	SOILTYPE	-112.736	3.111	1	.078

a. Based on conditional parameter estimates

Logit 6: Binary Regression, RVs, OIVs and KVs

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	299	85.7
	Missing Cases	50	14.3
	Total	349	100.0
Unselected Cases		0	.0
Total		349	100.0

a. If weight is in effect, see classification table for the total number of cases.

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	18.761	4	.001
	Block	18.761	4	.001
	Model	18.761	4	.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	171.653	.061	.129

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	SOILTYPE(1)	1.116	.646	2.986	1	.084	3.052	.861	10.817
	KEYMEDS(1)	1.446	.516	7.845	1	.005	4.245	1.543	11.674
	KEYCWOOD(1)	1.042	.417	6.255	1	.012	2.836	1.253	6.418
	HARMSOI(1)	.844	.428	3.896	1	.048	2.326	1.006	5.380
	Constant	-.246	.609	.162	1	.687	.782		

a. Variable(s) entered on step 1: SOILTYPE, KEYMEDS, KEYCWOOD, HARMSOI.

Correlation Matrix

		Constant	SOILTYPE(1)	KEYMEDS(1)	KEYCWOOD(1)	HARMSOI(1)
Step 1	Constant	1.000	-.184	-.791	-.522	-.466
	SOILTYPE(1)	-.184	1.000	.087	.037	-.030
	KEYMEDS(1)	-.791	.087	1.000	.128	.216
	KEYCWOOD(1)	-.522	.037	.128	1.000	.122
	HARMSOI(1)	-.466	-.030	.216	.122	1.000

Model if Term Removed[a]

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	SOILTYPE	-87.753	3.853	1	.050
	KEYMEDS	-89.405	7.156	1	.007
	KEYCWOOD	-88.950	6.246	1	.012
	HARMSOI	-87.915	4.177	1	.041

a. Based on conditional parameter estimates

Logit 7: Ordinal Regression, RVs Only

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	296.832			
Final	270.596	26.236	8	.001

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	128.898	139	.719
Deviance	130.089	139	.694

Link function: Logit.

Pseudo R-Square

Cox and Snell	.078
Nagelkerke	.086
McFadden	.033

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[LOGIT6 = 1]	-1.905	.519	13.463	1	.000	-2.922	-.887
	[LOGIT6 = 2]	-.394	.502	.618	1	.432	-1.378	.589
	[LOGIT6 = 3]	1.967	.516	14.540	1	.000	.956	2.978
Location	[FARMCATS= 5]	-.914	.383	5.702	1	.017	-1.665	-.164
	[FARMCATS= 6]	-.710	.334	4.509	1	.034	-1.366	-5.E-02
	[FARMCATS= 7]	-.353	.305	1.343	1	.246	-.950	.244
	[FARMCATS= 8]	0[a]	.	.	0	.	.	.
	[LAB.IN=1]	.803	.266	9.104	1	.003	.281	1.325
	[LAB.IN=2]	0[a]	.	.	0	.	.	.
	[LAB.OUT=1]	.675	.279	5.845	1	.016	.128	1.222
	[LAB.OUT=2]	0[a]	.	.	0	.	.	.
	[LIVESTCK=2]	.563	.503	1.251	1	.263	-.423	1.549
	[LIVESTCK=3]	5.446E-02	.524	.011	1	.917	-.972	1.081
	[LIVESTCK=4]	0[a]	.	.	0	.	.	.
	[MAJINCOM=1]	.503	.281	3.214	1	.073	-4.7E-02	1.053
	[MAJINCOM=2]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Logit 7: Ordinal Regression, RVs and OIVs

Case Processing Summary

		N	Marginal Percentage
Tree management intensity	npl.nfi	33	10.3%
	npl.fi	74	23.1%
	planted	156	48.8%
	planted&watered	57	17.8%
Farm size categories	21+ acres	49	15.3%
	11 - 20 acres	90	28.1%
	5 - 10 acres	125	39.1%
	< 4 acres	56	17.5%
Did HH hire in farm labourers within the	yes	68	21.3%
	no	252	78.8%
Do HH members sell their labour to work	yes	58	18.1%
	no	262	81.9%
Livestock holdings	cattle	236	73.8%
	goats/sheep/chicken only	69	21.6%
	no livestock	15	4.7%
Religion of HH	Christian or Muslim	154	48.1%
	indigenous religion	166	51.9%
HASHI village?	HASHI village	216	67.5%
	no	104	32.5%
Valid		320	100.0%
Missing		29	
Total		349	

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	438.968			
Final	401.879	37.088	9	.000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	273.121	249	.141
Deviance	258.278	249	.330

Link function: Logit.

Pseudo R-Square

Cox and Snell	.109
Nagelkerke	.120
McFadden	.047

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.
Threshold	[LOGIT7 = 1]	-1.147	.608	3.560	1	.059
	[LOGIT7 = 2]	.438	.597	.539	1	.463
	[LOGIT7 = 3]	2.862	.621	21.214	1	.000
Location	[FARMCATS= 5]	-.903	.387	5.448	1	.020
	[FARMCATS= 6]	-.688	.337	4.157	1	.041
	[FARMCATS= 7]	-.298	.309	.933	1	.334
	[FARMCATS= 8]	0[a]	.	.	0	.
	[LAB.IN=1]	.873	.267	10.680	1	.001
	[LAB.IN=2]	0[a]	.	.	0	.
	[LAB.OUT=1]	.827	.283	8.522	1	.004
	[LAB.OUT=2]	0[a]	.	.	0	.
	[LIVESTCK=2]	.755	.526	2.060	1	.151
	[LIVESTCK=3]	.241	.548	.193	1	.660
	[LIVESTCK=4]	0[a]	.	.	0	.
	[RELIGION=1]	.601	.216	7.710	1	.005
	[RELIGION=2]	0[a]	.	.	0	.
	[HASHI=1]	.581	.230	6.378	1	.012
	[HASHI=2]	0[a]	.	.	0	.

Link function: Logit.

Parameter Estimates

		95% Confidence Interval	
		Lower Bound	Upper Bound
Threshold	[LOGIT7 = 1]	-2.338	4.444E-02
	[LOGIT7 = 2]	-.732	1.609
	[LOGIT7 = 3]	1.644	4.080
Location	[FARMCATS= 5]	-1.661	-.145
	[FARMCATS= 6]	-1.349	-2.664E-02
	[FARMCATS= 7]	-.903	.307
	[FARMCATS= 8]	.	.
	[LAB.IN=1]	.350	1.397
	[LAB.IN=2]	.	.
	[LAB.OUT=1]	.272	1.382
	[LAB.OUT=2]	.	.
	[LIVESTCK=2]	-.276	1.787
	[LIVESTCK=3]	-.833	1.314
	[LIVESTCK=4]	.	.
	[RELIGION=1]	.177	1.024
	[RELIGION=2]	.	.
	[HASHI=1]	.130	1.032
	[HASHI=2]	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Logit 7: Ordinal Regression, RVs, OIVs and KVs

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	467.544			
Final	413.792	53.752	12	.000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	418.467	450	.854
Deviance	353.017	450	1.000

Link function: Logit.

Pseudo R-Square

Cox and Snell	.205
Nagelkerke	.226
McFadden	.097

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[LOGIT6 = 1]	-1.971	.418	22.266	1	.000	-2.790	-1.152
	[LOGIT6 = 2]	-.236	.380	.386	1	.535	-.981	.509
	[LOGIT6 = 3]	2.649	.428	38.306	1	.000	1.810	3.488
Location	[FARMCATS=5]	-.650	.457	2.022	1	.155	-1.546	.246
	[FARMCATS=6]	-.739	.376	3.852	1	.050	-1.477	-9.9E-04
	[FARMCATS=7]	-8.946E-02	.375	.057	1	.811	-.824	.645
	[FARMCATS=8]	0[a]	.	.	0	.	.	.
	[LAB.IN=1]	.647	.341	3.596	1	.058	-2.E-02	1.316
	[LAB.IN=2]	0[a]	.	.	0	.	.	.
	[LAB.OUT=1]	.531	.335	2.507	1	.113	-.126	1.187
	[LAB.OUT=2]	0[a]	.	.	0	.	.	.
	[RELIGION=1]	.549	.267	4.236	1	.040	2.6E-02	1.071
	[RELIGION=2]	0[a]	.	.	0	.	.	.
	[RADIO=3]	.895	.338	6.998	1	.008	.232	1.558
	[RADIO=4]	.606	.312	3.771	1	.052	-6.E-03	1.218
	[RADIO=5]	0[a]	.	.	0	.	.	.
	[KEYFODD=1]	-1.335	.538	6.168	1	.013	-2.388	-.281
	[KEYFODD=2]	0[a]	.	.	0	.	.	.
	[KEYMEDS=1]	.887	.410	4.685	1	.030	8.4E-02	1.690
	[KEYMEDS=2]	0[a]	.	.	0	.	.	.
	[KEYCWOOD=1]	.772	.297	6.751	1	.009	.190	1.355
	[KEYCWOOD=2]	0[a]	.	.	0	.	.	.
	[MAKERAIN=1]	-.504	.271	3.470	1	.062	-1.035	2.6E-02
	[MAKERAIN=2]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Logit 8: Nominal Regression, RVs Only

Case Processing Summary

		N	Marginal Percentage
Tree type cultivated	don't plant trees	108	33.8%
	cultivate exotic fruit trees	65	20.3%
	cultivate indigenous fruit trees	51	15.9%
	cultivate non-fruit trees	96	30.0%
Farm size categories	21+ acres	49	15.3%
	11 - 20 acres	89	27.8%
	5 - 10 acres	125	39.1%
	< 4 acres	57	17.8%
Trends in incidence of off-farm trees	roughly stable	207	64.7%
	decreasing	113	35.3%
Did HH hire in farm labourers within the	yes	67	20.9%
	no	253	79.1%
Livestock holdings	cattle	235	73.4%
	goats/sheep/chicken only	69	21.6%
	no livestock	16	5.0%
Valid		320	100.0%
Missing		29	
Total		349	
Subpopulation		36	

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	282.559			
Final	235.035	47.524	21	.001

Pseudo R-Square

Cox and Snell	.138
Nagelkerke	.148
McFadden	.055

Likelihood Ratio Tests

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	235.035[a]	.000	0	.
FARMCATS	261.511	26.476	9	.002
INCIDENC	241.793	6.758	3	.080
LAB.IN	243.693	8.658	3	.034
LIVESTCK	246.121	11.086	6	.086

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Parameter Estimates

Tree type cultivated		B	Std. Error	Wald	df
don't plant trees	Intercept	1.022	.810	1.592	1
	[FARMCATS=5]	.799	.544	2.154	1
	[FARMCATS=6]	.088	.470	.035	1
	[FARMCATS=7]	.203	.448	.206	1
	[FARMCATS=8]	0[a]	.	.	0
	[INCIDENC=1]	-.577	.306	3.550	1
	[INCIDENC=2]	0[a]	.	.	0
	[LAB.IN=1]	-1.059	.375	7.991	1
	[LAB.IN=2]	0[a]	.	.	0
	[LIVESTCK=2]	-.605	.791	.585	1
	[LIVESTCK=3]	-.501	.802	.390	1
	[LIVESTCK=4]	0[a]	.	.	0
cultivate exotic fruit trees	Intercept	.573	.843	.462	1
	[FARMCATS=5]	-1.153	.668	2.985	1
	[FARMCATS=6]	-1.386	.528	6.886	1
	[FARMCATS=7]	-.008	.454	.000	1
	[FARMCATS=8]	0[a]	.	.	0
	[INCIDENC=1]	-.273	.354	.593	1
	[INCIDENC=2]	0[a]	.	.	0
	[LAB.IN=1]	-.309	.395	.612	1
	[LAB.IN=2]	0[a]	.	.	0
	[LIVESTCK=2]	.011	.811	.000	1
	[LIVESTCK=3]	-1.173	.875	1.800	1
	[LIVESTCK=4]	0[a]	.	.	0
cultivate indigenous fruit trees	Intercept	.236	.866	.074	1
	[FARMCATS=5]	-.094	.614	.023	1
	[FARMCATS=6]	-1.191	.565	4.440	1
	[FARMCATS=7]	-.169	.487	.120	1
	[FARMCATS=8]	0[a]	.	.	0
	[INCIDENC=1]	.294	.401	.537	1
	[INCIDENC=2]	0[a]	.	.	0
	[LAB.IN=1]	-.471	.423	1.244	1
	[LAB.IN=2]	0[a]	.	.	0
	[LIVESTCK=2]	-.477	.825	.335	1
	[LIVESTCK=3]	-.980	.863	1.288	1
	[LIVESTCK=4]	0[a]	.	.	0

Parameter Estimates

Tree type cultivated		Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
				Lower Bound	Upper Bound
don't plant trees	Intercept	.207			
	[FARMCATS= 5]	.142	2.222	.765	6.455
	[FARMCATS= 6]	.851	1.092	.435	2.743
	[FARMCATS= 7]	.650	1.226	.509	2.952
	[FARMCATS= 8]	.	.	.	.
	[INCIDENC=1]	.060	.561	.308	1.024
	[INCIDENC=2]	.	.	.	.
	[LAB.IN=1]	.005	.347	.166	.723
	[LAB.IN=2]	.	.	.	.
	[LIVESTCK=2]	.445	.546	.116	2.573
	[LIVESTCK=3]	.532	.606	.126	2.920
	[LIVESTCK=4]	.	.	.	.
cultivate exotic fruit trees	Intercept	.497			
	[FARMCATS= 5]	.084	.316	8.530E-02	1.168
	[FARMCATS= 6]	.009	.250	8.875E-02	.704
	[FARMCATS= 7]	.986	.992	.408	2.413
	[FARMCATS= 8]	.	.	.	.
	[INCIDENC=1]	.441	.761	.380	1.524
	[INCIDENC=2]	.	.	.	.
	[LAB.IN=1]	.434	.734	.338	1.593
	[LAB.IN=2]	.	.	.	.
	[LIVESTCK=2]	.989	1.011	.206	4.960
	[LIVESTCK=3]	.180	.309	5.570E-02	1.717
	[LIVESTCK=4]	.	.	.	.
cultivate indigenous fruit trees	Intercept	.785			
	[FARMCATS= 5]	.879	.911	.273	3.035
	[FARMCATS= 6]	.035	.304	.100	.920
	[FARMCATS= 7]	.729	.845	.325	2.195
	[FARMCATS= 8]	.	.	.	.
	[INCIDENC=1]	.464	1.342	.611	2.947
	[INCIDENC=2]	.	.	.	.
	[LAB.IN=1]	.265	.624	.273	1.429
	[LAB.IN=2]	.	.	.	.
	[LIVESTCK=2]	.563	.621	.123	3.125
	[LIVESTCK=3]	.256	.375	6.919E-02	2.038
	[LIVESTCK=4]	.	.	.	.

a. This parameter is set to zero because it is redundant.

Logit 8: Nominal Regression, RVs and OIVs

Case Processing Summary

		N	Marginal Percentage
Tree type cultivated	don't plant trees	107	33.6%
	cultivate exotic fruit trees	64	20.1%
	cultivate indigenous fruit trees	51	16.0%
	cultivate non-fruit trees	96	30.2%
Farm size categories	21+ acres	49	15.4%
	11 - 20 acres	88	27.7%
	5 - 10 acres	125	39.3%
	< 4 acres	56	17.6%
Do HH members sell their labour to work	yes	57	17.9%
	no	261	82.1%
Did HH hire in farm labourers within the	yes	67	21.1%
	no	251	78.9%
Religion of HH	Christian or Muslim	152	47.8%
	indigenous religion	166	52.2%
Livestock holdings	cattle	234	73.6%
	no cattle	84	26.4%
HASHI village?	HASHI village	215	67.6%
	no	103	32.4%
Valid		318	100.0%
Missing		31	
Total		349	
Subpopulation		79	

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	461.966			
Final	392.687	69.279	24	.000

Pseudo R-Square

Cox and Snell	.196
Nagelkerke	.210
McFadden	.081

Likelihood Ratio Tests

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	392.687	.000	0	.
FARMCATS	421.767	29.080	9	.001
LAB.OUT	400.434	7.747	3	.052
LAB.IN	403.276	10.589	3	.014
RELIGION	404.496	11.809	3	.008
LSTOCK.2	400.455	7.768	3	.051
HASHI	405.038	12.351	3	.006

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

Parameter Estimates

Tree type cultivated		B	Std. Error	Wald	df
don't plant trees	Intercept	1.328	.531	6.268	1
	[FARMCATS=5]	.644	.554	1.349	1
	[FARMCATS=6]	-.015	.481	.001	1
	[FARMCATS=7]	.053	.460	.013	1
	[FARMCATS=8]	0[a]	.	.	0
	[LAB.OUT=1]	-.651	.411	2.507	1
	[LAB.OUT=2]	0[a]	.	.	0
	[LAB.IN=1]	-1.168	.384	9.273	1
	[LAB.IN=2]	0[a]	.	.	0
	[RELIGION=1]	-.468	.305	2.357	1
	[RELIGION=2]	0[a]	.	.	0
	[LSTOCK.2=1]	-.147	.349	.179	1
	[LSTOCK.2=2]	0[a]	.	.	0
	[HASHI=1]	-1.042	.323	10.411	1
	[HASHI=2]	0[a]	.	.	0
cultivate exotic fruit trees	Intercept	-.869	.628	1.912	1
	[FARMCATS=5]	-1.226	.673	3.322	1
	[FARMCATS=6]	-1.637	.542	9.109	1
	[FARMCATS=7]	-.023	.459	.003	1
	[FARMCATS=8]	0[a]	.	.	0
	[LAB.OUT=1]	.587	.423	1.928	1
	[LAB.OUT=2]	0[a]	.	.	0
	[LAB.IN=1]	-.191	.403	.225	1
	[LAB.IN=2]	0[a]	.	.	0
	[RELIGION=1]	.650	.347	3.506	1
	[RELIGION=2]	0[a]	.	.	0
	[LSTOCK.2=1]	.945	.424	4.959	1
	[LSTOCK.2=2]	0[a]	.	.	0
	[HASHI=1]	-.155	.392	.155	1
	[HASHI=2]	0[a]	.	.	0
cultivate indigenous fruit trees	Intercept	-.044	.619	.005	1
	[FARMCATS=5]	-.236	.615	.148	1
	[FARMCATS=6]	-1.283	.563	5.195	1
	[FARMCATS=7]	-.263	.488	.290	1
	[FARMCATS=8]	0[a]	.	.	0
	[LAB.OUT=1]	-.117	.484	.059	1
	[LAB.OUT=2]	0[a]	.	.	0
	[LAB.IN=1]	-.427	.424	1.014	1
	[LAB.IN=2]	0[a]	.	.	0
	[RELIGION=1]	.357	.361	.977	1
	[RELIGION=2]	0[a]	.	.	0
	[LSTOCK.2=1]	.232	.418	.308	1
	[LSTOCK.2=2]	0[a]	.	.	0
	[HASHI=1]	-.450	.399	1.272	1
	[HASHI=2]	0[a]	.	.	0

Parameter Estimates

Tree type cultivated		Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
				Lower Bound	Upper Bound
don't plant trees	Intercept	.012			
	[FARMCATS= 5]	.246	1.903	.642	5.639
	[FARMCATS= 6]	.975	.985	.384	2.526
	[FARMCATS= 7]	.908	1.055	.428	2.599
	[FARMCATS= 8]	.	.	.	.
	[LAB.OUT=1]	.113	.522	.233	1.167
	[LAB.OUT=2]	.	.	.	.
	[LAB.IN=1]	.002	.311	.147	.659
	[LAB.IN=2]	.	.	.	.
	[RELIGION=1]	.125	.626	.344	1.138
	[RELIGION=2]	.	.	.	.
	[LSTOCK.2=1]	.673	.863	.435	1.710
	[LSTOCK.2=2]	.	.	.	.
	[HASHI=1]	.001	.353	.187	.664
	[HASHI=2]	.	.	.	.
cultivate exotic fruit trees	Intercept	.167			
	[FARMCATS= 5]	.068	.293	7.851E-02	1.097
	[FARMCATS= 6]	.003	.195	6.726E-02	.563
	[FARMCATS= 7]	.960	.977	.397	2.404
	[FARMCATS= 8]	.	.	.	.
	[LAB.OUT=1]	.165	1.799	.785	4.123
	[LAB.OUT=2]	.	.	.	.
	[LAB.IN=1]	.635	.826	.375	1.818
	[LAB.IN=2]	.	.	.	.
	[RELIGION=1]	.061	1.915	.970	3.779
	[RELIGION=2]	.	.	.	.
	[LSTOCK.2=1]	.026	2.572	1.120	5.909
	[LSTOCK.2=2]	.	.	.	.
	[HASHI=1]	.694	.857	.397	1.848
	[HASHI=2]	.	.	.	.
cultivate indigenous fruit trees	Intercept	.944			
	[FARMCATS= 5]	.701	.790	.237	2.636
	[FARMCATS= 6]	.023	.277	9.197E-02	.836
	[FARMCATS= 7]	.590	.769	.295	2.002
	[FARMCATS= 8]	.	.	.	.
	[LAB.OUT=1]	.809	.889	.344	2.298
	[LAB.OUT=2]	.	.	.	.
	[LAB.IN=1]	.314	.652	.284	1.498
	[LAB.IN=2]	.	.	.	.
	[RELIGION=1]	.323	1.429	.704	2.899
	[RELIGION=2]	.	.	.	.
	[LSTOCK.2=1]	.579	1.261	.556	2.863
	[LSTOCK.2=2]	.	.	.	.
	[HASHI=1]	.259	.638	.292	1.393
	[HASHI=2]	.	.	.	.

a. This parameter is set to zero because it is redundant.

Logit 8: Nominal Regression, RVs, OIVs and KVs

Case Processing Summary

		N	Marginal Percentage
Tree type cultivated	don't plant trees	93	33.6%
	cultivate exotic fruit trees	57	20.6%
	cultivate indigenous fruit trees	44	15.9%
	cultivate non-fruit trees	83	30.0%
Farm size categories	21+ acres	43	15.5%
	11 - 20 acres	83	30.0%
	5 - 10 acres	103	37.2%
	< 4 acres	48	17.3%
Tenure status of farm	privately owned	228	82.3%
	partly rented or borrowed	49	17.7%
Did HH hire in farm labourers within the past	yes	54	19.5%
	no	223	80.5%
Religion of HH	Christian or Muslim	135	48.7%
	indigenous religion	142	51.3%
HASHI village?	HASHI village	187	67.5%
	no	90	32.5%
Do HH members listen to the radio?	daily/weekly	79	28.5%
	occasionally	82	29.6%
	don't listen	116	41.9%
Key product fodder	fodder	21	7.6%
	no	256	92.4%
Key product herbal medicine	herbal medicine	32	11.6%
	no	245	88.4%
Key product construction wood	construction wood	76	27.4%
	no	201	72.6%
Cited fertilisation effect	yes	80	28.9%
	no	197	71.1%
Cited harm to crops via soil	cited harm via soil	128	46.2%
	didn't cite	149	53.8%
Valid		277	100.0%
Missing		72	
Total		349	
Subpopulation		222	

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	691.803			
Final	533.968	157.835	42	.000

Pseudo R-Square

Cox and Snell	.434
Nagelkerke	.466
McFadden	.212

Likelihood Ratio Tests

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	533.968[a]	.000	0	.
FARMCATS	560.957	26.989	9	.001
TENURE	541.784	7.815	3	.050
LAB.IN	544.237	10.269	3	.016
RELIGION	544.939	10.970	3	.012
HASHI	546.098	12.130	3	.007
RADIO	546.999	13.031	6	.043
KEYFODD	553.128	19.160	3	.000
KEYMEDS	546.070	12.102	3	.007
KEYCWOOD	542.895	8.927	3	.030
FERTILAG	540.994	7.026	3	.071
HARMSOI	568.723	34.755	3	.000

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Parameter Estimates

Tree type cultivated		B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp(B) Lower Bound	95% Confidence Interval for Exp(B) Upper Bound
don't plant trees	Intercept	2.525	.733	11.867	1	.001			
	[FARMCATS=5]	.829	.644	1.656	1	.198	2.292	.648	8.105
	[FARMCATS=6]	-.304	.547	.308	1	.579	.738	.253	2.157
	[FARMCATS=7]	-.396	.552	.515	1	.473	.673	.228	1.985
	[FARMCATS=8]	0[a]	.	.	0	.	.	.	.
	[TENURE=1]	.475	.478	.988	1	.320	1.608	.630	4.104
	[TENURE=2]	0[a]	.	.	0	.	.	.	.
	[LAB.IN=1]	-1.466	.490	8.937	1	.003	.231	8.83E-02	.604
	[LAB.IN=2]	0[a]	.	.	0	.	.	.	.
	[RELIGION=1]	-.217	.365	.351	1	.553	.805	.393	1.648
	[RELIGION=2]	0[a]	.	.	0	.	.	.	.
	[HASHI=1]	-1.259	.409	9.474	1	.002	.284	.127	.633
	[HASHI=2]	0[a]	.	.	0	.	.	.	.
	[RADIO=3]	-.105	.469	.050	1	.822	.900	.359	2.257
	[RADIO=4]	-.153	.412	.138	1	.710	.858	.383	1.924
	[RADIO=5]	0[a]	.	.	0	.	.	.	.
	[KEYFODD=1]	-.050	.624	.006	1	.937	.952	.280	3.236
	[KEYFODD=2]	0[a]	.	.	0	.	.	.	.
	[KEYMEDS=1]	-2.127	.722	8.692	1	.003	.119	2.90E-02	.490
	[KEYMEDS=2]	0[a]	.	.	0	.	.	.	.
	[KEYCWOOD=1]	-1.126	.411	7.499	1	.006	.324	.145	.726
	[KEYCWOOD=2]	0[a]	.	.	0	.	.	.	.
	[FERTILAG=1]	-.458	.412	1.236	1	.266	.632	.282	1.418
	[FERTILAG=2]	0[a]	.	.	0	.	.	.	.
	[HARMSOI=1]	-1.455	.375	15.052	1	.000	.233	.112	.487

Parameter Estimates

Tree type cultivated		B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
don't plant	[HARMSOI=2]	0[a]	.	.	0	.	.	.	.
cultivate exotic fruit trees	Intercept	.784	.858	.836	1	.361			
	[FARMCATS=5]	-.724	.794	.831	1	.362	.485	.102	2.300
	[FARMCATS=6]	-1.849	.640	8.355	1	.004	.157	4.49E-02	.551
	[FARMCATS=7]	-.320	.571	.314	1	.575	.726	.237	2.223
	[FARMCATS=8]	0[a]	.	.	0	.	.	.	.
	[TENURE=1]	1.179	.616	3.663	1	.056	3.250	.972	10.869
	[TENURE=2]	0[a]	.	.	0	.	.	.	.
	[LAB.IN=1]	-.365	.501	.531	1	.466	.694	.260	1.852
	[LAB.IN=2]	0[a]	.	.	0	.	.	.	.
	[RELIGION=1]	.920	.432	4.530	1	.033	2.510	1.076	5.859
	[RELIGION=2]	0[a]	.	.	0	.	.	.	.
	[HASHI=1]	-.946	.498	3.615	1	.057	.388	.146	1.030
	[HASHI=2]	0[a]	.	.	0	.	.	.	.
	[RADIO=3]	1.301	.539	5.825	1	.016	3.672	1.277	10.560
	[RADIO=4]	.208	.526	.157	1	.692	1.232	.440	3.450
	[RADIO=5]	0[a]	.	.	0	.	.	.	.
	[KEYFODD=1]	-2.889	1.204	5.754	1	.016	.056	5.25E-03	.589
	[KEYFODD=2]	0[a]	.	.	0	.	.	.	.
	[KEYMEDS=1]	-.863	.618	1.952	1	.162	.422	.126	1.416
	[KEYMEDS=2]	0[a]	.	.	0	.	.	.	.
	[KEYCWOOD=1]	-.159	.448	.126	1	.722	.853	.354	2.052
	[KEYCWOOD=2]	0[a]	.	.	0	.	.	.	.
	[FERTILAG=1]	-1.046	.483	4.697	1	.030	.351	.136	.905
	[FERTILAG=2]	0[a]	.	.	0	.	.	.	.
	[HARMSOI=1]	-2.407	.467	26.591	1	.000	.090	3.61E-02	.225
	[HARMSOI=2]	0[a]	.	.	0	.	.	.	.

Parameter Estimates

Tree type cultivated		B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
cultivate indigenous fruit trees	Intercept	1.976	.795	6.182	1	.013			
	[FARMCATS=5]	.061	.704	.008	1	.931	1.063	.267	4.227
	[FARMCATS=6]	-1.613	.630	6.554	1	.010	.199	5.79E-02	.685
	[FARMCATS=7]	-.493	.586	.707	1	.400	.611	.193	1.928
	[FARMCATS=8]	0[a]	.	.	0	.	.	.	.
	[TENURE=1]	-.360	.497	.524	1	.469	.698	.263	1.849
	[TENURE=2]	0[a]	.	.	0	.	.	.	.
	[LAB.IN=1]	-.476	.519	.840	1	.360	.621	.225	1.720
	[LAB.IN=2]	0[a]	.	.	0	.	.	.	.
	[RELIGION=1]	.771	.432	3.192	1	.074	2.162	.928	5.039
	[RELIGION=2]	0[a]	.	.	0	.	.	.	.
	[HASHI=1]	-1.296	.482	7.239	1	.007	.274	.106	.703
	[HASHI=2]	0[a]	.	.	0	.	.	.	.
	[RADIO=3]	-.121	.529	.052	1	.819	.886	.314	2.498
	[RADIO=4]	-.801	.523	2.347	1	.126	.449	.161	1.251
	[RADIO=5]	0[a]	.	.	0	.	.	.	.
	[KEYFODD=1]	-8.845	22.952	.149	1	.700	.000	4.18E-24	5.E+15
	[KEYFODD=2]	0[a]	.	.	0	.	.	.	.
	[KEYMEDS=1]	-.215	.615	.122	1	.727	.807	.242	2.692
	[KEYMEDS=2]	0[a]	.	.	0	.	.	.	.
	[KEYCWOOD=1]	-.207	.453	.208	1	.648	.813	.335	1.976
	[KEYCWOOD=2]	0[a]	.	.	0	.	.	.	.
	[FERTILAG=1]	.129	.458	.079	1	.778	1.138	.463	2.793
	[FERTILAG=2]	0[a]	.	.	0	.	.	.	.
	[HARMSOI=1]	-1.066	.434	6.023	1	.014	.344	.147	.807
	[HARMSOI=2]	0[a]	.	.	0	.	.	.	.

a. This parameter is set to zero because it is redundant.

Logit 9: Ordinal Regression, RVs Only

Case Processing Summary

		N	Marginal Percentage
Location of tree cultivation	don't plant trees	108	33.5%
	plant in home garden only	86	26.7%
	plant in fields	128	39.8%
Farm size categories	21+ acres	49	15.2%
	11 - 20 acres	91	28.3%
	5 - 10 acres	125	38.8%
	< 4 acres	57	17.7%
Did HH hire in farm labourers within the	yes	68	21.1%
	no	254	78.9%
Trends in incidence of off-farm trees	roughly stable	208	64.6%
	decreasing	114	35.4%
Livestock holdings	cattle	237	73.6%
	no cattle	85	26.4%
Valid		322	100.0%
Missing		27	
Total		349	

Iteration History[b]

Iteration	Number of Step-Halvings	-2 Log Likelihood	Threshold [LOGIT8 = 1]	Threshold [LOGIT8 = 3]
0	0	180.123	-.6838434	.4158317
1	0	163.405	-.1992052	.9004700
2	0	163.177	-.1976295	.9498094
3	0	163.176	-.1969914	.9508893
4	0	163.176	-.1968359	.9510470
5	0	163.176	-.1968217	.9510612
6	0	163.176	-.1968196	.9510632
7	0	163.176	.1968194	.9510635
8	0	163.176[a]	-.1968193	.9510635

Redundant parameters are not displayed. Their values are always zero in all iterations.

Iteration History[b]

Iteration	Location					
	[FARMCA TS=5]	[FARMCA TS=6]	[FARMCA TS=7]	[LAB.IN=1]	[INCIDEN C=1]	[LSTOCK.2=1]
0	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
1	-.5464758	-.5506870	-4.86E-02	.6181049	.4544432	.4323254
2	-.5943468	-.5497196	-4.43E-02	.6420962	.4694975	.4462532
3	-.6012098	-.5507712	-4.51E-02	.6423794	.4703129	.4475339
4	-.6019592	-.5507454	-4.51E-02	.6424678	.4703875	.4476290
5	-.6020589	-.5507524	-4.51E-02	.6424751	.4703971	.4476431
6	-.6020708	-.5507526	-4.51E-02	.6424762	.4703982	.4476447
7	-.6020723	-.5507526	-4.51E-02	.6424763	.4703984	.4476449
8	-.6020725	-.5507526	-4.51E-02	.6424763	.4703984	.4476449

Redundant parameters are not displayed. Their values are always zero in all iterations.

a. The parameter estimates converge. Last absolute change in -2 Log Likelihood is .000, and last maximum absolute change in parameters is 1.860025E-07.

b. Link function: Logit.

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	180.123			
Final	163.176	16.947	6	.009

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	48.235	50	.544
Deviance	53.886	50	.328

Link function: Logit.

Pseudo R-Square

Cox and Snell	.051
Nagelkerke	.058
McFadden	.024

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.
Threshold	[LOGIT8 = 1]	-.197	.329	.359	1	.549
	[LOGIT8 = 3]	.951	.333	8.161	1	.004
Location	[FARMCATS= 5]	-.602	.378	2.535	1	.111
	[FARMCATS= 6]	-.551	.328	2.824	1	.093
	[FARMCATS= 7]	-4.508E-02	.301	.022	1	.881
	[FARMCATS= 8]	0[a]	.	.	0	.
	[LAB.IN=1]	.642	.264	5.921	1	.015
	[LAB.IN=2]	0[a]	.	.	0	.
	[INCIDENC=1]	.470	.221	4.539	1	.033
	[INCIDENC=2]	0[a]	.	.	0	.
	[LSTOCK.2=1]	.448	.250	3.198	1	.074
	[LSTOCK.2=2]	0[a]	.	.	0	.

Link function: Logit.

Parameter Estimates

		95% Confidence Interval	
		Lower Bound	Upper Bound
Threshold	[LOGIT8 = 1]	-.841	.447
	[LOGIT8 = 3]	.299	1.604
Location	[FARMCATS= 5]	-1.343	.139
	[FARMCATS= 6]	-1.193	9.156E-02
	[FARMCATS= 7]	-.635	.545
	[FARMCATS= 8]	.	.
	[LAB.IN=1]	.125	1.160
	[LAB.IN=2]	.	.
	[INCIDENC=1]	3.767E-02	.903
	[INCIDENC=2]	.	.
	[LSTOCK.2=1]	-4.301E-02	.938
	[LSTOCK.2=2]	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Logit 9: Ordinal Regression, RVs and OIVs

Case Processing Summary

		N	Marginal Percentage
Location of tree cultivation	don't plant trees	113	33.6%
	plant in home garden only	91	27.1%
	plant in fields	132	39.3%
Is farm 11 acres or larger?	big	146	43.5%
	small	190	56.5%
Did HH hire in farm labourers within the	yes	70	20.8%
	no	266	79.2%
Do HH members sell their labour to work	yes	58	17.3%
	no	278	82.7%
Trends in incidence of off-farm trees	roughly stable	221	65.8%
	decreasing	115	34.2%
Religion of HH	Christian or Muslim	157	46.7%
	indigenous religion	179	53.3%
HASHI village?	HASHI village	225	67.0%
	no	111	33.0%
Valid		336	100.0%
Missing		13	
Total		349	

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	277.595			
Final	237.295	40.300	6	.000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	94.350	90	.356
Deviance	107.736	90	.098

Link function: Logit.

Pseudo R-Square

Cox and Snell	.113
Nagelkerke	.128
McFadden	.055

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.
Threshold	[LOGIT9 = 1]	.421	.276	2.333	1	.127
	[LOGIT9 = 3]	1.651	.290	32.491	1	.000
Location	[FARM.BIG=1]	-.404	.212	3.637	1	.057
	[FARM.BIG=2]	0[a]	.	.	0	.
	[LAB.IN=1]	.792	.264	9.006	1	.003
	[LAB.IN=2]	0[a]	.	.	0	.
	[LAB.OUT=1]	.527	.282	3.497	1	.061
	[LAB.OUT=2]	0[a]	.	.	0	.
	[INCIDENC=1]	.352	.224	2.481	1	.115
	[INCIDENC=2]	0[a]	.	.	0	.
	[RELIGION=1]	.590	.212	7.780	1	.005
	[RELIGION=2]	0[a]	.	.	0	.
	[HASHI=1]	.855	.224	14.535	1	.000
	[HASHI=2]	0[a]	.	.	0	.

Link function: Logit.

Parameter Estimates

		95% Confidence Interval	
		Lower Bound	Upper Bound
Threshold	[LOGIT9 = 1]	-.119	.961
	[LOGIT9 = 3]	1.083	2.218
Location	[FARM.BIG=1]	-.819	1.119E-02
	[FARM.BIG=2]	.	.
	[LAB.IN=1]	.275	1.309
	[LAB.IN=2]	.	.
	[LAB.OUT=1]	-2.539E-02	1.080
	[LAB.OUT=2]	.	.
	[INCIDENC=1]	-8.610E-02	.791
	[INCIDENC=2]	.	.
	[RELIGION=1]	.176	1.005
	[RELIGION=2]	.	.
	[HASHI=1]	.415	1.295
	[HASHI=2]	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Logit 9: Ordinal Regression, RVs, OIVs and KVs

Case Processing Summary

		N	Marginal Percentage
Location of tree cultivation	don't plant trees	95	33.6%
	plant in home garden only	75	26.5%
	plant in fields	113	39.9%
Farm size categories	21+ acres	43	15.2%
	11 - 20 acres	85	30.0%
	5 - 10 acres	106	37.5%
	< 4 acres	49	17.3%
Did HH hire in farm labourers within the past	yes	56	19.8%
	no	227	80.2%
Trends in incidence of off-farm trees	roughly stable	184	65.0%
	decreasing	99	35.0%
Religion of HH	Christian or Muslim	138	48.8%
	indigenous religion	145	51.2%
HASHI village?	HASHI village	191	67.5%
	no	92	32.5%
Do HH members listen to the radio?	daily/weekly	80	28.3%
	occasionally	84	29.7%
	don't listen	119	42.0%
Key product fodder	fodder	22	7.8%
	no	261	92.2%
Key product herbal medicine	herbal medicine	32	11.3%
	no	251	88.7%
Key product construction wood	construction wood	76	26.9%
	no	207	73.1%
Valid		283	100.0%
Missing		66	
Total		349	

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	500.050			
Final	442.259	57.791	12	.000

Link function: Logit.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	360.002	338	.197
Deviance	365.334	338	.147

Link function: Logit.

Pseudo R-Square

Cox and Snell	.185
Nagelkerke	.208
McFadden	.094

Link function: Logit.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[LOGIT9 = 1]	.639	.421	2.300	1	.129	-.187	1.465
	[LOGIT9 = 3]	1.928	.435	19.612	1	.000	1.075	2.781
Location	[FARMCATS=5]	-.420	.413	1.034	1	.309	-1.230	.390
	[FARMCATS=6]	-.560	.351	2.549	1	.110	-1.248	.128
	[FARMCATS=7]	.112	.338	.110	1	.740	-.550	.774
	[FARMCATS=8]	0[a]	.	.	0	.	.	.
	[LAB.IN=1]	.772	.311	6.176	1	.013	.163	1.381
	[LAB.IN=2]	0[a]	.	.	0	.	.	.
	[INCIDENC=1]	.570	.252	5.132	1	.023	7.7E-02	1.064
	[INCIDENC=2]	0[a]	.	.	0	.	.	.
	[RELIGION=1]	.439	.241	3.330	1	.068	-3.E-02	.911
	[RELIGION=2]	0[a]	.	.	0	.	.	.
	[HASHI=1]	.599	.262	5.247	1	.022	8.6E-02	1.112
	[HASHI=2]	0[a]	.	.	0	.	.	.
	[RADIO=3]	.637	.301	4.471	1	.034	4.7E-02	1.227
	[RADIO=4]	.298	.283	1.111	1	.292	-.256	.851
	[RADIO=5]	0[a]	.	.	0	.	.	.
	[KEYFODD=1]	-1.243	.494	6.343	1	.012	-2.211	-.276
	[KEYFODD=2]	0[a]	.	.	0	.	.	.
	[KEYMEDS=1]	.713	.388	3.371	1	.066	-5.E-02	1.473
	[KEYMEDS=2]	0[a]	.	.	0	.	.	.
	[KEYCWOOD=1]	.747	.274	7.451	1	.006	.211	1.283
	[KEYCWOOD=2]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.